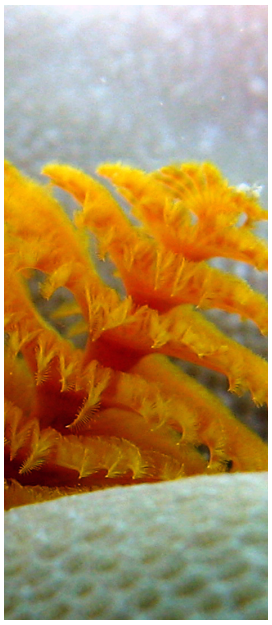
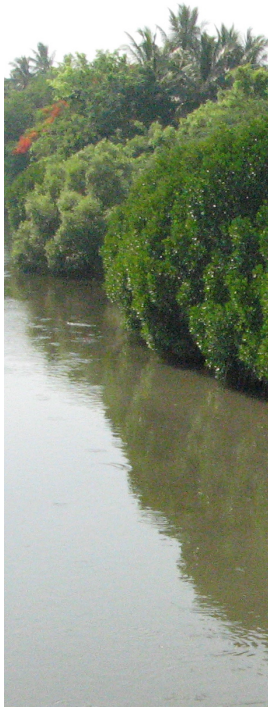
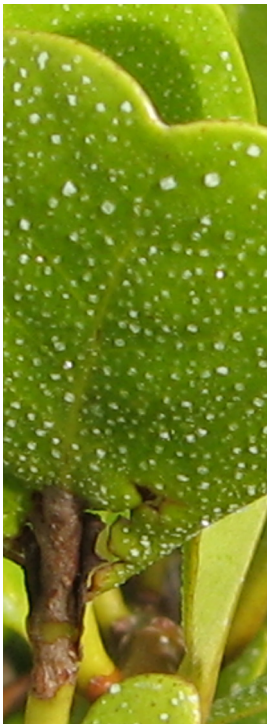
Post Tsunami Environment Initiative







Post Tsunami Environment Initiative

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Contents

Executive Summary

The earthquake and tsunami of 2004 was a catastrophe of unprecedented magnitude, leaving almost 230,000 people dead or missing, and several millions homeless as it travelled across the Indian Ocean (UN Office of the Special Envoy Report, 2006). In India, the full impact of the tsunami was felt in the Andaman and Nicobar Islands, a mere 450 km at the closest point from the point of origin at Banda-Aceh in Sumatra. It resulted in major changes to the topography of the island group, large loss of life and livelihoods, and untold damage to natural systems. Although nearly 2,000 km away the epicentre, the coasts of mainland of India also suffered hugely, and the tsunami affected more than 1200 km of coastline, across Andhra Pradesh, Tamil Nadu, Kerala and Pondicherry. Nearly 8500 people lost their lives, and thousands more were left homeless. By far the worst casualties were in Tamil Nadu, which alone accounted for 8009 deaths.

The tragedy of this event was further compounded by the inequity of its impact. Women and children were less able to get out of harms way, and accounted for an overwhelming majority of the deaths and injuries sustained. Typically, the communities worst affected by the tsunami were marginal fishing and agricultural communities living in tiny villages and hamlets that hugged the coastline, mostly dependent on natural systems for their livelihoods. The tsunami resulted in significant losses to their infrastructure and livelihoods, with thousands of fishing boats and gear destroyed, agricultural fields inundated, jetties and landing sites ruined, and roads and distribution networks badly affected.

While the full scale of the impact of the 2004 tsunami on people and their livelihoods is now being gradually understood, more than two years after the event, we do not yet have a complete picture of its consequences to nearshore marine and coastal ecosystems. Although studies have been conducted at several locations along the coast, a comprehensive picture of ecosystem status does not yet exist across the land and seascape. Addressing this need is one of the major objectives of the UNDP Post-Tsunami Environment Initiative. The primary aim during the initial phase of this project was to evaluate the nature of change wrought by the tsunami on natural ecosystems across coastal lands and seascapes, and to broadly assess impacts to socio-ecological systems along the affected coast of mainland India. At one level, the programme is geared towards bringing together a range of disparate studies conducted along the coast, both before and after the tsunami to provide a picture of trends in ecological processes and the impact of the tsunami on these trends. This analysis is complemented by an analysis of satellite imagery to evaluate the immediate and mid-term consequences of this event on coastal ecosystems. At another level, the programme reviews coastal policy and developmental trends in the coastal zone, assessing its applicability, relevance and implementation in a post-tsunami context. This forms part of a longer-term initiative that builds on the critical gaps in our knowledge identified in the first phase, with specific studies and on-ground activities.

Resilience and the coast

While it is impossible to deny the tragedy of the 2004 tsunami, it also presents an unprecedented opportunity to critically evaluate our coastal defences, and assess the overall resilience of the Indian coastline (coastal habitats and livelihoods) to natural disturbance events. After the tsunami, much attention has been paid on building early-warning systems, and on various hard and soft engineering solutions to prevent damage in the wake of another tsunami. While future tsunamis cannot be

discounted, on the level, the threat of them affecting the Indian coast lies on a more distant horizon than rather more frequent disturbances such as cyclones, storm surges, and other such unusual weather events. From the best predictions of climate change, these stochastic events are much more likely to increase in frequency and intensity, and the Indian coastline will, in all likelihood, see major changes in its weather systems. It makes good management sense to be concentrating on our immediate responses to these more proximate events, while keeping more distant hazards always in view.

In this light, understanding coastal responses to the tsunami becomes all the more important. The tsunami affected a very large section of the coast, and (with notable exceptions) with uniform intensity. Rarely has the response potential of such a large section of the Indian coast been put to test in quite the same way. A careful documentation of how different parts of the coast responded to this event can provide valuable insights on how best to bolster the resilience potential of these areas. It is important to ensure that policy, development planning and resource use patterns in the coastal zone are predicated on good science and careful analysis rather than knee-jerk responses. This will prevent one unprecedented disastrous event sparking off a series of planned disastrous transformations along the coast, from which retreat would be even more difficult.

Our programme is geared towards using the tsunami and its consequences as a heuristic tool to understand coastal resilience. At a broad spatial level, it may be possible to distinguish areas along a gradient of impact, from high to low. This gradient itself is difficult to define, not least because of the complexities involved in defining and measuring impact. Additionally, much of the information required for a spatially complete analysis of this nature is presently still not available. The broad framework we used for understanding this gradient of impact is depicted in the figure below:

Areas that suffered a higher impact could be inherently vulnerable, whereas areas that showed significantly lower impact could be inherently more resilient or resistant to disturbance. However, the role of contingency cannot be discounted in large events of this nature, and locations could have sustained higher or lower impact due to factors completely unrelated to resilience or vulnerability, making them either ‘lucky’ or ‘unlucky’. It may however still be possible to identify factors of similarity between areas that were subject to different levels of disturbance, within the broad bounds of this uncertainty. For instance, bathymetry and coastal topography could have been by far the most important factor in protecting coastlines from tsunami damage as has been found in many other areas of South East Asia. The integrity of coastal vegetation including plantations could also play an important role, although, as much of the region-wide research is showing, this may be highly dependent on local conditions. In the Indian context, our analysis indicates that coastal densities along the coast were particularly important in driving patterns of impact. The buffering influence of the Sri Lankan landmass was also important in providing considerable protection to the Palk Straits, and parts of the Gulf of Mannar. The first part of this report describes in detail the results of our spatial analysis, integrating data collected on a range of impact measurements with satellite imagery analysis.

The second and third sections of the report concentrate on ecological systems along the east coast, and provides a detailed description of the distribution and present ecological status of these systems in the tsunami-affected states. This is based on a structured literature survey, and attempts to identify gaps in our knowledge of baseline ecological information and post-tsunami assessments. For two, often ignored ecosystems, the programme conducted rapid field surveys to assess their condition

– sandy beaches and seagrass meadows. In the case of seagrass meadows for instance, while most assessments done after the tsunami suggest that the tsunami had negligible or no impacts on seagrass meadows, our research indicates that, even after 18 months, some meadows in the Gulf of Mannar show a very clear pattern of impact which could have been better understood if well-designed monitoring programmes were in place.

The fourth section of this report focuses on coastal policy and trends in coastal development planning in the tsunami-affected states. The section provides a detailed examination of the Coastal Regulation Zone Notification of 1991, analysing its effectiveness and applicability in a post-tsunami environment. An analytical framework was employed to assess the performance of the CRZ Notification against indices of environment protection, governance and efficiency. This section was written using data gathered in key informant interviews and through documents and publications collated from the affected states. The experience with implementation is pieced together from this data and categorised to facilitate an easier understanding of problems that eventually became inherent to the effectiveness of this law. A set of recommendations follows the analysis, providing imperatives for policy improvements of the mainland coast, post-tsunami.

The final section reviews the literature on the socio-ecological implications of the impacts of the tsunami and subsequent rehabilitation in the affected areas. It focuses on ecosystem-derived livelihoods, namely fisheries, agriculture and aquaculture. It also examines the socio-ecological and environmental aspects of rehabilitation and reconstruction efforts by the government and non-governmental organisations such as relocation, housing, environmental planning, hard engineering options, bio-shields and shelters belts.

This report reflects the efforts made by the PTEI team to better understand the influence that this phenomenal natural event had on coastal ecosystems and human communities. This research effort has led to a certain amount of learning, some of which finds translation as a set of recommendations or suggestions outlined at the end of each chapter. As stated earlier, in order to facilitate appropriate actions in the tsunami-affected regions, more effort needs to be channelled into efforts to understand these affected areas, ecosystems and people. Phase II of the Post-Tsunami Environment Initiative proposes to enhance and utilise this learning through a series of focused research and action projects.

Chapter 1 Understanding coastal vulnerability – the impacts of the 2004 tsunami on the Indian mainland

M.D. Madhusudan[1], V. Srinivas[2], R. Raghunath[1], V. Kapoor[1] & R. Arthur[1]

Introduction

It is only against the dimensions of space and time that natural phenomena can be best understood. One such natural phenomenon—the Asian tsunami of December 2004—affected states along India's southern and southeastern coast and visited huge losses to human life, livelihoods and public infrastructure. Over 12,400 people perished and nearly 7,000 were injured. Over 640,000 families were displaced, with livelihoods of over many hundred thousand families being impacted. Further, roads, bridges, port and other infrastructure worth over USD 1.2 billion – including c. 154,000 houses – were destroyed in the disaster. Natural ecosystems and habitats along the narrow coastal zone were also affected (Kumaraguru *et al.* 2005, Patterson 2005, Jayappa 2006, Rasheed *et al.* 2006).

As with any natural disaster, the immediate response to the tsunami was necessarily humanitarian, with most effort focusing on assisting affected human communities cope with the short-term impacts of the disaster. However, as the immediacy of the human tragedy passed, there has been growing appreciation that a medium-term response was equally important and indeed essential. This response focuses on gaining a sound understanding of the patterns and processes that determined how our coasts and the people inhabiting them responded to the events of December 26, 2004 (Synolakis and Bernard 2006). Although the tsunami was a huge regional-scale event to which nearly the entire south-eastern coastline of India was subject, there was tremendous variation in the levels of actual impact suffered by different parts of the coastline (Chang *et al.* 2006, Jayappa 2006, Narayan *et al.* 2006). Understanding coastal vulnerability and resilience to natural disasters such as the tsunami primarily revolves around a two-stage inquiry: the first stage involves description and understanding of the patterns of spatial variation in the impact of the tsunami across the affected regions. The second stage involves an analysis of factors that govern this spatial variation in the impact of the tsunami. This two-stage analysis can help understand factors that determine the inherent vulnerability of coastal systems and design appropriate safeguards and responses to natural disasters such as the tsunami.

To assist in this process, a conceptual framework (Figure 1) was designed within which to gather, analyze and understand a wide range of data concerned with determining the resilience of India's south-eastern coastline to environmental catastrophes. As a scientific inquiry into a process of change, the framework is founded on descriptions of ecological, demographic and socioeconomic baselines against which the changes brought about by the tsunami may be assessed. Depending on the baseline, sites along the coast show considerable variation in registering the impact of the tsunami. Such a variation in impact could be attributed either to the role of 'chance' factors (discussed later) or be a reflection of the true vulnerability/resilience of a coastal site to the catastrophe. Understanding the factors that determine the vulnerability or resilience of a coastal location has important implications

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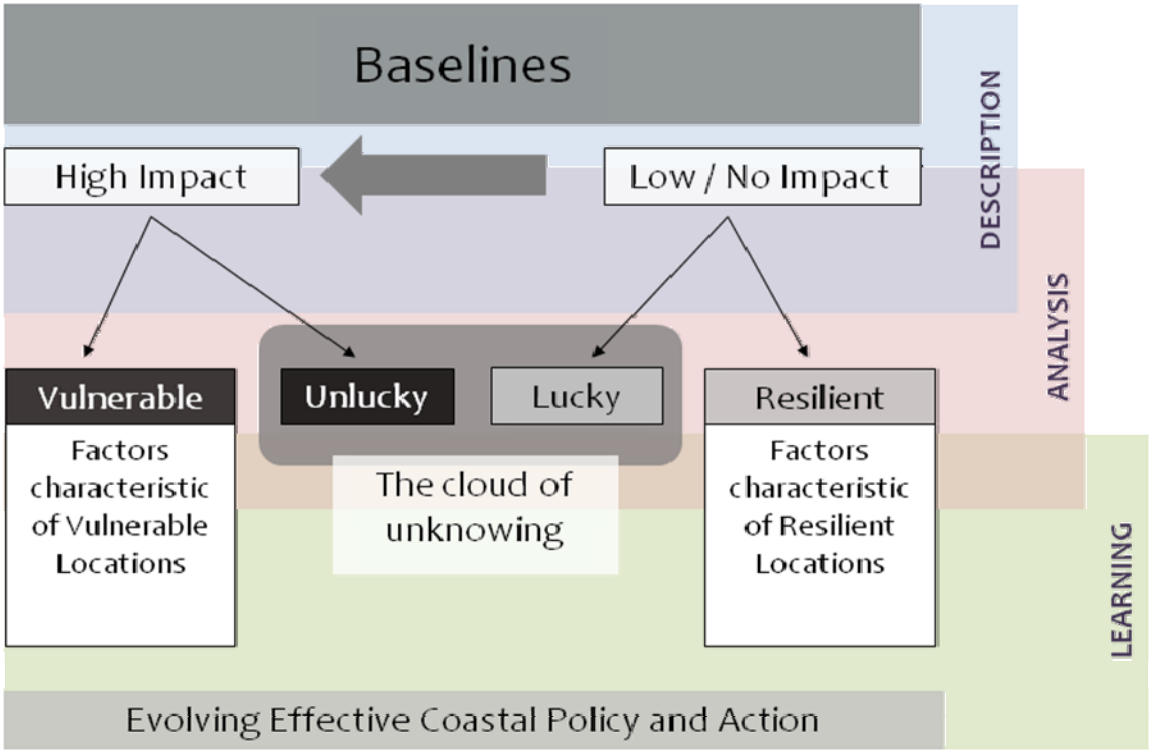
for policy and action, in order to secure fragile coastal ecosystems as well as human lives, livelihoods and property.

This framework also provides a structure to this chapter, which is organized in three broad sections. The first provides a *description* both of pre-tsunami baselines of ecological, demographic and socioeconomic status, as well as provides post-tsunami pictures of how and by how much these baselines shifted in response to the catastrophe. The second section presents *analyses* of some of the important issues concerned with defining and assessing the impact of the tsunami, as well as in identifying a suite of factors that could govern the resilience/vulnerability of a coastal location to environmental catastrophes. The final section of this chapter draws together *learning* from the preceding analyses and discusses its relevance to policy and action, as well as flags issues that need a better understanding if policy instruments and on-ground action to enhance coastal resilience are to be based on a firm scientific foundation.

Characterising the coast

Figure 1: A broad conceptual framework for understanding vulnerability of the coast to impacts of the December 2004 tsunami.



The work undertaken under this project presents a broad-scale picture of the tsunami-affected regions of the southern Indian states of Andhra Pradesh, Tamil Nadu, Pondicherry and Kerala. Given that over a year had elapsed from the date of the tsunami to the commencement of this project, the emphasis of our work was not on generating primary data on the tsunami and its immediate impact on the coast of the Indian mainland. Rather, it was on initiating an effort to identify, gather, collate and summarize a wide range of data that have remained scattered across varied efforts that followed the tsunami. This necessarily meant that our effort was geared to broadly assess status of the coast prior to—and after—the December 2004 tsunami.

We endeavoured to spatially reference as much of the data as possible in order to allow the visualization of spatial patterns and the analysis of spatial variation. A database was therefore set up to spatially reference available information at the highest available resolution to enable a description of the pre-tsunami status of the coastal regions, identification and analysis of spatial and thematic gaps in knowledge about the coast, as well as assess tsunami impacts using a variety of measures. The database was also meant to serve as a pilot effort to collate and disseminate available tsunami-related data, while allowing for its continual updating and refinement.

Data used to characterise the study region essentially fell into *three* broad categories. First, we described the *administrative* landscapes along the coast. In each of the affected states, we focused on gathering and compiling information at the scale of a *taluk* (syn. *tehsil, mandal* or sub-district) for each of the coastal districts. We chose this level because of the wide availability of baseline pre-tsunami data at the *taluk*-level and also since post-tsunami data were also widely summarized at this level. Moreover, given that most coastal management decisions were made along these administrative units, they also represented a useful template for the presentation of all other coastal data. Second, we also gathered information on a range of parameters that described the *human* landscape along the coast. These included variables pertaining to demography (e.g., size and density of human populations along the coast), human livelihoods (e.g., proportion of population dependent on fisheries, number and variety of fishing crafts and gear), as well as housing and civic infrastructure such as roads. Finally, necessary data were also gathered to enable a description of the *ecological* landscape along the coast. This was done not only to evaluate the location and status of ecosystems liable to be affected by natural disaster events along the coast, but also to assess their potential role in moderating the impact of these disasters on human landscapes. The following section describes data gathered in above descriptive categories, as well as summarises the its coverage and resolution (also see Table 1)

Data collection methods and data coverage

Delineating administrative landscape

Taluk boundaries for the coastal regions were extracted from the CensusInfo v2.0 package based on 2001 census data, developed and distributed by the Directorate of Census Operations, Government of India. The attribute data associated with the spatial data such as taluk and district names were validated against government sources and concatenated to create unique identifiers for each coastal taluk. A method called rubbersheeting was also used to spatially adjust and align the taluk boundaries to satellite imageries (which were used in the classification and mapping of coastal ecosystems) for further analyses. Polygons representing the taluks were then linked to a database designed to hold all pre- and post-tsunami data pertaining to demography, infrastructure, fisheries, and ecosystems from the coastal taluks.

Characterising the human landscape

A pre-tsunami baseline of demographic information for the study regions were summarized at the taluk level from the Census of India 2001. To retain comparability across various coastal taluks, we utilized population densities and proportion of population affected by the tsunami. Livelihood data focussing on fishing craft and gear were available only for the state of Tamil Nadu. Fishing crafts and gear were categorized as artisanal and non-artisanal crafts. Artisanal crafts included traditional fishing crafts like the *masulla, vallam, dugout* and *catamaran.* Non-artisanal crafts included the modern mechanised crafts like trawlers, gillnetters and liners. However, pre-tsunami data on fisheries themselves were not available for the four tsunami-affected states. Across the study region, agriculture is a critical aspect of human livelihood, but once again, no spatially-explicit data from the pre-tsunami

period on extent of actual cropping areas, diversity of crops, yields or agricultural risks were obtainable from any of the four states during our efforts. Some pre-tsunami data were available on ground water status (presence of sulphides, sulphates, chlorides and fluorides in ground water and its pH) from a few sample villages in the coastal districts of Tamil Nadu, whereas similar data were either unavailable for other states. With respect to civic infrastructure, our data gathering efforts focused on obtaining information on residential buildings, roads (*kachcha* or *pucca*) and other structure along the coast such as seawalls, bridges and jetties. These data (mainly housing) came for the entire region at the *tehsil*-level from the Census of India 200 and classified based on construction material used for making walls. Walls of mud, plastic, wood and grass were categorized as *kachcha* houses whereas houses with concrete, burnt brick, stone or metal walls were classified as *pucca* houses. However, pre-tsunami data on the length of roads, number of bridges and presence of seawalls was unavailable across the states and/or difficult to source.

Table 1: A state-wise summary of the pre- and post-tsunami data compiled along with the resolution at which data were gathered.

Theme	Data Fields	Pre Tsunami				Post Tsunami			
		Tamil Nadu	Pondicherry	Kerala	Andhra Pradesh	Tamil Nadu	Pondicherry	Kerala	Andhra Pradesh
1 Human Life	Population					-	-	-	-
	Deaths	-	-	-	-				
	Missing	-	-	-	-				
	Injuries	-	-	-	-				
2 Livelihoods: Fisheries	Fisheries								
	Artisanal Craft and Gear								
	Non-artisanal Craft and Gear								
3 Livelihoods: Agriculture	Agriculture								
	Groundwater Quality								
	Groundwater pH								
4 Civic Infrastructure	Housing - Kuccha/ Pucca								
	Roads								
	Bridges / Seawalls					P			
5 Ecosystems	Types								

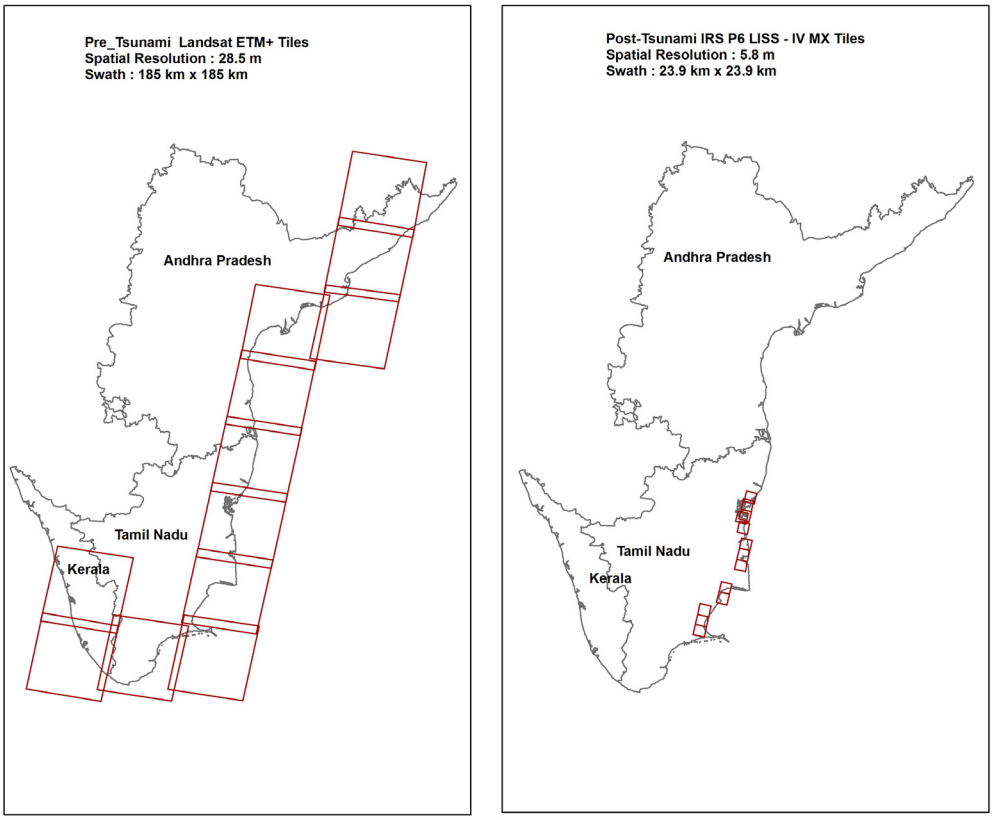
Legend

- *Data at tehsil level*
- *Data at district level*
- *No data*
- P *Patchy data*
- \- *Not Applicable*

Characterising the ecological landscape

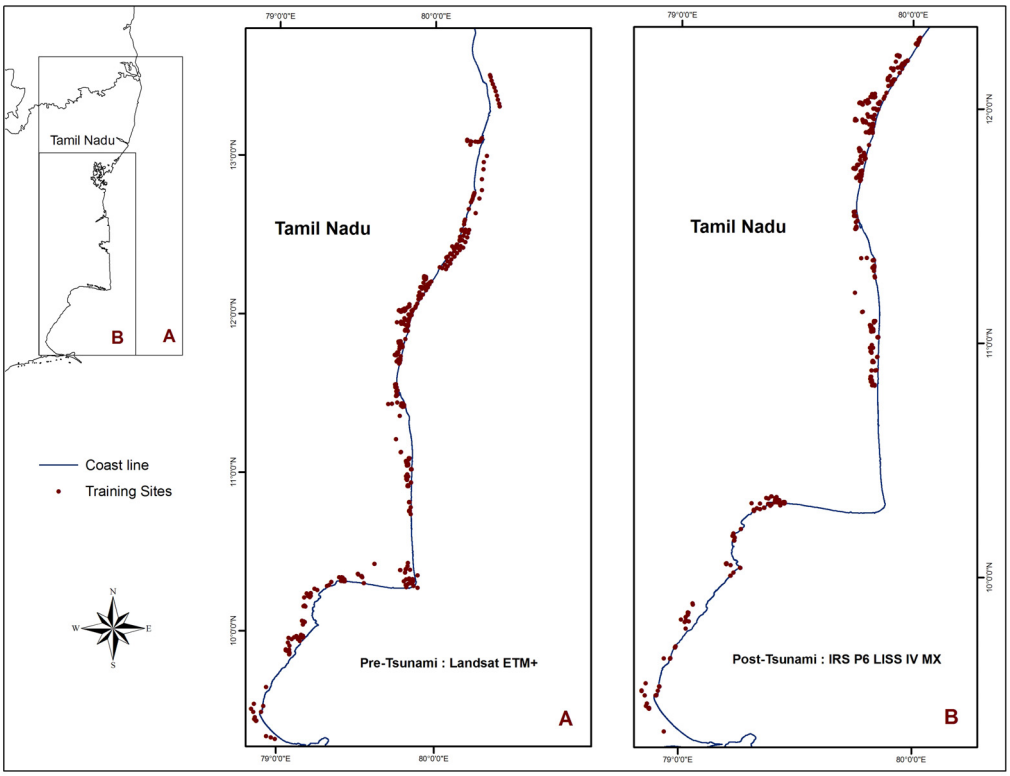
Despite their diversity of terrestrial and aquatic habitats, ecological landscapes along the coasts remain rather poorly understood, but nevertheless under intense human pressures (Daniels *et al.* 2006). Since a detailed field mapping of these ecosystems was beyond the scope of our work, we made a preliminary effort to classify coastal land cover and identify coastal ecosystems using a combination of remotely-sensed imageries from satellites in conjunction with opportunistic data from the field. LandSat ETM (28.5m resolution) images obtained from the Global Land Cover Facility (http://glcfapp.umiacs.umd.edu) were used for the analyses of pre-tsunami imagery and ecosystem classification. Figure 2 (*left*) shows the coastal regions for which images were obtained for analyses. As the images obtained were on different dates (between 1999 and 2002), large spectral differences necessitated the use of 5 separate mosaics and did not permit the creation of a single mosaic for the entire coast for further analysis. To assess the current status of various habitats along the coast, 5.3m IRS LISS4 MX images were procured for the Tamil Nadu and Kerala coast from the National Remote Sensing Agency (Figure 2, *right*). These images were georeferenced to UTM co-ordinates using the LandSat ETM as reference images. These images were edge matched and mosaiced before carrying out further analysis. As with the ETM tiles, a single mosaiced image for the entire region could not be produced as there were gaps in the availability of satellite images. Based on field visits, a collection of 432 training sites (Figure 3A) were developed to enable the classification of coastal ecosystems before the tsunami. Features along the coastline were classified into the two broad categories, anthropogenic ecosystems and natural ecosystems. Anthropogenic ecosystems were further classified into open agriculture (paddy, sugarcane, groundnut, millets, etc.), agricultural plantations (coconut, casuarinas, cashew, *eucalyptus*, etc.), built-up areas (both rural and urban) and salt-pans. Natural ecosystems

Figure 2: Satellite imagery tiles from LandSat ETM (left) and IRS-P6 (right) sensors used to identify coastal ecosystems in the tsunami impacted states.



comprised mangroves, dry scrub, *Prosopis* scrubland, coastal dunes, water, and bare soil. Besides training sites obtained during field surveys carried out during this study during July-August 2006, we also used training site information from other studies (FERAL, *unpubl. data*) to improve the dataset. All image processing was carried out using ERDAS Imagine v9.0 software. A coastline was digitized using the LandSat ETM PAN images and a buffer of 10km from

Figure 3: Training sites used to classify ecosystems from pre-tsunami LandSat ETM (left) and post-tsunami IRS-P6 (right) imagery.



the coastline was defined as the Area of Interest for subsequent analysis. In addition to standard satellite data, two addition layers of information NDVI and distance from coastline were derived and were incorporated into analysis. In addition to these two layers, we also derived a layer of texture for each of the 3 bands for analyses carried out with the IRS-LISS4-MX data set. To determine the choice of classifier, the area with most number of training sites was identified and results from various classifiers were examined. Based on the relative performance of these classifiers, we chose a classification tree model for subsequent analysis. Attributes for each training sites were extracted using ERDAS Imagine and the classification rules were developed using the statistical software, S-PLUS. These rules were then incorporated into ERDAS Imagine to run a knowledge classifier. Additional rules were specified to fine tune results from the classification tree analyses and to prevent over representation of certain classes in areas where they are less likely to occur. Classified images were smoothened with a 7x7 majority filter and proportions of different ecosystems were estimated at the tehsil and district levels.

Results

Besides the establishment of an evolving, open-access spatial database of pre-tsunami baselines for demography, livelihood and infrastructure, the major outputs from this section were in the form of maps. These maps depict spatial variation for data such as human population density, density of

houses and the distribution of fishing craft across tehsils. However, to enable a better visualization, of post-tsunami impacts against pre-tsunami baselines, these maps are presented in the following section (*Characterizing impact of the December 2004 tsunami*).

In this section, we mainly present results from our preliminary effort to map coastal ecosystems, both prior to and following the tsunami (Figure 4). Overall, through the acquisition and analysis of satellite imagery, it was expected that it would be possible to estimate the extent of coastal habitats *before* the tsunami struck, as well as assess the extent of change/damage to these ecosystems following the tsunami. However, there were several significant constraints that did not permit this. First, in order to assess the status of different habitat types prior to the tsunami, the resolution of 28.5 m LandSat ETM images are too coarse to accurately distinguish between different habitat types. Second, to classify ecosystems reliably along a coastline exceeding 1500 km in length requires an extensive ground-truthing effort that was not possible to undertake during this study. Most training sites were along the coast line and not well-distributed across the entire area of interest but largely restricted to the Coromandel Coast. Using this information to classification of ecosystems within the Coromandel performed fairly (see Figures 5, 6 & 7) but yielded wrong classifications elsewhere (see Figure 8) and left a large percentage of pixels in some regions unclassified (Table 2). For example, large stretches of the Kerala coast were incorrectly classified as mangrove owing to the total lack of ground truth points from this region. Third, classification of old satellite imagery (in this case, LandSat ETM) is constrained by the lack of training sites/ground-truthing locations from a matching period of time. This too has contributed to significant mismatch in ecosystem classification before and after the tsunami using satellite imagery. Finally, satellite imagery (post tsunami) was not available for significant stretches of the east coast.

Scope for further work in Phase 2 of the project

The issue of image resolution to identify different habitat types has been addressed by procuring fine resolution multispectral IRS P6-LISS4 MX images. The results for the Coromandel Coast, the most severely impacted area, serves as a benchmark for further analysis. The approach and systems put in place for during the first phase provides a frame work for carrying out advanced analysis and refinement of the present outputs. To achieve higher accuracies while differentiating habitats, we need to scale up the number of ground truth points and while doing so, these points need to be evenly distributed across the entire area of interest.

The use of multi resolution images, 0.6m pan (QuickBird) to 15m pan (LandSat ETM) and multispectral images (QuickBird, IRS-LISS4 & LandSat ETM between 2.4 – 28.5m), indicate that it might not be possible to exactly determine the extent of damage to different ecosystems without the use of multi-date high resolution satellite data products. This approach is expensive and dependent on the availability of high resolution data products, so, at best, results can only indicate coastal habitats that are likely to be impacted by the tsunami.

Assessing changes in land-use from the 1970s in this predominantly human landscape, the type and accuracy of the analysis will depend on availability and resolutions of satellite imagery. Given these two constraints, instead of spreading efforts thin, it is better if bulk of the focus is on select sites along the Coromandel Coast. Also it is important to define a priori what we consider as change, we are likely to observe considerable shift in cropping patterns over the last 30 years between open agriculture and agricultural plantations (and vice versa) and if the understanding of such changes are meaningful.

Figure 4: Overview of the classification of coastal ecosystems in a 10-km inland buffer from the coastline before and after (inset) the December 2004 tsunami

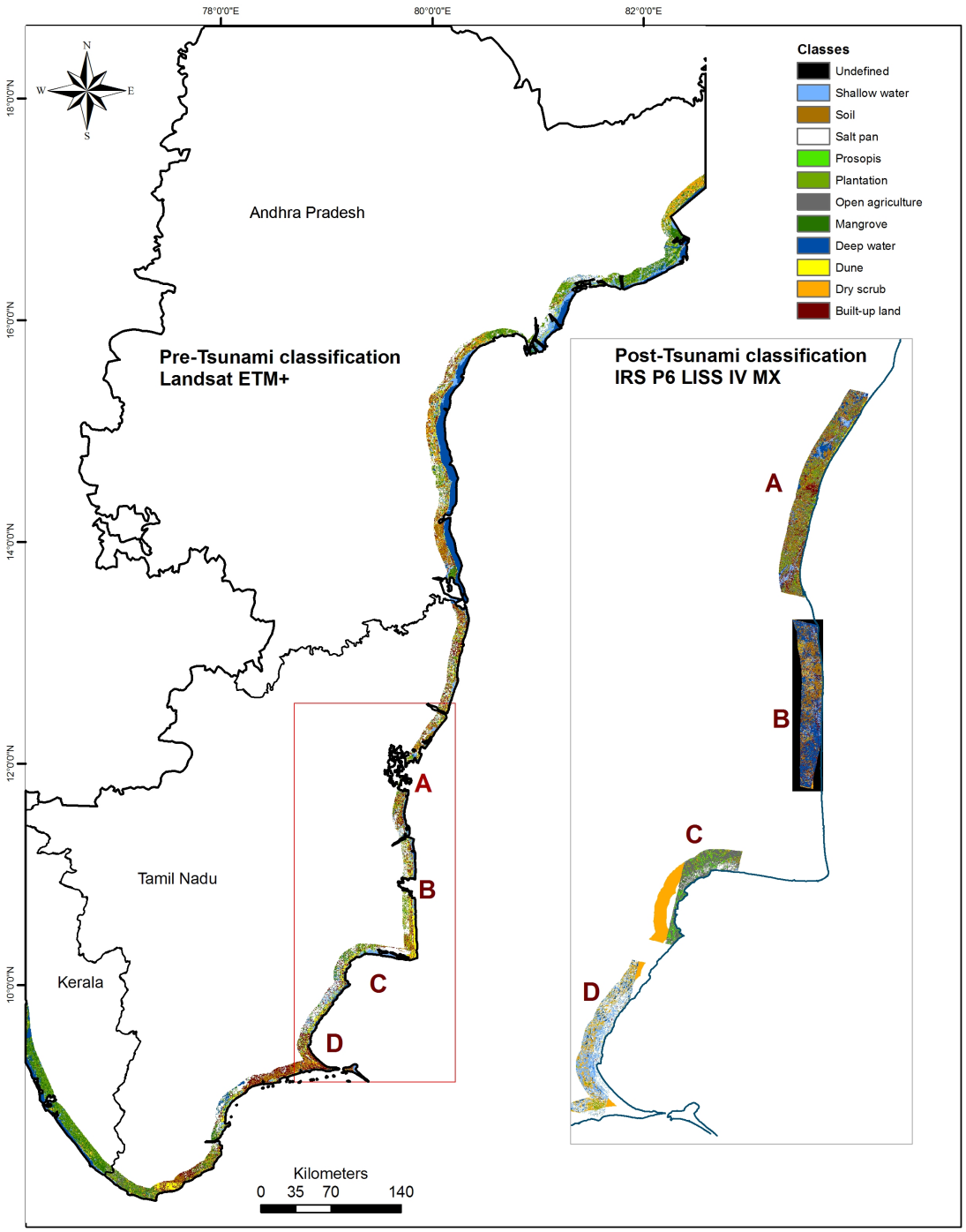


Figure 5: Sample detail from the preliminary classification of ecosystems from pre-tsunami satellite imagery from LandSat ETM+. Insets: (A) region north of Pondicherry clearly showing dune, built areas and bare soil; (B) mangrove forests to the west of Vedaranyam and (C) plantations and dry scrub habitats west of Kanyakumari

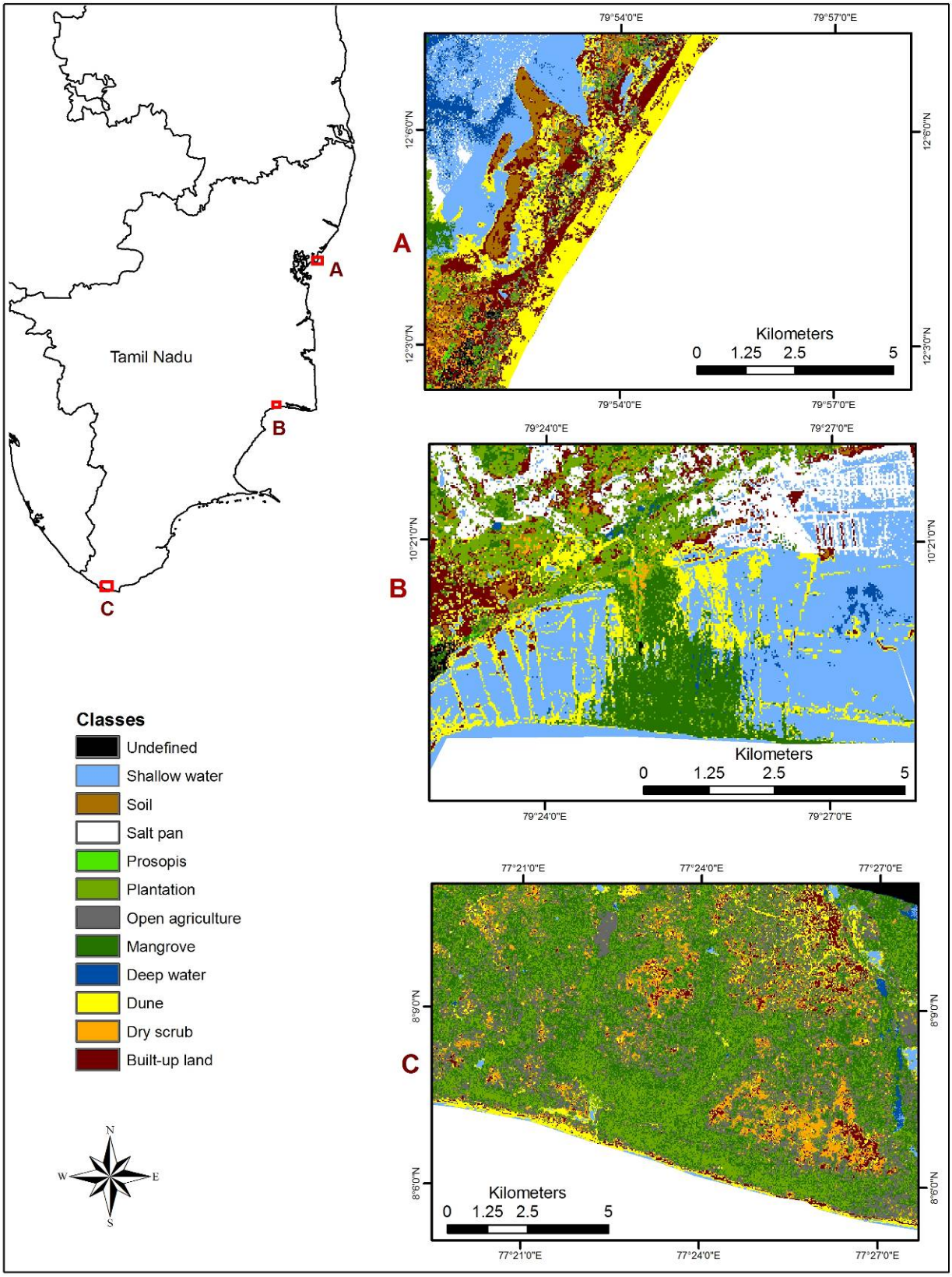


Figure 6: Sample detail from the preliminary classification of ecosystems from post-tsunami satellite imagery from IRS P6 – LISS IV. Insets: (A) dune ecosystems, open agriculture and bare soil north of Pondicherry; (B) interspersion of plantation and open agriculture south of Pondicherry and (C) bare soil, dry scrub and inland water bodies from a region south of Karaikal

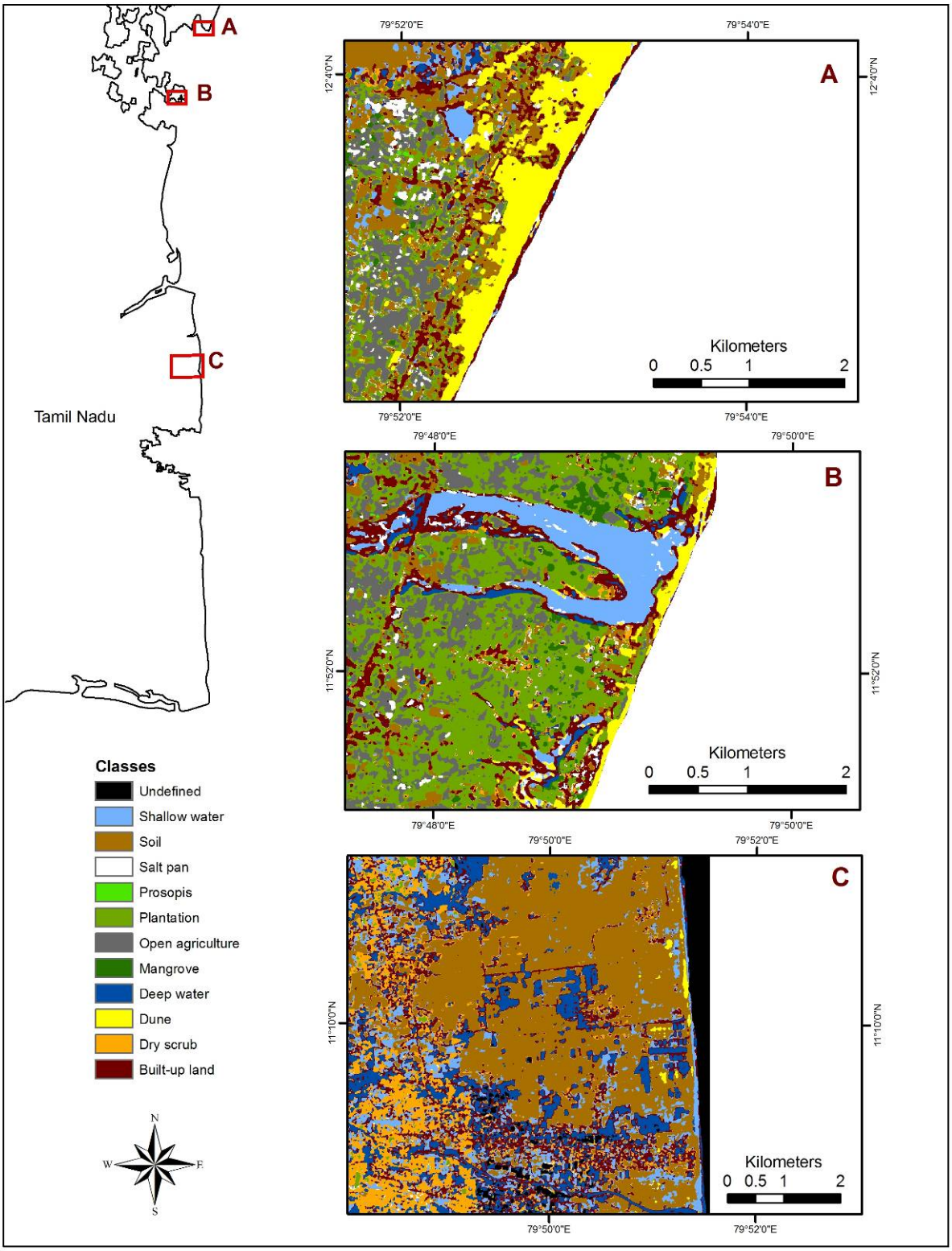


Figure 7: Comparison of coastal ecosystem classification from pre- and post-tsunami satellite imagery for the Pondicherry city area (built-up). There is a clear increase in the urban footprint of Pondicherry as well as a general increase in built-up regions. While no changes are evident in dune ecosystem some change is indeed suggested from dry scrub forests to open agriculture and plantations

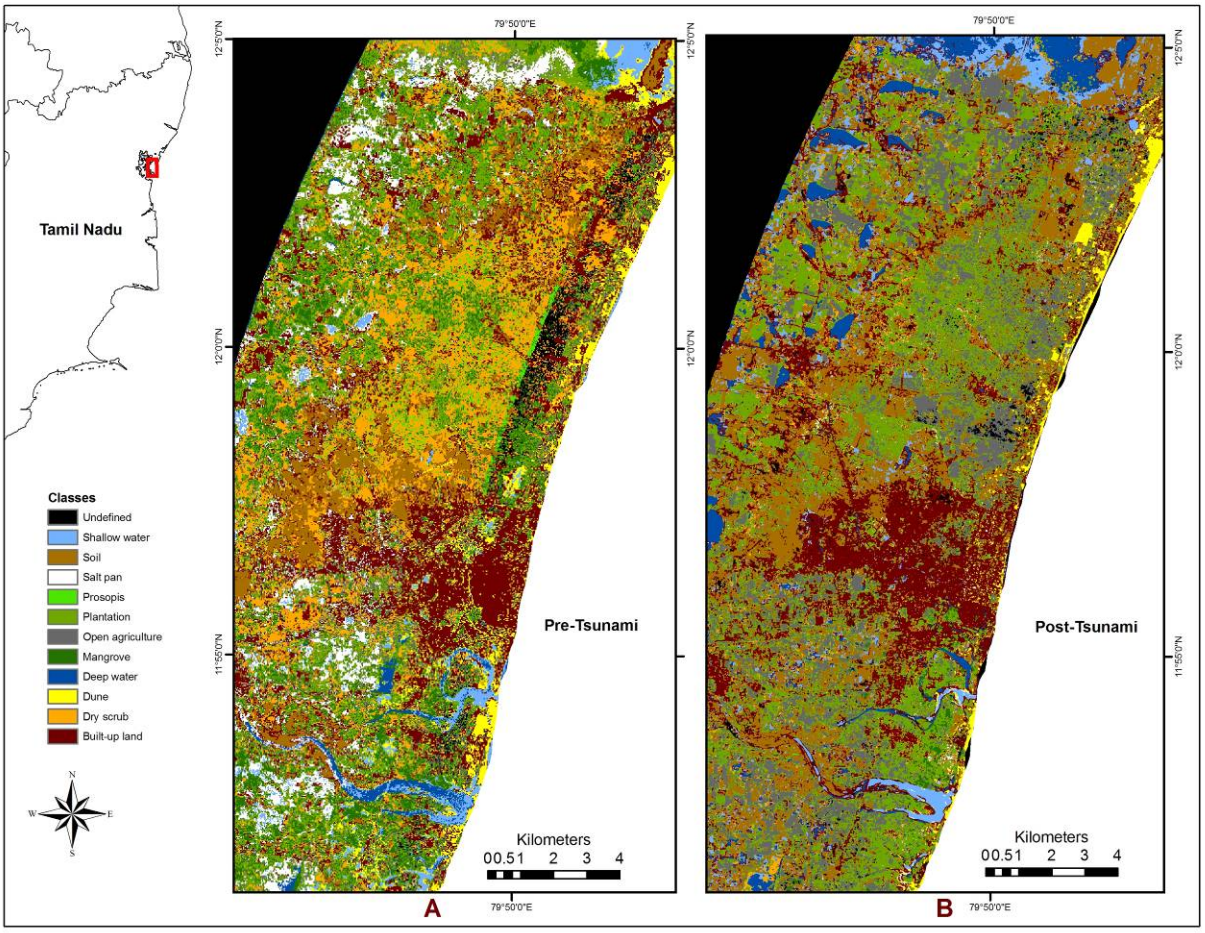


Figure 8: Limitations and problems in the preliminary exercise of classifying coastal ecosystems from pre- and post-tsunami satellite imagery. Inset: (A) region south of Pondicherry showing a distinct banding of built-up areas in the pre-tsunami classification (left); (B) despite using the same training site to classify mangroves (left), the pre-tsunami image clearly identifies mangroves west of Vedaranyam whereas the same region remains mostly unclassified in the post-tsunami classified image (right); and (C) a region west of Rameswaram showing areas identified as open agriculture and built-up regions in the pre-tsunami classification map that have been classified as salt-pans and shallow water in post-tsunami maps.

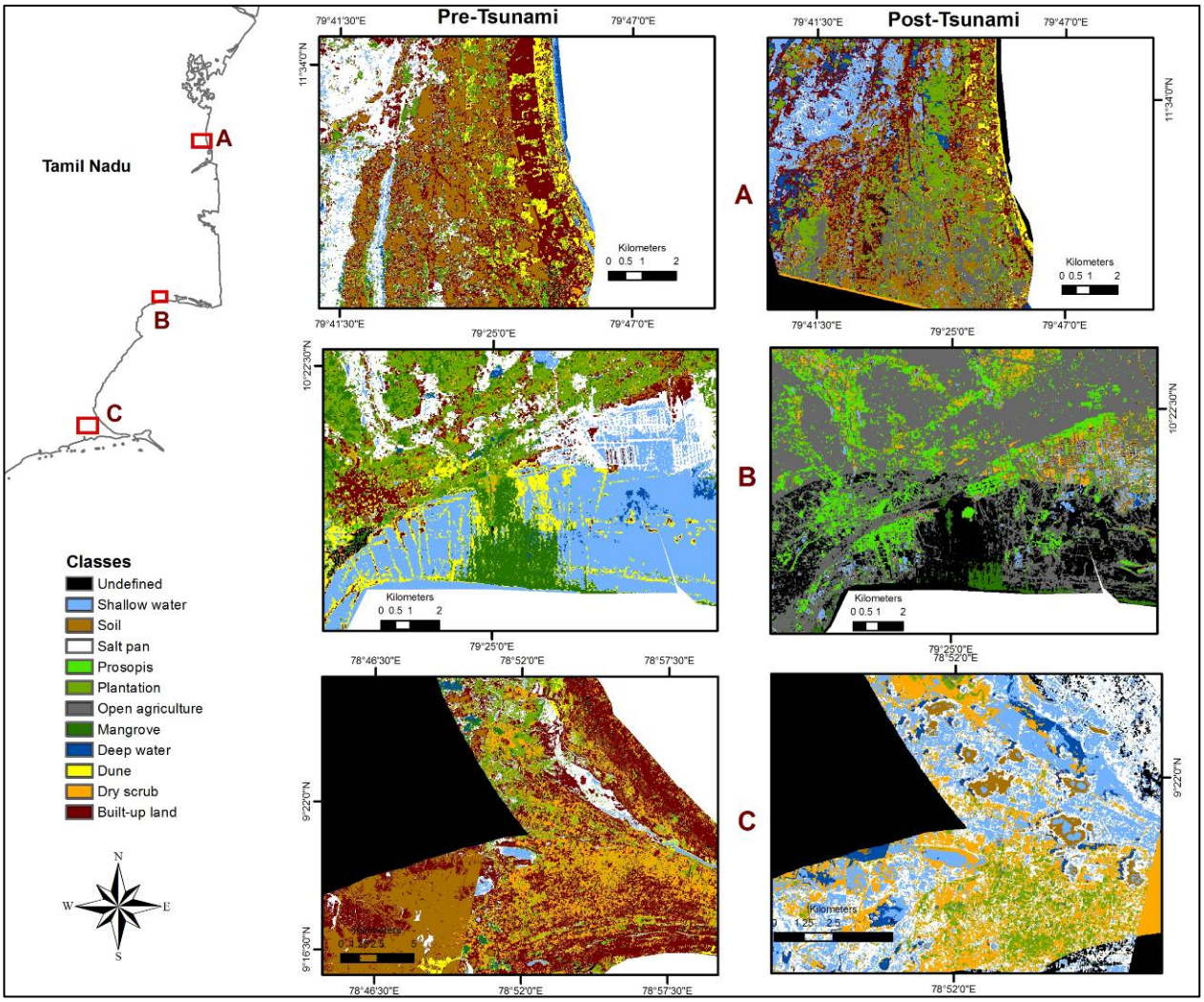


Table 2: Percent area of natural and anthropogenic ecosystems found within the boundaries of coastal taluks of the tsunami-affected states based on a classification of 2006 imagery from IRS P6-LISS IV

State	District	Taluk	Undefined	Salt pan	Mangrove	Prosopis	Plantation	Dry scrub	Crop-fields	Soil	Dune	Built-up
PONDICHERRY	Karaikal	*Karaikal(M)*	0.8	0.0	0.0	0.0	0.0	1.5	0.0	4.9	0.1	17.4
		Kottucherry Commune Panchayat	3.6	0.2	0.0	0.0	0.0	3.8	0.0	11.5	0.0	20.6
		Nedungadu Commune Panchayat	32.6	0.0	0.0	0.0	0.0	2.7	0.0	25.1	0.0	11.8
		Neravy Commune Panchayat1	0.0	0.5	0.0	0.0	5.2	24.7	0.2	1.4	0.0	20.9
		Neravy Commune Panchayat2	29.8	0.2	0.0	0.0	0.9	11.5	0.0	2.7	0.0	15.5
		Thirunallar Commune Panchayat	44.9	0.0	0.0	0.0	0.0	3.4	0.0	7.7	0.0	9.9
	Pondicherry	*Ariankuppam Commune Panchayat*	4.8	1.0	1.8	0.1	20.8	2.7	9.6	18.3	2.0	34.3
		Ozhukarai (M)	1.6	1.0	0.4	0.1	33.6	3.9	17.0	24.8	0.6	10.0
		Pondicherry (M)	5.5	1.1	0.1	0.2	27.8	1.0	24.9	24.3	3.4	10.5
		Villianur Commune Panchayat	64.0	0.2	0.0	0.0	8.6	1.9	2.5	11.6	0.0	7.1
TAMIL NADU	Cuddalore	*Kattumannarkoil1*	44.0	0.0	0.0	0.0	0.0	8.9	0.0	2.2	0.0	4.1
		Kattumannarkoil2	27.3	0.9	0.0	0.3	17.4	3.4	11.8	14.9	1.8	15.4
		Cuddalore	23.7	1.4	0.3	0.1	17.9	3.5	9.1	14.3	0.9	15.6
		Panruti	87.0	0.1	0.0	0.0	5.4	0.8	2.2	2.5	0.0	1.6
	Kancheepuram	*Maduranthakam*	88.6	0.1	0.0	0.0	1.0	1.0	1.6	2.8	0.0	1.7
	Nagapattinam	*Kilvelur*	91.9	0.0	0.0	0.0	0.0	2.9	0.0	0.7	0.0	1.0
		Sirkali	21.1	0.2	0.0	0.0	1.4	10.1	0.0	21.6	0.5	12.0
		Tharangambadi	32.0	0.1	0.0	0.0	0.2	9.4	0.0	16.6	0.1	11.3
	Pudukkottai	*Aranthangi*	60.5	0.0	0.0	0.0	0.0	39.5	0.0	0.0	0.0	0.0
		Avudayarkoil	29.6	0.0	0.8	8.5	0.3	42.1	18.5	0.1	0.0	0.1
		Manamelkudi	54.1	7.1	0.0	0.0	1.8	27.6	0.6	0.1	0.0	0.4
	Ramanathapuram	*Paramakudi*	92.1	1.1	0.0	0.0	0.3	2.3	0.0	0.0	0.0	0.0
		Ramanathapuram	49.3	14.4	0.0	0.0	2.5	11.5	0.2	1.0	0.0	0.3
		Tiruvadanai	57.4	14.0	0.0	0.0	2.0	8.3	0.6	0.4	0.1	0.4
	Thanjavur	*Pattukkottai*	45.7	0.1	0.6	8.9	2.7	4.5	34.8	1.1	0.0	0.1
		Peravurani	45.0	0.0	0.7	3.9	0.4	38.3	11.8	0.0	0.0	0.0
	Thiruvarur	*Thiruthuraipoondi*	36.7	0.5	1.2	3.8	4.5	3.9	43.1	2.1	0.0	0.6
	Viluppuram	*Tindivanam*	87.2	0.1	0.0	0.1	2.1	0.8	2.0	4.2	0.0	1.9
		Vanur	59.0	0.3	0.1	0.0	4.7	1.8	2.9	9.2	2.3	5.2
ANDHRA PRADESH			-	-	-	-	-	-	-	-	-	-
KERALA			-	-	-	-	-	-	-	-	-	-

Characterising impact of the December 2004 tsunami

Understanding impact

The tsunami, although a brief event of short duration, had wide-ranging consequences on human and natural systems given the sheer force of the wave that buffeted the coast. Following from the immediate consequence—the inundation of coastal habitats and habitations—there were knock-on effects that included loss of human lives, injuries, and loss or damage to property. There were also consequences that were not as rapid but nevertheless serious. These included a breakdown in systems of access and delivery to goods and services, impairment of local livelihoods based both on land and sea, as well as serious social disruptions such as displacement. As part of the follow up examining the impact of the tsunami, it is important to acknowledge divergent yet valid ways in which to measure the impact of the disaster. From the perspective of understanding the vulnerability of our coasts and people residing along them, it is necessary to see if these divergent measures yield similar patterns of impact, or whether they provide information that complement each other.

How we characterized impact

As part of our assessments we identified the following measures of impact, both immediate and eventual. First, we used the run-up distance of the tsunami wave front as a measure of the physical force with which the tsunami hit various parts of the east coast. To assess run-up distance and the level of inundation we used high-resolution IKONOS and QuickBird images that were made available on request from the Pacific Disaster Centre (http://www.pdc.org) and UNOSAT (http://www.unosat.org). Only those images acquired immediately after the tsunami event were used for analysis. All images were georeferenced to UTM co-ordinates using the pre-tsunami LandSat ETM as reference images. Using the multi-spectral and panchromatic images, we visually identified the extent of inundation based on standing water and washed-up debris. When areas in the imagery appeared to be under water and when it was not possible to ascertain if this was due to accumulation of rain water or due to the tidal action, such points were eliminated from further analysis. Secondary data from other sources were also added to this database (Yeh et al. 2006). The distance of sea-water ingress inland as described by run-up distance from the coast was not possible to model for the remainder of the coastline because no data at the required resolutions were available for the wave force, nearshore bathymetry and coastal topography. Therefore the tsunami run-up was described by plotting distance of seawater ingress for 617 points along the Coromandel Coast, rather than drawing a run up *line.* Further, we also used the run-up zone (an area bounded by the coastline on the east and the run up points on the west) to assess the range of ecosystems that were likely vulnerable to tsunami impact.

Choosing surrogates of impact

Besides the physical impact of the tsunami, we also collated information on its impact in broadly three ways. First, we compiled data on *injury and loss of human life.* Second, data on *loss to infrastructure* such as houses and roads was compiled. Finally, information was also collected on *losses to ecosystem-derived livelihoods*, primarily in the form of loss to fishing gear and crafts. As shown in Table 1, an important lacuna in the data we compiled was the non-availability of data on tsunami impacts to agriculture. The database created as part of this programme allows for this information to be added as and when it becomes available, so that this can be used to strengthen the analysis further. We considered these measures to be essentially naïve but vitally heuristic surrogates of the impact of the tsunami on the Indian coastline. Other measures and further refinements of the chosen indices could well be conceived within this analytical framework without dramatically altering the lessons learnt from this

analysis. We used these normalised spatial analyses to compare the impact of the tsunami on human lives with surrogate indices of ecosystem derived livelihoods and infrastructure listed above.

The influence of measurement

Within each of these three broad 'lenses' through which to assess the impact of the tsunami, we also assessed to what extent the picture of tsunami impacts varied with different measures of impact. For instance, we considered whether differing pictures of human casualty emerged depending on whether we used the total number of lives lost, or the fraction of the *tehsil's* population that perished in the disaster. We also mapped out pictures that emerged when human densities were considered instead of just populations, as well as the effect of normalizing (dividing values for human casualty in all *tehsils* by the highest value).

Results

Run up zone and associated impact

As has been well-established, the land mass of Sri Lanka provided a significant protective buffer to large parts of the east coast of India. The Palk Bay region was not heavily impacted by the tsunami in terms of human deaths and other impacts, while the Gulf of Mannar and the west coast were affected by a wave reflected off the southern extreme of the Sri Lankan mainland. The worst of the impact was recorded in regions not protected by Sri Lanka. The northern tip of the Palk Bay (Point Calimere) was the closest straight-line distance from the point of origin of the tsunami (~1930 km), but the run-up distance was higher in regions further north, increasing uniformly in regions north of Nagapattinam before reducing once again (Figure 9). This points to the fact that the intensity of the tsunami was influenced strongly by local factors such as nearshore bathymetry and coastal topography as has been found elsewhere (Murthy et al. 2006, Chatenoux and Peduzzi 2007). At its maximum, the wave inundated areas as far inland as 2.5 km. The available data on tsunami run-up distance show a close correspondence with the distribution of human casualties along coast (Figure 9). The low-profile, mostly beach and dune dominated Coromandel Coast from Pondicherry to Point Calimere was the worst affected, with high number of casualties concentrated in Nagapattinam.

In terms of the land-cover types and ecosystems affected by the tsunami, the data from the run-up zone are not conclusive (Table 3). The principal constraint here is that a large fraction of pixels from the run-up zone remain unclassified, given that this effort was primarily one of aggregating and compiling secondary data, whereas the data required to carefully map out ecosystems would involve considerable amount of field work. However, we believe that a careful process of identifying the most vulnerable coastal ecosystems that is based on primary field work in the forthcoming detailed phase of the Post Tsunami Environmental Initiative would be invaluable.

Impact of the tsunami: surrogates and the influence of measurement

Our analysis clearly highlights a set of issues that must be considered in understanding the impact of a natural disaster. First, it is extremely important to understand impact such as human casualty in relation to human density and settlement patterns along the coast. As Figure 10 illustrates, there are broad correlations between the density of human populations along the coastal tehsils and the pattern of human deaths that occurred here. Yet, there are important departures from this pattern. Although the regions around Chennai are among the most densely settled regions on the East Coast (Figure 10, *top left*), casualty levels are the highest along the Nagapattinam coast (Figure 10, *top right*). These point to impacts of the tsunami being more complex than merely an artefact of coastal settlement patterns. A similar pattern may be seen even with respect to artisanal fishing crafts. Although relatively lower numbers of artisanal craft existed around the Nagapattinam region (based on the 2001 Fisherfolk

Census; Figure 10, *bottom left*), the reported losses in this region are amongst the highest (Figure 10, *bottom right*). These patterns need further examination to ascertain if they are artefacts of the quality of data, or actually point to realities that are poorly understood.

Second, pictures of tsunami impact emerging from alternate measures also have a profound effect on how we understand the fallouts of the tsunami. For instance, loss to artisanal fishing craft show variable patterns of impact (Figure 11, left to right) depending on whether we map: (a) the total number of craft lost/damaged in a tehsil, (b) proportion of existing craft lost/damaged in a tehsil or (c) normalize data to obtain a picture of relative loss compared to areas that sustained the greatest absolute losses. Similar differences may also been seen with respect to human casualties. This discrepancy in the pictures of impact that emerge depending on whether we consider total loss/damage, proportional loss/damage and relative loss (relative to the worst affected regions) highlight the sensitivity of tsunami impact assessments to the measures used.

Finally, impact of the tsunami also presents a highly variable picture based on the surrogates used to index impact. Figure 12 illustrates how different regions of the coast show up as the most severely affected in the tsunami based on whether human life (Figure 12, top left), damage to housing (top right) or damage/loss to fishing craft (bottom left & right) was used to index damage. It would be extremely important, particularly in Phase 2 of this project, to understand to what extent reconstruction and rehabilitation efforts in each coastal taluk corresponded with the kind of impact experienced by that taluk. This is an important aspect for careful study, particularly given that many policy and ground-level interventions post-tsunami (see chapter discussing coastal policy) have largely been founded on good intentions, but still rather weak on data.

Table 3. Proportion of various land-cover/ecosystem types represented within the run-up zone (see Fig 9) of the December 2004 tsunami, based on analysis of satellite imagery from IRS-P6/LISS-IV. The large proportion of pixels that remain unclassified seriously limit the value of these analyses.

Ecosystem Type	Sirkazhi to Nagapattinam	Cheyyur to Kattumannarkoil
Mangrove	0.00	0.58
Dry Scrub	0.70	1.23
Prosopis Scrub	0.00	0.06
Coastal Dune	2.65	15.39
Bare Soil	9.53	7.42
Open Agriculture	0.00	0.89
Plantations	0.00	4.25
Built Area	6.37	11.93
Salt Pan	0.28	1.51
Shallow Water	5.00	3.23
Deep Water	12.09	1.24
Unclassified	63.38	52.27

Figure 9: A schematic representation of the run-up distance of the December 2004 tsunami measured at 617 points along the Coromandel coast. Run-up distances ranged from 45 m to 2500 m from the coastline, with longer red bars indicating greater distances of water ingress. Coastal taluks from the Coromandel coast are also shown representing low (green) to high (orange) levels of human casualty in the tsunami.

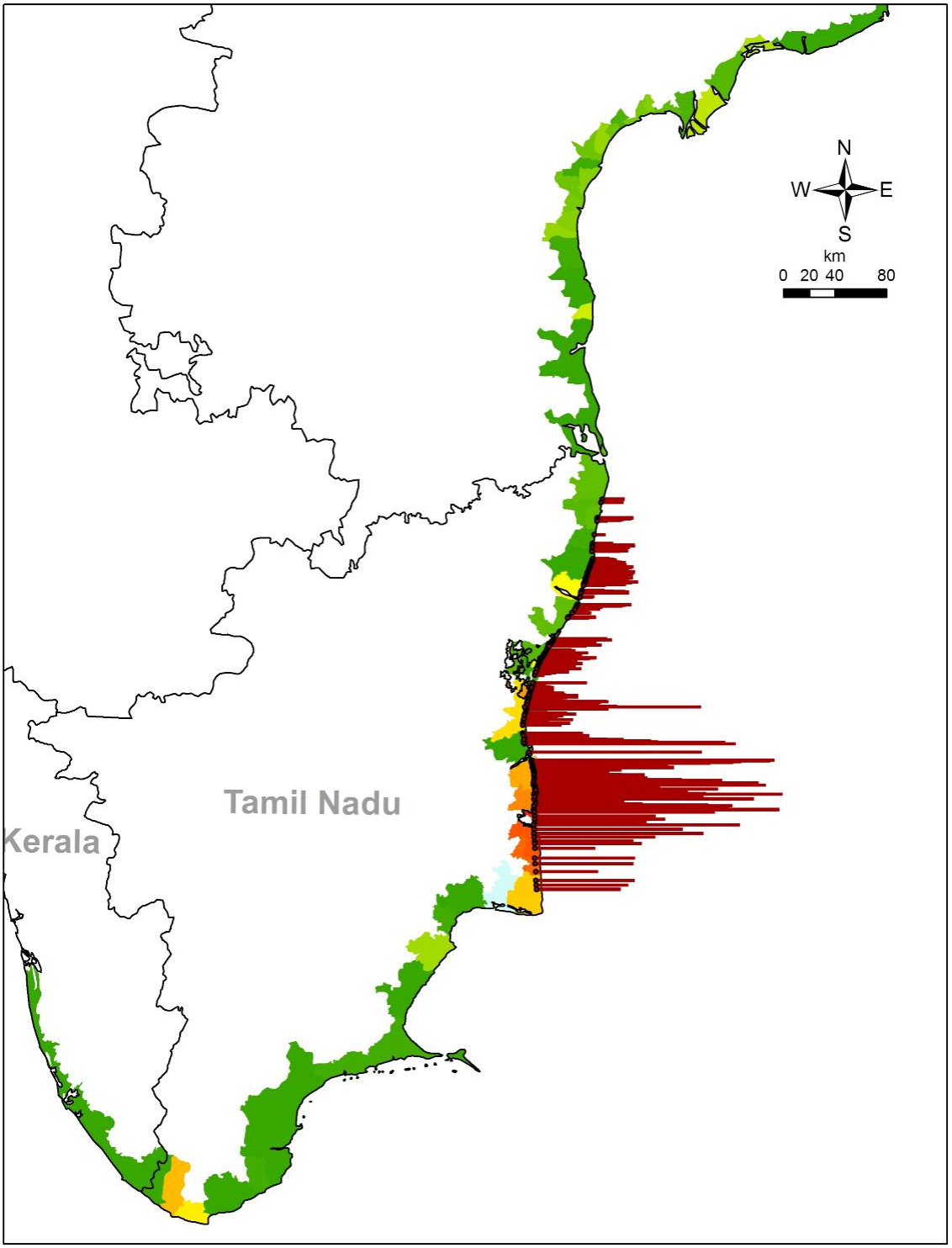


Figure 10: Human casualties caused by the tsunami in Tamil Nadu (top right), in relation to the distribution of human population in the tsunami affected states of southern India (top left). Note how the densely settled northern coastal taluks of Tamil Nadu are affected to a lesser degree than the southern taluks of the Coromandel coast (Nagapattinam region). Similarly, damage to artisanal fishing crafts in Tamil Nadu against 2001 baselines (bottom left) show disproportionately greater losses in the south Coromandel region (bottom right)

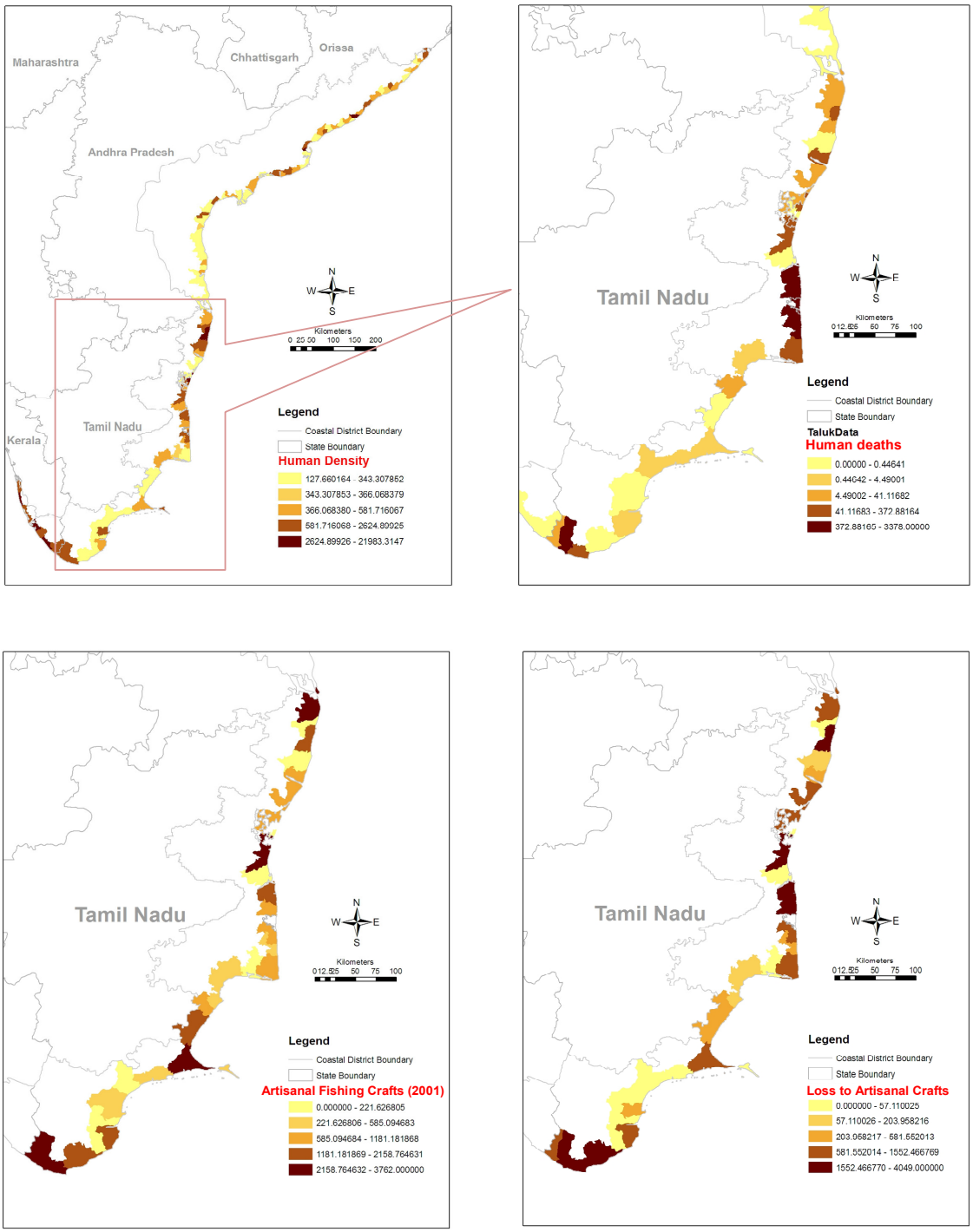


Figure 11: Maps showing effect of the tsunami on artisanal fishing crafts in Tamil Nadu using three different measures of impact: (a) total number of artisanal fishing crafts damaged (left); (b) proportion of total artisanal fishing craft damaged (centre); and (c) normalized proportion of artisanal fishing craft damaged in the tsunami (right). This discrepancy between total loss, proportionate loss and relative loss underlines the need for explicit definitions of impact in assessments that form the basis for rehabilitation and reconstruction efforts

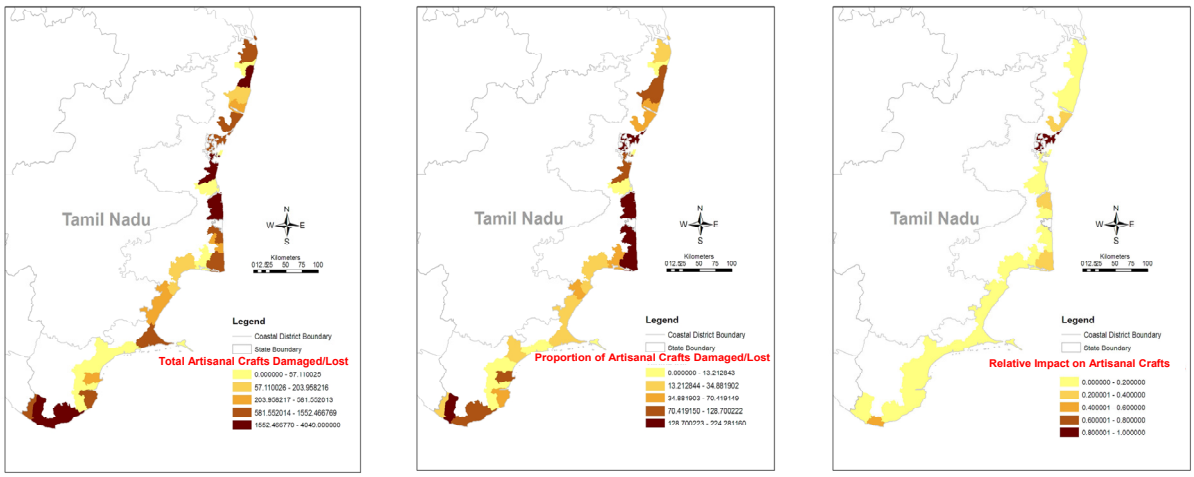
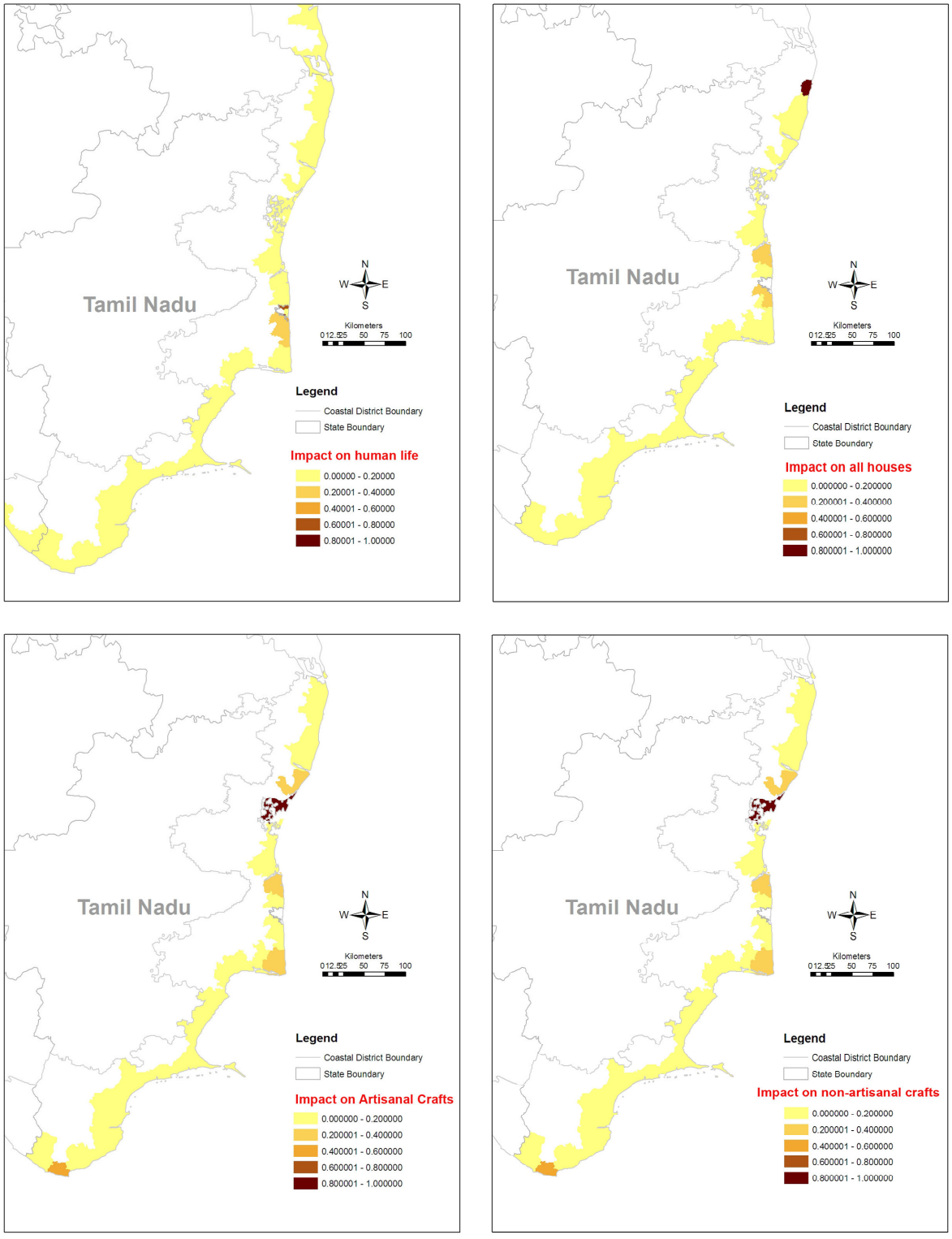


Figure 12: Maps showing the relative impact of the tsunami across various coastal taluks based on different surrogates. Based on the surrogate of human casualties (top left) the taluks of Cuddalore and Nagapattinam are impacted the heaviest, whereas based on the surrogate of damage to housing (top right), Chennai shows the greatest impact, and surrogates pertaining to loss/damage to artisanal and non-artisanal fishing crafts show areas around Pondicherry as showing the most impact.



Lessons learnt

Understanding impact

The tsunami has had a profound impact not just on the psyche of local communities, but on the governance of the coastal system. It has made policy makers and managers think much more about development along the coast, and the hidden costs of coastal degradation. There is no doubt that this rethinking is important, even essential, but it is equally clear that it requires to be grounded in a much clearer understanding of coastal impacts than that expressed in current discourse. The 'impact' of the tsunami is a much used shibboleth, with little dissection or acknowledgement of the complexities inherent in defining and describing it. As this analysis shows, the impact of the tsunami changes dramatically when viewed with different lenses, and points to the importance of different drivers of impact.

Nevertheless significant points do emerge from the foregoing analyses. It is clear that near-shore bathymetry and coastal topography have been the primary drivers determining the run-up distance of the wave that struck the coast. Thereafter, the human fallouts of this have largely been functions of settlement patterns along the coast, although exceptions to this rule do exist (e.g., the role of contingency in explaining high casualties in Velankanni, Kanniyakumari district). Our analyses also offer an important lesson underlining the need for a more nuanced understanding of 'impacts' of the tsunami, which tend to be extremely variable depending on the currency used to assess it, as well as the measures used to quantify such impact. We believe that such a multifaceted understanding of impact must play a critical part in determining coastal management policy.

Nevertheless, one particular factor believed to moderate impacts of natural disasters on coastlines merits further discussion. Much has been made on the importance of coastal vegetation and the integrity of coastal and marine environments. However, much of the evidence for the prophylaxis provided by natural vegetation comes from rather shallow analysis, or from case studies conducted over very small spatial scales (see Danielsen *et al*. 2005, Kathiresan and Rajendran 2005, Chang *et al.* 2006 among others). More complete analyses often reveals that these protective roles were not as extensive or unequivocal as projected (Kerr *et al*. 2006). For instance, a recent study of the protective role of ecosystems conducted across the tsunami-affected region indicated mixed responses (Chatenoux and Peduzzi 2007). While some coastal systems such as seagrasses appeared to help attenuate the strength of the tsunami wave, reducing impact on coastal systems, the presence of coral reefs actually exacerbated the impact in some instances (Baird *et al.* 2005, Chatenoux and Peduzzi 2007). Interestingly, Chatenoux and Peduzzi (2007) point out that it was difficult to find areas with substantial mangrove cover in areas exposed to the tsunami, making it impossible to determine what protective role mangroves had, if any. They attribute this to the fact that mangroves, by their very nature, tend to grow in areas with a naturally protected topography.

It is obvious that in the face of large-scale events of this nature, vegetative cover and ecosystem integrity may indeed provide some protection against the event, but it is important not to stretch this putative protective role beyond what the ecosystem can deliver. This is crucial in the light of the fact that much of the post-tsunami planning paradigms are being driven by soft-engineering solutions such as the development of coastal green belts of *Casuarina*, the restoration of mangroves, etc. While these initiatives need to be evaluated on their own merits (providing livelihood opportunities, supporting timber needs, etc), it would be naïve to believe that they served the purpose of coastal protection. A more careful quantitative analysis of field and remote-sensed data is essential to assess the actual role of

coastal vegetation in mitigating tsunami impacts. However, this was beyond the scope of our work, given the non-availability of high resolution data both from remote sensing as well as on the ground.

Given that developmental policy will be reactive, particularly in the wake of disasters of this nature, it is important to understand its scope and limitations. While much of the post-tsunami discourse on coastal resilience has concentrated on future tsunamis, this is perhaps not the most urgent imperative for coastal planning. Given the return time of tsunamis on this part of the coastline, it is unlikely (though not impossible) that an event of this magnitude and nature will affect the same coast for at least another 200 years. Keeping an eye on this distant horizon is indeed commendable, but it should not make us lose sight of the more immediate threats that challenge our coastal resilience at annual and decadal scales. These include insidious and anthropogenic threats such as coastal pollution, resource overuse, beach erosion and landscape transformation, as well as natural events such as storm surges, cyclones, floods, and unseasonal rainfall events. The latter (cyclones, floods, etc), are, in all probability, likely to increase in their intensity and frequency as changes in global climate increase in pace, and our coastline will have cope with these changes much more frequently than with tsunami events. The tsunami has provided us an opportunity to evaluate how a large part of the coast would fare in the face of these events, and coastal policies should be more responsive to increasing the resilience of coastal systems to these more proximate events.

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Annexure 1

A list of sources for pre- and post-tsunami data from Andhra Pradesh (AP), Tamil Nadu (TN), Kerala (KL) and Pondicherry (PY)

Human demography and casualty

Overall: Planning Commission, Government of India, http://www.planningcommission.gov.in/

Overall: CensusInfo India 2001 v1.0, Directorate of Census, Govt. of India.

TN: NIC-Tamil Nadu State Centre GIS Division, http://www.tnmaps.tn.nic.in/

TN: Tsunami Resource Centre, http://www.tntrc.org/

TN: Disaster Management and Mitigation Department, http://www.tn.gov.in/tsunami/

TN: Tsunami Reconstruction-Externally Aided Projects, http://www.tn.gov.in/tsunamiEAP/

TN: Tsunami division, Commissionerate of Municipal Adminsitration, Ezhilagam, Chennai

KL: Department of Disaster Managament, Kerala Govt. Secretariat, Trivandrum.

KL: Revenue Department, Alapuzha district, http://kollam.nic.in/tsunami/tsunami.htm

PY: Tsunami Relief and Rehabilitation, http://pondicherry.nic.in/tsunami/tsunamimain.htm

AP: Department of Disaster Management, Government of Andhra Pradesh.

Housing

TN: Highways Department, Government of Tamil Nadu

TN: Tamil Nadu Maritime Board, Government of Tamil Nadu.

TN: Commissioner of Fisheries, Government of Tamil Nadu.

KL: SIFFS Kerala Information Centre, The Tsunami in Kerala

Fisheries

TN: Marine Fisherfolk Census 2000, Commissioner of Fisheries, Govt. of Tamil Nadu

TN: Department of Fisheries, Govt of Tamil Nadu, Endeavour and Achievements, 2005- 2006.

TN: ICSF Information on Post – tsunami rehabilitation of fisheries livelihood, January 2005.

Groundwater

TN: Central Groundwater Board, Regional Office, Rajaji Bhavan, Chennai, Tamil Nadu

AP: Central Ground Water Board, Southern Region, Hyderabad.

Chapter 2 A gap analysis of ecological impact assessments done in the tsunami-affected states

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Introduction

Though nearly two years have passed since the 2004 tsunami, many questions remain. Studies have been carried out to ascertain what areas were inundated, what beaches were washed away, what reefs were damaged or uplifted and how has the topography changed (Kumaraguru *et al.*, 2005; Murthy *et al.*, 2006; Krishnankutty 2006). Assessments of the impacts on wildlife and their habitats largely focused on similar parameters (Kaul and Menon, 2006a, 2006b). Similarly, studies of sociological impacts have also documented fairly thoroughly loss of lives and livelihoods, damage to houses and boats, etc (Chandrasekharan *et al.*, 2005; Kurien, 2005a). Apart from the physical impacts, ecological and sociological systems have also been affected by policy and reconstruction and rehabilitation after the tsunami.

Nearly two years after the massive tsunami hit the Indian coastline in December, 2004; the volume of literature dedicated to its aftermath barely reaches a total of about 100 odd documents (see appendix). These documents comprise of both scientific papers published in peer reviewed journals as well as reports prepared by various governmental and non-governmental institutions. The gamut of topics covered in these reports and scientific journals ranges from impact assessments of the tsunami (both from ecological and sociological standpoints) to future recovery strategies after the tsunami. We looked at studies that dealt with ecosystem surveys along the entire tsunami-affected coastline to specific taxa-centric documentation of the damage caused by the tsunami, in addition to reports on social impact. Though these documents might not represent all work done in this context (as a result of a partial and incomplete search by us), it nevertheless points to the paucity of information both in the natural and social sciences. The depth and quality of some of the available literature sources are another grey area. Often qualitative judgments have been made while assessing the impact of the tsunami as there is hardly any baseline information available to compare its effect. Nevertheless, a bird's eye view of the published sources does provide one with the flavour of ongoing research trends and institutional efforts in the light of the tsunami.

It is critical at this juncture first to review the state of knowledge with regard to the impact of the tsunami in terms of ecological and social perspectives and second to be able to evaluate the direction in which this research is headed. Thus this chapter attempts to understand the trends in research and the focus of post-tsunami efforts. The purpose of this gap analysis is to bring out the importance of the facets (both ecological and social) that have not been covered in sufficient depth in the existing literature but need urgent research attention. We address the issues of emerging trends in research, in which we analyse the processes driving these trends and possible lacunae in them. We also

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highlight a few emerging controversies in the research in this field. Towards the end we look at future trajectories that might be useful for restoration of coastal habitats.

Methodology

Various methods were used to collect literature on post-tsunami studies, including internet searches, searches through online databases, visits to institutions and information from networking components of the project. We used various lenses to analyse the database.

A. Subject areas:

We focussed on four broad sets of questions: -

a. Ecosystems: Which ecosystems were looked at? Were some ecosystems over-represented while some neglected?

b. Coastal geomorphology and Inundation: Were seawater inundation levels in various affected areas looked at?

c. Geographical area: Which geographical areas were studied? Was this in proportion to the impact of the tsunami?

d. Publication types: What are the major publication types under which the information falls?

B. Background knowledge: (trends/indicators)

It is essential to find out whether there was any baseline data available before any assessment could be made on the impact of the tsunami. Often such information is lacking. We examined the data to investigate whether the impact assessments that were made in the wake of the tsunami referred to any background or baseline data. Further, we also tried to look at wheather any novel study was done or method employed (eg. type of indicator used) in the published reports.

C. Follow up:

It is imperative to conduct long duration studies to understand the long-term implications of any event. We therefore investigated wheather there was any follow up of studies conducted before the tsunami

D. Controversial subjects:

Post-tsunami studies generated some heated debates on subjects that are crucial from a management and policy perspective. We thus try to focus on a few of the ongoing debates in this context. At the outset, we would like to mention that this is still an ongoing process and hopefully in the coming months our database would only grow. Further, we used only a few lenses while looking at the data. Undoubtedly, many more issues can be addressed and we hope that the current analysis forms a baseline for further research.

State of knowledge

a. Which ecosystems were looked at, and were some ecosystems under-represented in the database?

Our database comprises of documents dealing with most of the major coastal ecosystems. We present the data in two forms: first in the form of a table giving a broad overview of the studies done till date on various ecosystems in light of the tsunami and second in the form of a bibliography list categorising studies under each ecosystem.

Type of ecosystem	Mangroves	Sandy beaches	Coral Reefs	Estuaries	Seagrass	Dry Forests	Total
No. of publications	14	12	8	3	2	4	43
Percentage	32.55	27.90	18.60	6.98	4.65	9.30	100

i. Mangroves:

Studies conducted

Mangroves can check the wrath of tsunami. Current Science 88(5).(Kar & Kar, 2005)

This was perhaps the first published article in a peer-reviewed journal in India after the tsunami that talks about the protective role of mangroves in minimising the effect of a tsunami. It advocates that government and non-governmental organisations should restore mangroves to protect people living close to the shore and also to prevent coastal erosion in the event of future tsunamis.

Coastal mangrove forests mitigated tsunami. Estuarine, Coastal and Shelf Science 65. (Kathiresan & Rajendran, 2005)

This paper marked the beginning of a heated debate which is yet to be resolved in scientific circles. Kathiresan and Rajendran conducted a study after the tsunami in 18 coastal hamlets along a 25km coastline at Parangipettai, Tamil Nadu. They concluded that the human death and loss of wealth due to the tsunami decreased with the area of coastal vegetation, distance and elevation of human habitation from the sea. They therefore suggested that human habitation should be not be encouraged closer than 1 km from the shoreline and stressed the need for dense mangroves and or other coastal vegetation.

Comments on "Coastal mangrove forests mitigated tsunami" by K. Kathiresan and N. Rajendran [Estuar. Coast. Shelf Sci. 65 (2005) 601-606]. Estuarine, Coastal and Shelf Science 67. (Kerr et al., 2006)

Six months after the previous paper was published, Kerr *et al.* pointed out in this paper that there were "several fundamental errors in their statistical analysis" in Kathiresan and Rajendran's study. According to their reanalysis of the data, 87% of the mortality was explained by distance from the sea and elevation, while distance inland explained 61% of the loss in wealth. In their opinion, the protective role of coastal vegetation was "overstated".

Reply to 'Comments of Kerr et al. on "Coastal mangrove forests mitigated tsunami"[Estuar. Coast. Shelf Sci. 65 (2005) 601-606]. Estuarine, Coastal and Shelf Science 67. (Kathiresan, K & N. Rajendran. 2006)

Immediately after the comments by Kerr *et al* (2006), Kathiresan and Rajendran in defence of their study pointed out that the study was limited to 18 hamlets of a particular area and the tsunami run up there was 2.8 m only. They concluded that their results were very similar to Danielson *et al.,* 2005 and substantiated their argument by citing past studies by Massel *et al.,* (1999) and Hirashi and Harada (2003).

Mangroves mitigate tsunami damage: A further response. Estuarine, Coastal and Shelf Science 69. (Vermaat & Thampanya, 2006)

The debate took another dimension when Vermat and Thampanya contributed to it by re-analysing Kathiresan's data with "an ANOVA-model with covariates". They came to the conclusion that the first conclusion of Kathiresan and Rajendran (2005) that "mortality and property loss were less behind mangroves" holds, but the second proposition of "relocation of human settlements 1 km inland" was impractical.

The Asian Tsunami: A Protective Role for Coastal Vegetation. Science 310. (Danielsen et al., 2005)

A group of authors from various parts of the world added to the debate by publishing the above article in SCIENCE. Their study suggested that mangroves and shelterbelt plantations (*Casuarina*) were effective in reducing the intensity of the tsunami induced waves and in shoreline protection.

Coastal Vegetation and the Asian Tsunami. SCIENCE 311. (Dahdouh-Guebas, & Koedam. 2006)

In this volume, the controversy reached its crescendo. Dahdouh-Guebas and Koedam addressed some caveats in Danielson *et al.* (2005). They remarked that the previous authors did not utilise satellite imagery to its fullest potential to ascertain the "cryptic ecological degradation" of the mangrove forests

prior to the tsunami. Secondly they stated that the previous authors did not consider the possibility of variation in housing construction and within site variation in tree cover as critical factors influencing the damage to hamlets.

As a response to this critique, Danielson *et al.* stated that (a) their field sites were relatively homogenous (b) the high resolution images to compare the effect of the tsunami were not available (c) housing construction were relatively uniform. They concluded by stating the beneficial roles of coastal forests, wetlands and dunes in the light of the tsunami.

Brachyuran crab diversity in natural (Pitchavaram) and artificially developed mangroves (Vellar estuary). Current Science 88(8). (Khan et al., 2005)

This study, conducted in the mangroves of Pitchavaram and Veller estuary addressed an entirely different topic than the preceeding discussion. Though, this study was published a few weeks after the tsunami, it was actually conducted few months prior to the tsunami. Therefore, it forms a potential baseline study to assess the effect of the tsunami in the same site. This study documents the brachyuran crab species diversity in the two mangrove patches and attributes the difference in crab species diversity (38 and 8 respectively) to the difference in age of the mangrove patches (1600-1700 years for Pitchavaram and 13 years for the Vellar mangroves respectively). This study advocates the need for long-term monitoring of these mangrove patches for crab species diversity for understanding colonisation rates in relatively recent mangroves.

Influence of human-induced disturbance on benthic microbial metabolism in the Pichavaram mangroves, Vellar–Coleroon estuarine complex, India. Marine Biology 147 (Alongi et al., 2005)

This study was conducted prior to the tsunami, like the previous one and hence forms a potential baseline study. The authors looked at rates of total carbon oxidation and sulphate reduction to find out if human intervention was causing any change in biogeochemical activity within the benthic microbial community. They found significant difference between the undisturbed and disturbed sites and concluded that "human induced disturbance" caused a "sharp zonation of dry, hypersaline soil" thereby adversely affecting growth of surface microbes and roots.

Mangroves: Natures defence against Tsunamis. A report on the impact of mangrove loss and shrimp farm development on coastal defences Report. (EJF. 2006)

The above report was compiled by Environmental Justice Foundation, London. It deals with the loss of mangroves due to shrimp farming particularly in Asia and suggests that loss of mangroves were predominantly responsible for the vulnerability of coastal populations to the December, 2004 tsunami. It strongly recommends the restoration of mangroves for coastal protection in similar.

Common Guidelines and Methodology for Rapid Field Assessment. Report. (Anon 2005)

This report compiled by IUCN, set guidelines for a common methodological framework for rapid field assessment of the tsunami's impact on terrestrial coastal ecosystems. This was critical, because a large number of national and international bodies were involved in ecological impact assessment studies post-tsunami. In the absence of a common framework, it would be difficult to compare the impacts in different regions and later on to form baselines for future restoration.

Gaps

Studies on documentation of flora and fauna, area and extent of mangrove ecosystems and their ecological status and stress factors are available only for major mangrove areas like Muthupet, Pichavaram, Godavari and Krishna mangroves and such studies are not available for other areas. It is imperative to have a clear-cut documentation of the area, diversity of flora and fauna, ecological status

and local threats for all the mangrove areas, as a baseline for monitoring and also for management decisions.

ii. Corals:

Studies

Rapid assessment of status of corals in Gulf of Mannar after tsunami. Report. (Patterson, 2005).

This report deals with a post-tsunami survey done on corals in Gulf of Mannar Marine Biosphere Reserve (GoMMBR) by Sugandhi Devadasan Marine Research Institute (SDMRI), Tuticorin. They concluded that the reefs and associated habitat were not affected significantly by the tsunami except/or "minor transitional damages".

Impact of the tsunami of 26 December 2004 on the coral reef environment of Gulf of Mannar and Palk Bay in the southeast coast of India. Current Science, 89 (10). (Kumaraguru et al., 2005)

In this paper the authors project an entirely different scenario than the precceding report. According to their findings live coral cover had declined from 48.5% to 36% after the tsunami in the Gulf of Mannar. About 30% of the coral cover was under silt deposition due to the tsunami and roughly 6.7% of corals were either killed, upturned or broken. The situation was similar in Palk Bay though the losses were more moderate than that of the Gulf of Mannar.

Gaps

Moreover, studies on coral biology and reproduction are very limited. Though the continuous monitoring of reefs in GoMMBR and Palk Bay are being carried out in a regular basis by the local research institution, the surveys are mainly to look at the life farm categories and change live coral cover only. Changes occurring in the ecosystem function and the associated flora and fauna have to be thoroughly investigated for the better understanding of the system and conservation.

iii. Seagrasses:

Studies

Ecological impact of tsunami on Nicobar Islands (Camorta, Katchal,Nancowry and Trinkat) Current Science 89 (1) (Ramachandran et al., 2005)

This is the only published scientific study that makes a passing mention about damages caused to seagrasses. Though the authors discuss increased sedimentation rate damaging seagrasses, no quantitative data is presented. This study is based on interpretation of satellite images and therefore it might not have been possible within the framework of this study to analyse the loss of seagrasses.

Gaps

Work on distribution of seagrasses along the Tamil Nadu coast and also for the entire Indian coast has been carried out. (Ramamurthy *et al.,* 1992; Parthasarathy *et al.*, 1991; Jagtap,1991; Jagtap *et al.*, 2003a). But there is no recent survey on distribution and area of the seagrass system along the coast. Even the system at some particular regions has not been documented. For eg., in the Palk Bay area south of Mimesal, seagrasses were observed in places like Thonithurai, Sangumal and Agnitheertham* but are neither surveyed nor documented. Likewise during the field visit (sandy beach survey) of this project cast ashores of *Halodule* species were observed at Manginipudi beach near Machillipatnam, indicating the need to do an intensive survey in these areas for the survey and documentation of seagrasses. Studies on the status of the system including the present threats and policy responses have been carried out. (Jagtap *et al.*, 2003a; Jagtap *et al.*, 2003b). Floral biology of *Halophila beccarii* and species description of *Halophila decipiens* has been carried out. (Parthasarathy *et al.*, 1988a; Parthasarathy *et al.*, 1988b). Studies on the structural components of seagrass ecosystems and

observations on depth-wise species distribution were also carried out on the southeast coast of India (Jagtap, 1996).

a) **Research and documentation**: In general studies on seagrass ecosystem in India are very limited. Though there are certain studies on documentation of associated flora and fauna, studies focusing on the interaction between associated organisms and seagrass ecosystem is almost absent. As mentioned earlier, studies on ecosystem structure and functioning are also yet to be undertaken. Although the system is sensitive to certain environmental parameters, the system may not show an immediate response like disappearance or decrease in meadow area for certain stress factors like siltation. Such long-term effects will be revealed only by a continuous monitoring program, which is currently lacking. Socio-economic analysis of ecosystem services provided by seagrasses are also absent.

b) **Awareness**: As pointed out by Jagtap *et al. (*2003 **a**), there is complete lack of awareness about the ecological value of seagrass ecosystems. There appears to be a dearth of knowledge both at the level of local communities and among coastal zone managers.

iv. Sand dunes and sandy beaches:

Studies

Trails of the killer tsunami: A preliminary assessment using satellite. Current Science 89 (5). (Ramakrishnan et al., 2005)

This scientific correspondence states that the effects of the tsunami were observed upto 3km on land to 40km in the ocean. The stretch from Baticola (Sri Lanka) to Portonovo (India) was the worst affected. The authors were able to detect a decrease in radiance of the coastal waters post-tsunami and attributed it to an increase in water depth and alteration in sediment type.

Ecological impact of tsunami on Nicobar Islands (Camorta, Katchal,Nancowry and Trinkat). Current Science 89 (1). (Ramachandran et al., 2005)

Though outside the purview of this project, our analysis would remain incomplete without the mention of this study. This is perhaps the only published scientific paper that has looked at changes in sandy beaches and quantified it. The authors report the increase in two of the four islands in Nicobar (Trinkat: 18.7 ha and Katchal 1242.02ha), while sand cover decreased in Camorta 368.72ha (103.43%) and Nancowry 78.98 ha (31%). In our opinion, this is a fairly important study in the context of the tsunami.

Gaps

Very few studies have been carried out on coastal systems compared to other terrestrial habitats such as forests. Studies have focused on indicator species of the sandy beach like the mole crab, which is an indicator of heavy metal accumulation. Some studies have been carried out on the diversity of sandy shore fauna (Ansell *et al.*, 1972a,b,c; McLusky *et al.*, 1975; Silas and Sankarankutty 1967; Trevallion *et al.*, 1970). And there are several reports of survey of marine turtle nesting beaches (Bhupathy & Saravanan 2006; Tripathy *et al.,* 2006). A few studies of sand dunes have also been carried out (Masceranhas, 2002a, b).

However, a large amount of work remains to be done. Basic studies have to be done on the taxonomy of the flora and fauna along the coast. Sand dunes must be monitored periodically for their biodiversity. Ecologically sensitive fauna/flora have to be identified. More research needs to be carried out especially on geomorphological changes as a consequence of human interference such as seawalls, ports and harbours and other developmental activities.

b. Were the sea water inundation levels in various affected areas looked at?

Studies

Run-up and inundation limits along southeast coast of India during the 26 December 2004 Indian Ocean tsunami. Current Science 88 (11) (Jayakumar et al., 2005)

This paper points out that inundation levels were lower along the coast in places protected by sand dunes than in areas where there were no dunes. The authors found that run up heights were higher in the northern regions of Tamil Nadu compared to the south and this was due to the bathymetry of the continental slope.

Run-up and Inundation Pattern Developed During the Indian Ocean Tsunami of December 26, 2004 Along the Coast of Tamil Nadu (India) Gondwana Research (Gondwana Newsletter Section) 8 (4) (Narayan et al., 2005)

The major finding of this paper was that there was large variability in the inundation pattern caused by the tsunami. The largest run up was observed in Nagapattinam district while the lowest were measured in Thanjavur, Puddukkotai and Ramnathpuram districts of Tamil Nadu. The authors attributed several factors like presence of shadow of Sri Lanka, interference of direct waves with reflected waves and variation in the width of the continental shelf for the variability in run up.

Inundation characteristics and geomorphological impacts of December 2004 tsunami on Kerala coast. Current Science 90 (2). (Kurian et al., 2006)

This study throws light on the aspects of inundation and geomorphological changes in various parts of the coastline in Kerala. They report that the effect of the tsunami was significantly greater in some zones like the Kayamkulam inlet in southern Kerala (as it coincided with the high tide in that area) while it was markedly less in the northern part (as it coincided with the ebb tide). It advocates region-specific strategies of soft engineering (bioshields, beach nourishment and sand dunes) as important mitigating factors for beach erosion and inundation.

Factors guiding tsunami surge at the Nagapattinam-Cuddalore shelf, Tamil Nadu, east coast of India. Current Science 90 (11). (Murthy et al., 2006)

This study deals with the bathymetry and shelf morphology of the Cuddalore- Nagapattinam shelf in light of the tsunami surge in that area. The key findings of this study are that the structure of the basement, the sea bed morphology and land ocean tectonics were critical factors influencing the run-up heights in case of the Nagapattinam-Cuddalore shelf.

Characterization of soils in the tsunami-affected coastal areas of Tamil Nadu for agronomic rehabilitation. Current Science 91 (1). (Chaudhary et al., 2006)

The focus of this study was to evaluate the changes in soil and water composition after the tsunami. According to the authors both water and soil in the affected areas had undergone marked increase in salinity due to the inundation of seawater. Though the outcomes are intuitive, such studies are essential to quantify the impact of the tsunami.

The tsunami of the great Sumatra earthquake of M 9.0 on 26 December 2004 – Impact on the east coast of India. Current Science 88 (8). (Chadha et al., 2005)

Like the previous study, this too looks at inundation areas, tsunami heights in addition to damages caused by the December 26 tsunami but its study area is the east coast, particularly Tamil Nadu. The major findings of this study were that the run up height of the tsunami surge at Tamil Nadu varied from 2.5 to 5.2m. Severity of the tsunami damage in terms of loss of life and property were reported in the first 100m from the coast. Minor differences in coastal topography resulted in amplified differences in tsunami inundation and associated loss of life and property.

Inundation of sea water in Andaman and Nicobar Islands and parts of Tamil Nadu coast during 2004 Sumatra tsunami. Current Science 88 (11). (Ramamurthy et al., 2005)

This study also deals with inundation of sea water as a result of the tsunami in parts of Tamil Nadu and Andaman and Nicobar Islands. The authors found that in the case of Andaman and Nicobar, "in the North and South Andaman group of islands, the run-up levels varied from 1.5 to 4.5 m and the

distance penetration from the coast ranged from 100 to 250 m". The penetration of sea water was greater in Nicobar group than in Andaman Islands primarily due to difference in slope between the two regions.

c. Which geographical areas have been looked at?

From our secondary database it appears that a disproportionate number or documents have focussed on Tamil Nadu (43). This is followed by Andhra Pradesh (13) and then Kerala (8). The figures are subject to change after further analysis, the trend is not very surprising as it follows the pattern of the intensity of the tsunami's impact in mainland India. Alongside about 20 odd documents have looked at Andaman and Nicobar Islands while one has looked at Lakshadweep. Some studies (18) have looked at the general coastline without focussing on any particular state.

d. What are the major publication types under which the information falls?

60 documents pertaining to the tsunami in our database belong to articles published in peer reviewed journals. A large fraction of these have been published in the Indian Journal *Current Science* (41) followed by *Estuarine Coastal and Shelf Science* (5). Interestingly about 5 articles were published in *Nature* (2) and *Science* (3). The rest of the documents are reports (19) brought out by various national and international agencies, 3 books, and one master's thesis.

Background Knowledge

From our preliminary analysis it is evident that there is considerable baseline data available for mangroves in Tamil Nadu followed by Andhra Pradesh. However, baseline data is lacking for most other coastal ecosystems. Seagrasses in particular have been neglected. Sand dunes and sandy beaches are another important component that has long since been ignored by the scientific community. The fact that they deserve attention and have important ecological and sociological functions are only being recently recognised in intellectual circles. At present, there are no peer reviewed papers that speak about their conservation or restoration in India, though as we shall see in subsequent chapters, there is ample traditional knowledge about their significance.

Follow up

Most of the studies that we looked at were one-time studies and there was hardly any subsequent follow up. On an average these studies were conducted over a time period of less than 3 months. To our knowledge there are no studies that have looked at both pre and post-tsunami status of any particular ecosystem. In the absence of long-term monitoring it is often difficult (if not impossible) to ascertain the impact of any particular event (for example the tsunami) on any ecosystem. Long-term studies are also vital to our understanding of coastal vulnerability, conservation needs and restoration initiatives. It is therefore imperative at this juncture to initiate monitoring of these coastal ecosystems on a long-term basis.

Conclusion

Little information exists on physical or biological parameters on the Indian coast and there are few baselines for environmental or ecological assessments. During the first phase of the project, information on biological and environmental studies on coastal and marine ecoystems was collated to determine the current state of knowledge on various biological and environmental parameters of coastal and marine ecosystems. A comprehensive document analysis of all available published and grey literature on coastal and marine ecosystems in the affected states was used to arrive at an understanding of gaps in knowledge. It becomes clear from an analysis of the ecological literature available for the affected areas of the coast that any attempt to examine trends and impacts of chronic

or pulse disturbance events is severely hampered by the lack of sustained high quality information on species and ecosystem ranges, status of critical marine populations and communities, and ecosystem functioning. Not only do these gaps in our knowledge make it difficult to establish how these ecosystems and species fared in the wake of the tsunami, it makes rational coastal planning for these systems fraught with uncertainty.

There has also been debate and controversy over particular issues. With regard to the environment, for example, there has already been a great deal of discussion about the protective role of coastal vegetation, particularly mangroves (Danielson et al., 2005; Kathiresan and Rajendran, 2005; Vermaat and Thampanya, 2006). The Tamil Nadu Forest Department has initiated large-scale planting of Casuarina along the coast. This has been undertaken without a careful analysis of whether such plantations are indeed beneficial in the long term for coastal sustainability. Elsewhere, Casuarina plantations on the coast have been cited as a major cause of beach habitat loss and were not found to play a significant protective role in protection from storms (Pandav, 2001). Moreover, other studies have shown that there is no relationship between vegetation cover and inundation (FERAL/WWF/Greencoast project, unpublished data). On the other hand, coastal features such as sand dunes which may be critical to coastal integrity have been given scant attention, and have been used for reconstruction or plantations.

Though we did not undertake a detailed analysis of sociological research, the subject of fisheries development has received greater attention than coastal management and many negative fallouts of the rapid mechanisation of fisheries have been highlighted such as destruction of marine habitats, increased indebtedness of fisherfolk, greater unemployment among fisherfolk, polarisation of classes among fishing communities and the 'masculanisation' of the industry, among others (Kurien, 1985; Anon, 1990; D'Cruz, 1998 ; Salagrama, 2002; Gillet, 2002; Kurien, 2005b). There also exist a few well-researched accounts on traditional and community-based fisheries and marine management practices in the country (Mathew, 1991; Baavink, 2003; Salagrama, 2003; Lobe & Berkes, 2004). These studies illustrate the different community arrangements for fisheries management whose designs are based on varying community institutions and structures, fishery practices, governance mechanisms and habitats. In summary, both well directed research and long-term monitoring needs to be established for both ecological and socio-ecological systems in order to better manage the coast and respond to disasters such as the tsunami.

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Chapter 3 An overview of coastal ecosystems and the impact of the December 2004 tsunami on mainland states in India

B. Muthuraman[3], A. Gokul[1], Nibedita Mukherjee[1], Kartik Shanker[1] and Rohan Arthur[4]

The coastal system is a complex interface of terrestrial, marine, and human influences. Natural ecosystems comprise coastal, near shore and offshore systems. Coastal ecosystems include coastal forests such as tropical dry evergreen forests, mangroves, sandy beaches and dunes, rocky shores and intertidal systems. Important near shore marine ecosystems include seagrass meadows and coral reefs. Estuarine systems include backwaters, lagoons, and riverine deltas.

Many ecosystems suffered impacts during the December 2004 tsunami. Assessments done in the wake of the tsunami have debated both the impact of the event on ecosystems, as well as their role in mitigating the tsunami's impact on the coastal belt. Danielsen *et al.* (2005) reported that the Indian Ocean tsunami had major effects on coastal communities and ecosystems. While some assessments of coastlines after the tsunami indicate that coastal vegetation such as mangroves and beach forests helped to provide protection and reduce effects on adjacent communities (Vermaat & Thampanya. 2006; Kathiresan, & Rajendran. 2005; Danielsen, *et al.,* 2005), others have shown that coastal vegetation had little mitigating effect (Kerr *et al.*, 2006). Wolanski (2006) mention that mangroves are protective against small and medium size tsunamis, while in case of a larger tsunami it worsens the situation, as the vegetation debris would cause more damage than the actual impact of the tsunami. He points out the requisite structural attributes of mangrove forests to be protective against tsunamis. He also points out that other non-mangrove coastal vegetation like *Casuarina* have very little protection against tsunamis.

More recently, a comprehensive study of the protective role of coastal and marine environments in the face of the tsunami shows that the relationship is not as simple as it is often made out to be, and is often counter-intuitive (Chatenoux and Peduzzi 2007). For instance, they conclude that while large intact meadows of seagrasses served to attenuate the force of the tsunami wave, the presence of coral reefs actually appeared to exacerbate the force of the wave and the consequent impacts on the shore. Of particular interest to the Indian coastline, the paper excludes mangrove ecosystems from the analysis because there were not enough mangroves growing in areas exposed to the tsunami wave to ensure statistically reliable conclusions to be made of their protective value. The authors conclude that this is perhaps due to the fact that mangroves tend to grow in areas that were naturally sheltered from the worst ravages of the coast, and, rather than protecting coasts, were themselves protected by their position in relation to the coast. In recent years, mangroves and other coastal vegetation have been cleared or degraded along many coastlines, possibly increasing their vulnerability to storm and tsunami related damage.

The width of continental shelf and bathymetry may have played a major role in the pattern of tsunami damage (Narayan *et al.,* 2005). Narayan *et al.* (2005) inferred that the width of the

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continental shelf and the interference of reflected waves from Sri Lanka and Maldives Islands with direct waves and receding waves were responsible for intense damage in Nagapattinam and Kanyakumari districts, respectively.

Tsunamis are infrequent but cause high intensity disturbances on marine communities (Krishnankutty, 2006). The bio-geological impacts of the earthquake and the tsunami have been discussed by various authors focusing mainly on rehabilitation of ecosystems impacted by the tsunami (David Mariakan and Mohan, 2005; Johnson Raj, 2005; Lal Mohan, 2005; Lal Mohan and Srinivasakumar, 2005; Mercy, 2005; Michael, 2005; Nammalwar Rajan, 2005; Thrivikramji, 2005; Udayakumar, 2005; Victor Rajamanickam, 2005).

We provide here a brief overview of a few important coastal ecosystems from the perspective of biodiversity conservation along the tsunami-affected states, and summarise the information regarding the impacts of the tsunami to these habitats. The habitats selected include two critical terrestrial and two near shore marine ecosystems, which represent a significant proportion of the terrestrial and marine biodiversity in the tsunami-affected regions of mainland India. On the coast, mangroves have received substantial attention for their role in mitigating the tsunami and extensive restoration efforts have been initiated or are planned. Sandy beaches and dunes, on the other hand, have received scant attention and their importance as coastal habitats needs to be emphasised. Similarly, coral reefs have received significant attention, while the role of seagrass beds as indicators and effective barriers has not been sufficiently examined or emphasised.

The following key ecosystems are detailed here:

- Sandy beaches and dunes
- Mangroves
- Coral reefs
- Seagrass beds

For each system, we provide the following information:

- Distribution
- Flora and fauna
- Impacts of the tsunami
- Status and threats
- Research gaps and priorities
- Recommendations
- Literature cited
- Other important literature

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SANDY BEACHES AND DUNES

Sandy beaches are an integral part of the coastal ecosystem and more than half of the Indian coast is sandy. The east and west coast of India are geo-morphologically different in their sandy beaches, shelves, and marshes. Sand dunes may be considered as a sign of ecological equilibrium between the powerful physical forces of the ocean such as wind tide and current pattern but like most ecosystems sandy beaches and dunes have also been under increasing pressure due to population increase, urbanisation and various developmental activities (Venkataraman, 2003).

Sandy beaches tend to be relatively unstable due to sand movement caused by the wave action, which also reduces both primary and secondary productivity of the habitat (Dexter, 2001). Sand is moved along the shore by the direction of the waves, as well as onshore and offshore by changes in wave height. Large waves tend to remove sand from a beach whereas small waves tend to deposit sand on a beach. The energy of the wave determines the particle size and distance moved. A steady stream of large waves over a period of days or weeks may actually remove all the sand from a beach, leaving only boulders. On the contrary, a steady stream of small waves may deposit so much sand on a beach that it increases the width of the beach many times. Some preliminary work on the nutrient content and water on sand has done by Ansell *et al.* (1972a,b,c, 1978).

The beach soil texture and associated organisms are highly interrelated; soil texture may also act as a limiting factor for organisms (Vohra, 1971). Macrophyte wracks, dead animals, and dissolved and particulate organics are washed into the sand by waves (Urban-Malinga & Opaliński, 2001). Compared to temperate regions, the zonation and the diversity of faunal communities have received less attention in tropical and subtropical sandy beaches (Vohra, 1971). Species in the tropical countries like India exhibit greater activity, mobility, faster growth, shorter life span, higher mortality rates, and greater production than temperate species (Ansell *et al.,* 1978). Seasonal movements of beach organisms have been reported by Vohra (1971). The macrofauna on the beach is a vital part of the system (Ansell *et al.* 1972b,c, 1978). The shifting sands and rapidly changing conditions make it a difficult habitat and therefore only a few species have been successful in adapting to this habitat. These species enjoy lower levels of competition and can grow to larger populations. According to Dexter (2001) macrofaunal communities increase in protected beaches. Basic studies have also been conducted on the physical environment, distribution and abundance of macrofaunal communities in tropical and temperate beaches. (McLusky *et al.*, 1975).

Sand dunes form in relatively exposed locations, and in a number of physiographic situations. Sand dunes are of different types, the most common being 'bay dunes', where a limited sand supply is trapped between two headlands, 'spit dunes', which form as sandy promontories at the mouths of estuaries, and 'hind shore dunes', which occur in the most exposed locations where large quantities of sand are driven some distance inland, over a low-lying hinterland (Mascarenhas, 2002 a, b). Less common types are 'ness dunes', which build out from the coast, dunes on offshore islands, which are often superimposed on a base of other material such as shingle, 'climbing dunes' where sand is blown up on to high ground adjacent to the beach and '*tombolos'*, where a neck of sand is deposited between two islands or between a promontory and an island.

Distribution

More than half of the 7500km of the Indian coast consists of sandy beaches (Venkataraman, 2003). The Tamil Nadu and Andhra Pradesh coasts largely comprise of sandy beaches. Along much of the Kerala coast, seawalls have been constructed and sandy beaches are present only in short stretches.

Flora and Fauna

Ipomeoa pes-caprae, *Suaeda* sp., *Spinifex* sp., and *Cyprius* sp. occur along the beaches. Shrubs of *Prosopis* sp., *Thespesia* spp. are commonly distributed. Plantations of *Casuarina* sp., *Eucalyptus* sp, both exotics, are dominant along the tsunami-affected beaches. *Ipomea pes-caprae* is a dominant and widely distributed creeping sand binder in tropical sand dunes.

Generally the dominant tropical sandy beach mieofauna includes nematodes, turbellarians, and gastrotrichs (Urban-Malinga and Opaliński, 2001). The fauna of beaches in southwest India include crabs of the genus *Ocypode* and the isopod *Eurydice* sp. which occur upto the high water mark, polychaetes of the genera *Glycera, Onuphis, Scoloplos* and *Lumbrinereis* in the mid-intertidal region and below, with some occurrence of the tidal migrants like *Bullia melanoides* (Gastropoda), *Donax incarnatus* and *D. spiculum* (Bivalvia) and *Emerita holthuisi* (Crustacea)(Trevallion et al. 1970). The occurrence of *Donax incarnatus* and *D. spiculum* was also reported (Ansell et al., 1972a).

Shore crabs are quite common along the sandy beaches. Some of the common shore crabs observed along the sandy beaches of the coast are, *Ocypode ceratophthalma, O. cordimana, O. macrocera, O. platytarsis, Scopimera proxima, S. pilula, Uca annulipes, Dotilla myctroides, Macrophthalmus depressus, Metapograpsus thukuar* (Silas and Sankarankutty, 1967). Ocypode crabs usually make their burrows beyond high tide line and can be good ecological indicators. Similarly, *Emiratus asiatica* may indicate the accumulation of heavy metals in sandy beaches. *Uca spp*. is found abundant along the banks of estuaries and lagoons. These areas also have *Sesarma* spp., *Grapsus* spp., *Metapograpsus* spp., *Cardiosoma carnifex*, etc. Meiofaunal groups such as Copepods, Ostracods, Amphipods are commonly observed in the sandy beaches.

Five species of sea turtles (Green turtle – *Chelonia mydas*; Hawksbill – *Eretmochelys imbricate*; Loggerhead – *Caretta caretta*; Olive Ridley – *Lepidochelys olivacea* and Leather-back – *Dermochelys coriacea*) occur in Tamil Nadu waters, especially in the Gulf of Mannar (Bhupathy and Saravanan, 2006) Olive ridleys nest in significant numbers in Tamil Nadu (Bhupathy and Saravanan, 2006) and Andhra Pradesh (Tripathy et al., 2006) and in small numbers in Kerala (Dileepkumar and Jayakumar, 2006).

Impact of the tsunami

There was considerable variation within and between the east and west coasts of the impact due to the tsunami. Sandy beaches would have short-term impacts wherever there was temporary inundation and long-term impacts wherever inundation was permanent. In most parts of the mainland coast, inundation was temporary.

The damage along some parts of the coast such as Kanchipuram District may have been less due to the wider continental shelf in these areas. There was a decrease in the tsunami run-up from Cuddalore District to Kanchipuram District (Narayan et al., 2005). Similarly, the impact was less in Manakudi, Chotavalai, Azhikal and Colachel beaches when compared with Nagapattinam, Cuddalore and Chennai beaches (Chandasekhar, 2005).

A study carried out at Marina beach, shows that visible changes in the morphology of the intertidal area was observed immediately after the tsunami, where the intertidal area was much flatter compared to the gentle slope observed pre-tsunami. However, normal beach profile was restored 15 days after the tsunami. A visible change in soil grain size was also observed in the top 0-5 cm. layer, while the deeper layers remained unaltered. The density of meiofauna in the study site showed a drastic decrease the next day after tsunami but after two days there was a sudden increase in meiofaunal density as a result of vertical migration of meiofauna from the deeper layer to the top layer, where the most suitable grain size accumulated as a result of the tsunami. The group wise density of meiofaunal composition was also altered as a result of the tsunami. Overall, all the physico-chemical parameters, sand grain size and meiofaunal density were restored within 13, 24 and 7 days after the tsunami (Altaff *et al.*, 2005).

Status and threats

Sandy beaches receive a variety of organic materials from the sea (Urban-Malinga and Opaliński, 2001). Coastal marine ecosystems are affected by dissolved nutrient inputs from circulating offshore water, river runoff, and groundwater seepage. The regional nutrient budget also includes atmospheric deposition, fertilizer application, wastewater treatment plant discharge, livestock waste, and remineralisation of organic matter in sediment (Yusuke *et al.,* 2000). The population density is comparatively greater in coastal areas (Venkataraman, 2003). So far, ecologists have not paid much attention to groundwater as a source of inorganic nutrients for coastal marine ecosystems (Yusuke *et al.*, 2000). The agricultural waste and the ground water waste mixes with the sea and enhances inorganic content leading to pollution (Yusuke *et al.*, 2000).

Coastal vegetation can be destroyed by natural causes such as storms, cyclones, droughts, and erosion. The system is traditionally highly populated and in many instances, has lead to resource depletion (Venkataraman, 2003). Human interference such as clearing, grazing, vehicular or excessive foot traffic destroys dune vegetation. During the field visits of this project it was observed that cattle grazing of mangrove seeds and dune vegetation is quite common along the coast of Andhra Pradesh.

Moderate pressure by pedestrians may cause little damage, and may even help to counteract the effects of abandonment of grazing. However, excessive pedestrian use by local fishermen, shrimp farm operators and nearby villagers have been observed in the dune system along the Andhra coast. Vehicular movement and trampling by people and livestock, may destroy dune vegetation, which helps to trap mobile sand. As a result, dunes may gradually move inland, devaluing adjacent property. This may also crush animals buried in the sand, as well as the eggs and young of birds nesting above the drift line. Furthermore, their tracks can impede the movement of small animals, such as turtle hatchlings and ghost crabs.

Pollution also impacts sandy beaches, especially oil spills, which can have devastating consequences (Ansari and Ingole, 2002). Oil is toxic to most animals, and can smother them or affect their swimming ability. Invasive plants may alter dune ecosystems through stabilisation. Beach mining has adverse effects where this is undertaken.

Research gaps and priorities

Very few studies have been carried out on coastal systems compared to other terrestrial habitats such as forests. Studies have focused on the indicator species of the sandy beach like the mole crab, which is an indicator of heavy metal accumulation. Some studies have been carried out on the diversity of sandy shore fauna (Ansell *et al.*, 1972a, b, c; McLusky *et al.*, 1975; Silas and Sankarankutty 1967; Trevallion

et al., 1970). There are several reports of surveys of marine turtle nesting beaches (Bhupathy & Saravanan 2006; Tripathy *et al.*, 2006). A few studies of sand dunes have also been carried out (Masceranhas, 2002a,b).

However, a large amount of work remains to be done. Basic studies have to be done on the taxonomy of the flora and fauna along the coast. Sand dunes must be monitored periodically for their biodiversity. Ecologically sensitive fauna/flora have to be identified. More research needs to be carried out especially on geomorphological changes as a consequence of human interference such as seawalls, ports and harbours and other developmental activities.

Institutions

Some of the institutes working on sandy beaches are listed below.

1. Centre for Advanced Studies in Marine Biology, Parangipettai, Chidambaram.
2. University of Madras, Chennai.
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Conclusion

Sandy beaches and dunes are important coastal ecosystems that have perhaps not received adequate attention for their ecological and sociological values. A fuller consideration of these aspects is provided in Chapter 3c.

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MANGROVES

Introduction

Mangroves are plant communities that are adapted to grow in muddy and saline intertidal regions. Mangroves are highly productive ecosystems and support a vast array of flora and fauna. It has been shown that decomposing leaves of mangrove leaves attract finfishes and shellfishes (Rajendran & Kathiresan, 1999). Mangroves are important for coastal stabilisation and to prevent coastal erosion. Though mangroves themselves are susceptible to erosion, damage to the mangrove system could result in coastal erosion (Othman 1994; Mazda *et al.,* 2002; Thampanya *et al.,* 2006 & Field 1998). Mangroves offer a wide range of ecological and economical goods and services and provide primary livelihood options for dependent communities.

Indian mangroves account for about 5% of the mangroves in the world. Sunderbans in West Bengal accounts for half of the mangrove area in the country (State of Forest Report 2001). Mangroves are classified in the Coastal Zone Regulation act as CRZ-1, where developmental activities are restricted. Irrespective of the legal protection, mangrove ecosystems are still being converted for developmental activities, apart from other anthropogenic stress factors (Upadhyay *et al.*, 2002). This indiscriminate destruction and conversion of mangrove wetlands for developmental activities is mainly due to the under-valuation of the goods and services of this system (Ronnback, 1999).

Distribution

Indian mangroves are distributed in nine maritime states. The total mangrove cover in India is estimated to be of 4,482 km^2. It includes an area of 2,859 km^2 with dense mangroves and 1,623 km^2 with open mangroves (State of Forest Report, 2001). Mangroves in India comprise of 71 species, including true mangrove species and associated species and excluding species that occur on salt marshes (Kathiresan & Qasim 2005). The area under mangrove cover in Tamil Nadu and Andhra Pradesh is 28 and 333 km^2 respectively (State of Forest Report, 2001), while mangroves in Kerala are sparse.

Major and Minor mangrove wetlands of Andhra pradesh (Selvam et al., 2005)

Location	Name of the mangrove	Wetland area (ha)	Forested area (ha)
East Godavari District-Godavari Estuary	Godavari	33200	17000
Krishna and Guntur Districts Krishna estuary	Krishna	24999	9500
Machilipatnam-Krishna Estuary	Machilipatnam	2825	2100
Nizampatnam-Guntur District	Nizampatnam	1220	900
Muthukuru Mandal- Nellore District	Krishnapatnam	20	Not known
Chillakuru Mandal-Nellore District	-	50	Not known
Alluru mandal-Nellore District	Pennar	1200	Not known
Guduru and Dada Mandal Nellore District	Pulicat	2000	Not known
Chinaganjam mandal-Prakasam District	Chinaganjam	65	Not known
Vishakapatnam	Vishakapatnam Naval area	100	Not known
Vamsadhara Estuary-Srikakulam District	Vamsadhara Estuary	35	25

The major and minor mangrove wetland areas in Tamil Nadu are Pichavaram (1357 ha), Muthupet (12000 ha), Pudhupattinam (800 ha), Palk strait (700 ha), Gulf of Mannar Marine area (148 ha) and Gulf of Mannar Island area (30 ha) (Selvam *et al.*, 2002). In addition to large patches of

mangroves, there are several mangrove patches distributed along the coast of Tamil nadu ranging from 2ha to 5ha in size (Selvam *et al.,* 2005). In Andhra Pradesh, there are 11 areas with mangroves. Godavari and Krishna mangroves are the major mangrove areas in the state of Andhra Pradesh (Selvam *et al.*, 2005). Mangrove cover in Kerala is 16km^2 (Banerjee & Ghosh 1998).

Flora and Fauna

In Pichavaram, 13 true mangrove species have been recorded. *Avicennia marina* is the dominant species (74%) followed by *Rhizophora sp*. (15%). *Suaeda maritima, S. monica*, and *Salicornia brachiata* are associate mangrove species among which *S. maritima* is dominant. (Selvam *et al.*, 2002). However, *Suaeda* species has also been reported as an indicator of degradation (Kathiresan 2002). In Muthupet, 6 species of true mangroves were observed. Again, *Avicennia marina* is the dominant species (95%) followed by *Aegiceras corniculatum* and *Excoecaria agallocha*. In Muthupet, large stands of *Prosopis juliflora* are present among the mangroves. *Pemphis acidula (Keeri chedi-Tami vernacular name*) is a true mangrove species and is endemic to the islands of Gulf of Mannar (Selvam *et al.,* 2002).

In Andhra Pradesh, there are 16 true mangrove species and 19 associated mangrove species . Among these, *Avicennia marina, A. officinalis, Ceriops decandra and Sonneratia apetala* are the common true mangrove species. *Scyphiphora hydrophyllacea* is endemic to Godavari mangroves (Ravishankar *et al.,* 2004).In Cochin backwaters, 10 mangrove species belonging to 9 genera and 7 families were recorded. *R. mucronata* is the most dominant species followed by *A. officinalis* and *A. ilicifolius* (Sunil kumar, & Antony 1994).Due to its age and vast extent, Pichavaram has good brachyuran crab diversity. A total of 38 species of brachyuran crabs were observed (Khan *et al.,* 2005). From the Pichavaram mangroves, 52 species of bacteria, 23 species of fungi, 82 species of phytoplankton, 22 species of seaweeds, 3 species of seagrass, 95 species of zooplankton, 40 species of meiobenthos, 52 species of macrobenthos, 177 species of fish and 200 species of birds have been reported (Kathiresan, 2000).

The mangrove ecosystems of Godavari and Krishna support 23 species of molluscs belonging to 20 genera and 14 families (Ramamurthy & Rao, 1993). In the Cochin mangroves depth-wise distribution of macro-invertebrates and ecology of polycheates has been studied. 33 species of polycheates belonging to 20 genera and 10 families have been observed (Sunil Kumar, 1997; Sunil Kumar & Antony, 1993).

Impact of the tsunami

There are very few post-tsunami impact assessment studies in mainland India on mangrove ecosystems; only one focuses exclusively on mangroves (Baranidharan, 2005), while the others are general tsunami impact assessment studies with a mention about effects of the 2004 tsunami on mangroves. Though there was a great extent of damage by the tsunami to the mangrove ecosystems in the Andaman Islands (Daniels *et al.,* 2005) tsunami damage to mangroves in mainland India was not much. According to Patterson *et al.* (2005), mangrove forests on mainland Tamil Nadu were not seriously affected. Baranitharan (2005) reported the uprooting of 100-150 trees, 350-400 trees, and 10-15 trees at Pichavaram, Muthupet and Ramnad mangroves, respectively, as a consequence of the tsunami. Newly planted saplings (Nov-2004 plantation) were completely washed away in Muthupet mangrove area. Increase in soil salinity was observed in different mangrove areas of Tamil Nadu, but after the subsequent monsoonal flood, the salinity range returned to normal. Siltation upto various levels (1 foot at Pichavaram, 2 feet at Muthupet and nil at Ramnad mangroves) was also observed in different mangrove areas in the Tamil Nadu coast.

Status and threats

In the Pichavaram mangroves, poverty among the local people and their heavy dependence on mangroves for fodder collection is the main cause of degradation. Trough formation in the interior mangrove area and grazing in the periphery are other causes of degradation in Pichavaram.Decreased fresh water discharge, closure of the canal mouth and shoreline changes are other reasons for degradation. (Selvam *et al.*, 2002). A study comparing both degraded and healthy areas in the Pichavaram mangrove area revealed that higher salinity level, low level of available nutrients and poor microbial count in the substratum are the main natural causes for degradation (Kathiresan, 2002).

As in the case of the Pichavaram mangroves, clear felling in the Muthupet mangroves has resulted in the trough shaped topography leading to degradation. Lateral movement (from degraded trough -shaped area) of hyper saline pore water towards the healthy areas leads to '*shoot die back syndrome',* which needs to be further investigated for developing proper management strategies (Selvam *et al.*, 2002). A very recent study (Ramasubramanian *et al.,*2006) on mangroves of the Godavari delta states that about 14% of aquaculture farms have been constructed on mangrove lands outside the forest reserves and the rate of conversion of mangroves into shrimp ponds between 1997 and 1999 increased substantially. The extent of mangroves has also changed due to the erosion of mangroves along the coast and accretion near river mouths, leading to the formation of new mangrove areas. The ain causes of degradation in the Krishna mangroves are changes in microtopography due to coupe-felling, cyclones, progradation of shoreline, collection by local villagers, conversion for aquaculture purpose and reduction in fresh water inflow (Ravishankar *et al.,*2004).

Research gaps and priorities

In the Pichavaram and Muthupet mangroves, studies on geomorphology, zonation, soil properties, hydrological conditions, socio-economic profile, management issues, human influence on benthic microbial activities, methane emission, brachyuran crab diversity, causes of natural degradation, assessment of restoration success, forest structure, and associated fauna and flora, have been well studied (Selvam *et al.*, 2002; Ravishankar *et al.*, 2004; Purvaja & Ramesh, 2000; Khan *et al.*, 2005; Kathiresan, 2002; Selvam *et al.*, 2003;).

In the same way, geomorphology of wetlands, diversity of flora and fauna, mangrove zonation, soil properties, hydrological conditions, wood and fishery resources, socio-economic conditions, land use around mangroves (cropping, salt pan, aquaculture), dependency, causes of degradation, present management practices, productivity, forest structure, shoreline changes over a period of time etc., have been described for the Godavari and Krishna mangroves in Andhra Pradesh (Ravishankar *et al.*, 2004).

Sediment analysis, comparative studies on hydrography and species composition, heavy metal concentrations in mangrove flora and sediment, associated fauna and their vertical distribution have been studied in mangroves of Kerala (Badarudeen *et al.* 1998; Thomas & Fernandaz, 1993; Sunil Kumar, 1997; Thomas & Fernandaz, 1997)

Studies on documenting the flora and fauna, area and extent of mangrove ecosystem and their ecological status and stress factors are available only for major mangrove areas like the Muthupet, Pichavaram, Godavari and Krishna mangroves and such studies are not available for other areas. It is imperative to have an accurate documentation of the area, diversity of flora and fauna, ecological status and local threats for all the mangrove areas, as a baseline for monitoring and also for management decisions.

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Restoration of Mangroves

Though several vegetative propagation methods such as air-layering, tissue culture etc., have been studied (Selvam *et al.*, 2005; Kathiresan & Ravikumar, 1995), mangrove restoration efforts in practice comprises collection of seeds and establishing of nurseries for plantation or direct seed sowing only.

Canal-bank method (with fishbone canal models) is the major method of restoration carried out by the Tamil Nadu Forest Department at elevated sites for facilitating good water inundation and seems to show better results (Baruah, 2004).

A study carried out at Pichavaram emphasises that the presence of the salt marsh plant *Suaeda* sp. is an indicator of higher salinity and degradation (Kathiresan, 2002). While interviews with a few Forest Department officials during this project period reveals that they consider the presence of *Suaeda* sp. as a criterion for site selection for mangrove plantations. They mention that once plantation with *A. marina* is carried out, *Suaeda* gets eradicated over a period of time. This is basically due to the fact that the salt loving *Suaeda* is eradicated over a period of time due to the canal-bank plantation method, where comparatively better water inundation results in reduction of soil salinity leading to the disappearance of the salt marsh species and the growth of *A. marina*. Thus *Suaeda* is not par se an indicator of better sites for mangrove plantation.

In the Muthupet mangroves, a study to evaluate the success of restoration efforts (community based restoration) was carried out by comparing satellite imageries of different time periods before and after restoration. This study concluded that the restoration efforts seems to be successful (Selvam *et al.*, 2003). Nevertheless, such a study only looks at a quantitative measurement (increase in forest cover) of the restoration effort and needs to be assessed in a qualitative way by looking at the health of the system, where increase in floral diversity of mangroves, associated mangroves and associated fauna would serve as indicators to assess restoration success.

As few of the post-tsunami studies revealed that mangroves tend to mitigate the effects of tsunami (Vermaat & Thampanya, 2006; Kathiresan & Rajendran, 2005; Danielsen *et al.,* 2005), there has been extensive plantation efforts all along the coast.

Moreover, plantation in all areas is largely mono-specific, mainly with *A. marina* and occasionally with *Rhizophora*, mainly because *A. marina* is very tolerant and shows better survival rate. Also, it is the primary successional species that allows the establishment of other species in future. However, plantation of other species at least in the established forests of *A. marina* has not been observed.

In a case study in Bangladesh, it was found that planting of mangroves even as mono-specific stands could protect the shore from coastal erosion and help in shoreline stabilisation (Field, 1998). But when the plantation is carried out with a view to protecting against calamities like cyclones and tsunami, it is important to consider the structural attributes of these future mangrove forests, like alignment of the forest with the shore line and wind direction, expected tree height and density, etc.

Hence, it is important to see the suitability of the site selected and monitor the performance of planted saplings (such as growth rate, survival rate etc) as there is a clear understanding that different kinds of mangrove forests provide different goods and services. For example, the important service of fringe mangroves (planted along the coast) would be essentially coastal protection, while riverine mangrove forests essentially provide ecological services such as breeding and feeding grounds for animals & productivity (Ewel *et al.*, 1998).

Recommendations

From the preliminary studies, it is evident that mangrove ecosystems in the tsunami-affected states in the mainland were not severely impacted by the tsunami. However, it is important to monitor and study the indirect impacts and general health of the system such as community structure and function, erosion and mangrove progradation.

Pre-tsunami studies have shown that dependence of local people on mangroves is clearly an important cause of degradation in almost all mangrove areas (Selvam *et al.*, 2002; Ravishankar *et al.,* 2004). Hence sociological and economic analyses, in addition with the identification of local natural and anthropogenic stress factors for all mangrove areas should be carried out, which in turn would result in preparation of appropriate management plans and efficient conservation of the system.

A community-based mangrove plantation program helps stakeholders to understand the processes well and helps them to develop sympathy towards the environment. Both community development and mangrove regeneration happens simultaneously. It improves the socio-economic status of the local community, which ultimately decreases the stakeholders' dependence on mangroves. Unfortunately, the major post-tsunami mangrove plantation initiatives carried out by the State Forest Department (programs like ETRP, NCRMP) are not community-based programs. Hence, serious consideration must be given to involve the stakeholders' participation in restoration activities so as to ensure better restoration success.State of Forest Report (2001) reports that the remote sensing analysis of mangrove cover in Tamil Nadu state during the year 2001 shows cover of 23 km^2 against earlier reports of 21 $km^{2.}$ The 2001 analysis was carried out digitally and also with a higher resolution whereas the previous analyses were carried out by visual interpretation and with lower imagery resolution. This change in methodology was effective enough to detect minor mangrove patches clearly indicating the need to study, ground-truth and document minor patches of mangroves and their diversity in the state and also to study their ecology and local threats, to eventually conserve them.

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CORAL REEFS

Corals form one of the most successful benthic communities of tropical waters, capable of building extensive reefs of various types (Pillai, 1975). Coral reefs form a dynamic marine ecosystem with a rich diversity of marine life, providing shelter and nourishment to thousands of marine flora and fauna. The world coral reefs constitute a shallow water ecosystem, largely restricted to the area between the latitudes 30°N and 30°S. They serve as a barrier in protecting the coastlines of Indian maritime states such as Gujarat and Tamil Nadu and oceanic islands of Lakshadweep and Andaman and Nicobar.

Distribution

Among the tsunami-affected states, Tamil Nadu is the only state with coral reefs, with reef structures in the Gulf of Mannar and the Palk Bay. In the shallow, highly sedimented waters of the Palk Bay region, corals are distributed as scattered reef patches, most no larger than 200m in width, limited to a 25-30km stretch of the coast from Mandapam to Rameshwaram Island. (Kumaraguru *et al.*, 2005). However, surveys in Sri Lankan waters indicate that the offshore waters of this region may also possess well-developed reef formations that have not been explored yet (Arjan Rajasuriya, *personal communication*)

In contrast, the Gulf of Mannar region has considerably better reef formations, with relatively clearer waters than the Bay, and with fewer fresh water inputs. The Gulf of Mannar Marine Biosphere Reserve (GoMMBR) that spans this region covers an area of 1,050,000 hectares on the south-east coast of India across from Sri Lanka. It is one of the world's richest regions from a marine biodiversity perspective. The biosphere reserve comprises 21 islands with estuaries, beaches, forests of the nearshore environment, including a marine component with algal communities, seagrasses, coral reefs, salt marshes and mangroves. The reserve houses some 100,000 people living in 47 villages along the coast, and many of them are dependent on the sea for their livelihood.

The Gulf of Mannar Marine Biosphere Reserve is made up of 21 uninhabited islands ranging from 0.25 ha to 130 ha in size and lying between one and four km offshore, surrounded by shallow waters (Khwaja, 2000; Rai, 2000; Singh, 2003; Venkataraman *et al.*, 2002). Most of the islands have a shallow lagoon of 100 to 150 m wide, with offshore fringing reefs. Together, they form part of the Mannar barrier reef, which is about 140 km length and 25 km wide between Pamban and Tuticorin (Venkataraman, 2003). The islands encompass a range of marine and coastal habitats from coral reefs, rocky patches, seagrass beds, algal beds and sandy bottoms. Recent studies have shown that the geomorphology of some of the islands has undergone drastic changes due to the sea level rise, sediment supply, wave action, mining of corals and discharge of effluents (Ramunujam and Mukesh, 1998).

The islands of GoMMBR are classified into three major groups, the Mandapam group (Shingle, Krusadai, Pullivasal, Poomarichan, Manauli, Manuli Putti, and Hare), the Keelakarai group (Mulli, Vaalai and Thalayari, Poovarasanpatti, Appa, Palliyarmunai and Anaipar), and the Tuticorin group in the far south (Nallathanni, Puzhuvinachalli, Upputhanni, Vilanguchalli, Karaichalli, Kasuwar and Van). The islands range from less than 1 ha to nearly 130 ha in size, and, depending on their area, are covered with stunted scrubby beach vegetation, mangrove stands and coastal forests. The islands are circled with sandy and clayey bottom sediments, with often vast stretches of seagrass meadows (discussed later) and patchy and fringing reefs (Venkataraman *et al.*, 2002; Gokul, 2006).

Flora and Fauna

Perhaps the most important vegetation type growing on these islands are mangroves. At the beginning of the 20th century, mangroves were presumably very abundant on all the islands of the Gulf of Mannar. What remains today is limited to small remnant stands on 14 of the 21 islands, which continue to be lost to fuelwood extraction and other pressures (Kathiresan and Rajendran, 1998). The richest mangrove stands are found today in the Mandapam group of islands, particularly Shingle, Krusadai, Poomarichan and Pullivasal (Gokul, 2006). The dominant mangrove species is *Avicennia marina* (James, 2005).

The tree diversity of the island is dominated by introduced species including, coconut, palmyra and casurina. Large trees like margosa, banyan and gooseberry are also present. The beach and ground vegetation is composed of *Ipomea biloba, Spinifex squarrosus, Launea pinnatifida, Vites negundo, Gloriosa superba* among others . Dense patches of shrubs are also recorded including *Dodonea viscose*, *Indigofera oblongifolia* and *Scaevola frutescens*. Grasses like *Cymbopogen caesius* and *Fimbristylis spathacea* are found on the sandy coast of the island (Jeyabaskaran and Lyla, 1996).

The Gulf has a rich diversity of bird life, both aquatic (84 species) and terrestrial (183 species, Balachandran, 1995; Venkataraman, 2006). A range of other fauna populate the islands including beetles, butterflies, moths, dragon-flies, red-cotton bugs, ants, termites, snakes, lizards, scorpions, centipedes and spiders. Permanent resident birds are the spotted owlet, the house and jungle crows, the skylark, the sun bird, the myna and the grey patridge. The terrestrial mammals are the black rat *Rattus rufescenes* and the white rat *Tatera cuvieri* (Jeyabaskaran and Lyla, 1996).

The regions' coral reefs are highly diverse, and represent among the highest marine diversity hotspots in mainland India. This includes a high diversity of coral reef and other marine fish species (>538) (Venkataraman, 2006), including many ornamental fish species (Sekar, 2000 and Gopakumar, 2000), Molluscs (428) (Venkataraman *et al.*, 2004), Sponges (319), Echinoderms (112) (James 2001), Corals (94) (Pillai, 1983), Dolphin (4) (Lipton *et al.,* 1995), Whales (7) (James, 2005), Stomatopods (15) (Shanbhogue 1986), Brachyuran crabs (237) (Kathirvel and Gokul, 2006). We describe below the diversity of select groups.

Corals: Pillai (1983) recorded a total of 94 species of Scleractinian corals under 37 genera in the Palk Bay and Gulf of Mannar region. While Venkataraman *et al.* (2003b) reported 82 species of Scleractinian corals under 27 genera from Gulf of Mannar and Palk Bay region. 66 species of corals belonging to 23 genera were recorded in Palk Bay region alone (Pillai, 1971).

Sea weeds: According to Kaliaperumal (1998), 147 species of algae (42 green, 31 brown, 69 red and 5 blue-green) are known to occur in Gulf of Mannar, of which, the economically important algae are: *Gelidiella acerosa, Gracilaria edulis, G. follifera, G. crassa, Hypnea spp., Acanthophora spp., Sargasssum spp. Turbinaria spp., Cystoseira trinodis, Hormophysa triquetra, Ulva spp., Eneromorpha spp., Caulerpa sp. Codium sp., Hydrocalathrus sp.* and *Laurencia sp.*

Seagrass: Jagtap (2003) reported 14 species of seagrass from GoMMBR and Palk Bay (see later section on seagrasses)

Sponges: A total of 250 species of sponges are recorded in Gulf of Mannar, belonging to 8 orders, 38 families and 136 genera of the class Desmospongiae under the phylum Porifera, of which, 74 are recorded from the adjacent Palk Bay. Venkataraman (2006) assessed the occurrence of 319 species of sponges from Gulf of Mannar and Palk Bay. Most of the species were collected from the shore area,

where they washed ashore. Some were obtained from corals reefs, seagrass and sandy beds. Out of 250 species, 2 are obtained from a depth range of 165-180 m. The growth of these sedentary organisms is influenced by the surface wind patterns (Thomas,1986a)

Gorgonids: Among the 22 commercially important species recorded from Indian waters, 15 are known to occur in the Gulf of Mannar. Among the commercial varieties, 5 species, namely, *Echinogorgia indica, Heterogorgia flabellum, Gorgonella umbraculum, Juncella juncea* and *Leptogorgia australiensis* are dominant (Thomas and Rani Mary George, 1987).

Crustaceans: A total of 299 crustaceans including 36 shrimps & prawns, 12 lobsters, 237 brachyuran crabs, 30 anomuran crabs and 15 stomatopods were reported (Sankarankutty 1966; Nair *et al.,* 1973; Thomas, 1979, 1986b and 1989; Shanbhogue 1986; Jeyabaskaran and Ajmal Khan, 1998; Kathirvel and Gokul, 2006).

Molluscs: A total of 263 species of molluscs (4 species of cephalopods, 158 bivalves, 100 gastropods and 1 amphineuran) were recorded from this area (Devaraj, 1998). Similarly, Venkataraman *et al.,* (2004) reported the updated checklist as 428 species. The Gulf of Mannar has pearl oyster beds on its far eastern side at a depth range of 4-22 m, where 6 species of pearl oysters are known to occur. *Pinctada fucata* is the dominant species in the fishery.

Echinoderms: A total of 95 species of echinoderms (9 species of Crinoids, 26 Asteroids, 19 Ophiuroids, 19 Echinoids and 22 Holothuroids) have been reported from the coral reefs and adjoining seagrass beds, sandy shores, rocky coasts and muddy flats of Gulf of Mannar. Out of 22 holothurids, 6 are commercially important. *Holothuria scabra, H. spinifera, Actinopyga echinites, A. miliaris*, and *Bohadschia marmorata* are exploited commercially (James, 1998). However James (2001) reported 112 species of Echinoderms in Mannar.

Fishes: About 200 species of fish are economically important that are caught by shore seine, boat seine, gill net, hooks & line and trawl nets. Dorairaj (1998) reported 450 species of fishes are known to occur in Gulf of Mannar, of which, at least 122 species are associated with coral reef areas, 32 species in seagrass beds, about 40 species in the near shore areas and adjoining mangroves and a few hundred pelagic fishes in the coloumnar waters. However, Venkataraman (2006) estimated the occurrence of 538+ species of fishes in Indian marine waters.

Sea Turtles: Five species of sea turtles (Green – *Chelonia mydas;* Hawksbill – *Eretmochelys imbricata*; Loggerhead – *Caretta caretta*; Olive Ridley – *Lepidochelys olivacea* and Leatherback – *Dermochelys coriacea*) are reported from this area (Bhupathy & Saravanan, 2006)

Dolphins: Four species of dolphins (the Spinner dolphin - *Stenella longirostris*, Humpback dolphin - *Sousa chinensis,* Bottle nose dolphin - *Tursiops truncates aduncus*, Saddleback dolphin – *Delphinus delphis*) have been recorded so far and are caught either in trawl and gill nets or washed ashore after getting injured in trawl boats or gill netting. (Krishna Pillai and Kasinathan 1989; Lipton *et al.,* 1995).

Whales: Though whales are not resident of Gulf of Mannar, their strandings have been recorded from time to time. So far 7 species of whales (*Physeter macrocephalus* (James and Soundararajan 1984; Sivadas *et al.,* 1987), *Pseudorca crassidens* (Thiagarajan *et al.,* 1984), *Balenoptera musculus, B. borealis* (Mohamed Kasim and Balasubramanian, 1989), *Globiocephalus macrorhynchus* (Alagarswami *et al.,* 1973), *B. physalus* and *B. acutrostrata* have been recorded.

Seacow: The Sea cow or Dugong (*Dugong dugon*) is known to inhabit the shallow waters (up to 9 m) of Gulf of Mannar and Palk Bay, where dense patches of seagrasses (*Cymadocea serrulata* and *C. isoetifolia*) are abundant. The seagrass patches are densely distributed around Krusadai, Musal, Talayari, Valai, Anaipar, Valiamunai, Nallathanni, Upputanni, Appa and Paluvinichalli islands which serve as feeding grounds for dugongs. Anthropogenic impacts coupled with natural calamity such as cyclone have reduced the extent of feeding grounds for both dugongs and sea turtles, resulting in the declines in these species in the Gulf of Mannar (Nair *et al.,* 1975; Jones 1981; Silas and Bastin Fernando 1988; Bensam and Menon, 1996; Devaraj, 1998).

Impact of the tsunami

Few detailed impact assessments were conducted after the tsunami, and the few that surveyed the reefs found no significant damage (Patterson, 2005; Kumaraguru *et al.,* 2005). A few tabular Acroporids (mostly *Acropora cytherea*) had toppled over or tilted due to wave action, and some branching species (*Acropora intermedia* in particular) had broken fragments. Dislodged seagrass and algal fronds were entangled with the live coral, and scattered in the reef. Significant movements of sediment had occurred as a result of the tsunami, and much of this had accumulated in the cup-shaped *Turbinaria* corals: virtually every surveyed individual had a collection of fine sand, 4-5 cm deep. In contrast, branching and massive corals did not collect sediments – this is unsurprising since they are structurally better able to deal with sediments than foliose growth forms (Patterson *et al.,* 2005). While bleaching increased, siltation, deposition of debris and toppling were commonly observed. There was no significant change in diversity, between pre and post-tsunami surveys. However, 1-2% of table and branching corals show signs of physical disturbance like colony uprooting and broken branches (Patterson, 2005).

Despite this apparent lack of damage, live coral cover estimates in January 2005 at the Tuticorin group of islands indicate a drop in percent cover from 42% (in November 2004) to 31% post-tsunami (Kumaraguru et al., 2005). It is difficult to know how to interpret this result given the paucity of information provided by these reports on how the data was collected or the error margins associated with these results.

Status and threats

There has been some work on the status and conservation of coral reefs and associated faunal communities in India (Murugesan *et al.,* 2000) and in the Gulf of Mannar (Pillai, 1975; Venkataraman, 2000; Muley *et al.* 2000; Patterson, 2000; Rajasurya *et al.*. 2000 and Gopakumar, 2000). Coral reefs in India are threatened by natural events such as cyclones and *El Nino* events. For example, in 1964, a heavy cyclone caused considerable damage to the branching coral of the Gulf of Mannar (Pillai, 1975). Due to high water temperature related to the *El Nino*, bleaching of shallow water corals occurred from mid 1997 to late 1998 (Venkataraman, 2003). Kumaraguru *et al.* (2003) recorded mass bleaching of corals in the Palk Bay region and monitored the recovery rate.

Corals are also affected by anthropogenic activities. Mining of living and dead corals has also caused severe damage to the coral reef and asssociated fauna in Gulf of Mannar Marine Biosphere Reserve (Pillai, 1975; Mahadevan and Nayar, 1972; Gopakumar, 2000; Venkataraman, 2000; Venkataraman *et al.,* 2003a; Muley *et al.,* 2000).

The fresh water run off and industrial effluents damage reefs in semi-enclosed bays and lagoons by lowering the salinity, deposit of large amount of sediments and accumulation of the heavy metal compounds (Murugesan *et al.,* 2000). Murugesan *et al.* (2000) argue that lethal concentration of

crude oil, hydrocarbons, fly ash and pesticides contamination directly affect the coral reef and its associated faunal communities. Sedimentation from development activities, eutrophication due to sewage and agricultural waste disposal, physical impacts like dredging, collection and destructive fishing practices, pollution from industrial sources and oil refineries are some of the serious anthropogenic disturbances threatening coral reef ecosystems (Ravikumar and Lazarus, 2000). Sewage is a major cause of eutrophication and includes the discharge of the industrial and human waste and waste release from ships (Ravikumar and Lazarus, 2000).

Research gaps and priorities

The very first International Coral Reef Symposium, the most important global gathering of reef scientists was held in Mandapam Camp in southern Tamil Nadu in 1969. More than half of the participants in the symposium were Indian scientists and was a testament to the pioneering research done by Pillai, Scheer and their ilk in Indian coral reefs. Since then however, the science of Indian coral reefs has failed to keep up with the considerable advances made elsewhere in the tropics on furthering our understanding of these important ecosystems. For the Gulf of Mannar and Palk Bay, as for most other reef regions in the country, the peer-reviewed literature is still dominated by species lists, distribution studies, and a status surveys (See Venkatraman 2006 for a review). These studies are an important first step in establishing baselines, but they do not adequately address either the important scientific questions that need answering in these waters, nor do they provide clear directions for the conservation and management of these reefs.

Much of the reason for this bias in research prioritisation has been the lack of professionals trained to conduct field research. Additionally, most coral reef science done today is a logistically fairly intensive affair, which requires considerable investment in field diving equipment, underwater data recording and measuring tools, and laboratory establishment. These lacunae are now being addressed, with several institutions both governmental and private, recognising the need to invest in building local capacities to do research. More crucially, coral reef research in India has been slow to pull itself out of the paradigm of list-making and taxonomic surveys, and unless more attention is paid to question-driven research while building professional capacities, this is perhaps going to be the biggest stumbling block to quality research from these waters.

We have outlined a list of potential priorities areas for research and monitoring for the coral reefs of this area. This is a list of imperatives, and is by no means exhaustive:

1. Community mapping: This has received some attention recently, but a much more comprehensive picture of the spatial distribution of reefal communities is required. Designs of these studies should be geared to additionally identify environmental gradients along which these communities are distributed. Of particular importance for this region are sedimentation rates, depth, light, and the seasonality of the monsoons.
2. Population structure: The last few years have seen a few monitoring programmes (under the aegis of programmes like GCRMN and CORDIO) being have been initiated in the Mannar reefs. While these protocols are good for broad-scale monitoring of reefs, they do not provide detailed information on the population structure of important reef elements, such as corals and fish. This is often among the most useful information to determine ecosystem trends, and responses to chronic or pulse disturbances. Additionally, they could form the basis of modeling studies to determine, for instance, the recovery rates of corals after a mass bleaching event, or the effects of fishing on important fish populations.

3. Connectivity and Recruitment studies: Given the increasing stochasticity of the marine environment, understanding recruitment patterns of corals and fish at a seascape level is vital to rational marine protected area design, given that recovery of reefs after major mortality events is likely dependent on the integrity of source-sink mosaics. The region has a diversity of marine ecosystems (coral reefs, mangroves, seagrasses, rocky patches), and the links between these need to be explored, particularly in relation to ontogenetic shifts in ecosystem use by important fish species. This will determine the degree of interdependence of these ecosystems to enable more holistic management planning for the region.
4. Effects of environmental degradation and development activities: In the light of increased developmental pressures from a variety of sources in the Gulf of Mannar, focused studies are required in this region on impacts of these developmental activities on the reefs and their diversity. These need to be designed specifically with particular sources of environmental degradation in mind, so that the results are not equivocal on the impacts of these disturbances. These can also feed into existing monitoring programmes, as an early-warning system to ensure that managers are aware of trends in the reef in response to disturbance. In particular, priority needs to be given to studies focusing on the impacts of dredging related sedimentation, the influences of introduced algal culture (such as *Kappaphycus*) on the reefs, and the effects of nutrient and pollution inputs on reef systems.
5. Human use, and Traditional Knowledge: This is a region that has high human densities, and dependencies on marine resources are high. Understanding the nature of this dependence is crucial to managing the reefs and their sustainability. Destructive human practices such as coral mining have in the past resulted in considerable damage to these reefs, and these need to be studied in more detail. Many fishing communities have inherent systems of functional protection which they afford the system, based on locally-implemented systems of tenure. The nature of these tenure systems need to be better understood for this region, and traditional knowledge of fishers needs to be engaged to identify and properly manage important fish breeding locations such as fish spawning aggregations and nursery sites.

Institutions

Very few institutions are involved in coral reef studies. This may be due to limitations in equipment and capacity. Few institutions possess dive equipment and the number of dive training centers and instructors are also limited. An improvement in this is required to enhance research and monitoring of coral reefs.

1. Marine Biological Station, Zoological survey of India, Chennai.
2. Centre for Advanced Studies in Marine Biology, Parangipettai, Chitambaram.
3. Institute of Ocean Management, Anna University, Chennai.
4. Central Marine Fisheries Research Institute, Mandapam.
5. Madurai Kamaraj University, Madurai.
6. Suganthi Devadasan Marine Research Institute, Tuticorin.
7. National Institute of Ocean Technology, Chennai.
8. M. S. Swaminathan Research Foundation, Chennai.

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SEAGRASS MEADOWS

Seagrasses are a specialised group of marine flora found in tropical and temperate regions. Though seagrasses are highly productive and support an array of associated flora and fauna, little is known about their status in India in comparison to other coastal marine ecosystems like mangroves (Jagtap *et al.*, 2003a). Seagrasses are submerged monocotyledonous plants forming meadows in shallow, calm and protected coastal areas with the substratum ranging from coarse sand to clay and also coral rubble. Seagrass meadows are highly dynamic and contribute to nutrient regeneration and shoreline stabilisation processes. In particular, seagrass meadows are important grazing grounds for the endangered marine mammal *Dugong dugong*. Seagrasses are sensitive to environmental perturbations like change in salinity and siltation levels.

Barring a few taxonomical and distributional surveys, research on seagrasses in India started primarily in 1980s (Jagtap *et al*, 2003b). Little is known about their structural and functional attributes. Their resilience to environmental fluctuations is largely unexplored. Ecosystem services provided by seagrasses are also poorly investigated.

Distribution

Seagrass habitats are mostly limited to mudflats and sandy regions from the lower intertidal zone. They are found up to a depth of 10-15 m along the open shores and in the lagoons around the islands (Jagtap *et al.*, 2003 a). In India seagrass meadows are predominantly found along a) the Southeast coast (Gulf of Mannar and Palk Bay) b) Lakshadweep Islands c) Andaman and Nicobar Islands (Jagtap *et al.,* 2003b). The maximum area (30 km^2)] of seagrass meadows distribution is found in the southeast coast (Gulf of Mannar and Palk Bay) and is followed by the Nicobar group of Islands with a value of 8.3 sq kms. (Jagatap *et al.,* 2003 a). Little is known about seagrass distribution in Andhra Pradesh and Kerala.

Flora and fauna

There are only 58 species of seagrasses in the world and out of them 14 have been reported so far in India. *Cymodocea rotundata, Cymodocea serrulata, Enhalus acoroides, Halodule pinifolia, Halodule uninervis, Halodule wrightii, Halophila beccarii, Halophila decipiens, Halophila ovalis, Halophila ovalis var. ramamurtiana, Halophila ovata, Halophila stipulaceae, Syringodium isoetifolium, Thalassia hemprichii,* and *Ruppia maritima* are the 14 seagrass species found on the Indian coast. All 14 species are found in the Tamil Nadu coast and a new variety *Halophila ovalis* var. *ramamurtiana* is found only on the Tamil Nadu coast. *Halodule pinifolia, H. uninervis, H. wrightii, Halophila beccarii, H. ovalis,* and *H. ovata* are the six species present on the coast of Andhra Pradesh. *Enhalus acoroides* is the only seagrass species found on the Kerala coast. (Jagatap *et al.,* 2003a)

The associated flora consists of 100 species of marine algae, 13 species of phytoplankton and 9 species of fungi (compiled by Jagatap *et al.* (2003b). Studies on various associated faunal components of seagrass ecosystem including fishes, crustaceans, molluscs, echinoderms, sea turtles and mammals for the seagrass beds of India and benthic community composition for selected areas has been compiled by Jagtap *et al.,* (2003b).

Impact of the tsunami

Various post-tsunami studies report that there was no effect of tsunami on seagrasses in mainland India, however damage has been reported in the Andaman Islands (Patterson *et al.,* 2005, Daniels *et al.*, 2005 and Patterson, 2005). Seagrasses in the Palk Bay region were reportedly unaffected by tsunami, though there was an increase in sedimentation rate in this region (Patterson *et al.,* 2005). Rapid post-tsunami surveys along the Tamil Nadu coast showed that there was no impact of the tsunami on the seagrass bed, though a large quantity of seagrass fragments were washed out due to the tsunami wave energy (Patterson, 2005). However, the findings of the rapid survey carried out in this project indicates that tsunami effects can be detected in seagrass systems.

Status and threats

There is a dearth of research activities enumerating the causes leading to seagrass decline in India. A few natural causes of seagrass destruction in India reported by Jagtap *et al.,* [2003a] are cyclones, waves, intensive grazing and infestation of fungi and epiphytes, as well as die back disease. Eutrophication might be a potential contributor of seagrass decline. Anthropogenic activities harmful to seagrasses are steadily on the rise. Anchoring, dredging, sewage disposal, coastal engineering constructions are some of the major causes of seagrass destruction in India. (Jagtap *et al.,* 2003a). However, the exact effects of each of these factors on seagrasses and their response to them have not been studied.

Research gaps and priorities

Work on distribution of seagrasses along the Tamil Nadu coast and also for the entire Indian coast has been carried out. (Ramamurthy *et al.,* 1992; Parthasarathy *et al.,* 1991; Jagtap1991; Jagtap *et al.,* 2003a). But there is no recent survey on distribution and area of the seagrass system along the coast. These systems in some particular regions, have not been documented. For eg., in the Palk Bay area south of Mimesal, seagrasses were observed in places like Thonithurai, Sangumal and Agnitheertham[5] but are neither surveyed nor documented. Likewise during the field visit (sandy beach survey) of this project cast ashores of *Halodule* species were observed at Manginipudi beach near Machillipatnam, indicating the need to do an intensive survey in these areas for the survey and documentation of seagrasses. Studies on the status of the system including the present threats and policy responses have been carried out. (Jagtap *et al.,* 2003a; Jagtap *et al.,* 2003b). Floral biology of *Halophila beccarii* and species description of *Halophila decipiens* has been carried out. (Parthasarathy *et al.,* 1988a; Parthasarathy *et al.,* 1988b). Studies on the structural components of seagrass ecosystems and observations on depth wise species distribution were also carried out on the southeast coast of India (Jagtap 1996).

1. Research and documentation: In general studies on seagrass ecosystems in India are limited. Though there are certain studies documenting the associated flora and fauna, studies focusing on the interaction between associated organisms and seagrass ecosystem are almost absent. As mentioned earlier, studies on ecosystem structure and functioning are also yet to be undertaken. Although the system is sensitive to certain environmental parameters, the system may not show an immediate response like disappearance or decrease in meadow area for certain stress factors like siltation. Such long-term effects will be revealed only by a continuous monitoring program, which is currently lacking. Socio-economic analysis of ecosystem services provided by seagrasses are also absent.

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2. Awareness: As pointed out by Jagtap *et al.*(2003 a), there is a complete lack of awareness about the ecological value of seagrass ecosystems. There appears to be a dearth of knowledge both at the level of local communities and among coastal zone managers.

The following institutions have been engaged in seagrass research:

1. Salim Ali School of Ecology, Pondicherry University, Pondicherry.
2. National Institute of Oceanography, Donapaula, Goa.
3. Center for Advanced studies in Marine Biology, Annamalai University, Chidambaram.

Recommendations

The tsunami event highlights the need for maintaining updated information on area and diversity of this system by continuous monitoring, which would serve as the baseline data for post-calamity events and help in management. It is imperative to document the long-term indirect effects such as increased siltation rate, change in floral and faunal composition and ecosystem functioning of seagrasses to improve our understanding about the ecosystem. Site-specific studies on seagrass health in relation to the prevailing stress factors and possible control measures are important in this context. This in turn would help us to conserve the ecosystem better in the long run. For eg., a recent study (during July 2006) carried out as a part of the first phase of this project clearly reveals that the seagrass ecosystem at particular sites does show the impact of increased siltation rate caused by tsunami and the study also indicated that particular seagrass species can be effectively used an indicator of siltation levels in the area (see chapter on seagrasses).

Efforts should also be made to identify areas with high diversity and healthy seagrass ecosystems. Adequate conservation attention should then be given to such areas. Though seagrass ecosystems are protected under the Coastal Regulation Zone Notification, this system is currently facing severe anthropogenic threat highlighting the need for further research and formation of better management practice.

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Chapter 3a Analysis of post-tsunami coastal plantation initiatives of the Forest Department and non-governmental organisations in Tamil Nadu

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Introduction

Following the Indian Ocean tsunami in 2004, there has been considerable interest in activities concerning "bioshields". The term 'bioshields' is used to refer to coastal vegetation structures (both natural and planted) that contribute to protection of the coast from storms, cyclones and even tsunamis to varying extents. In a majority of cases bioshields consist of mangroves and *Casuarina* plantations. There is an ongoing debate about the effectiveness of these plantations and other coastal forests in providing protection from the tsunami both in scientific and social circles (Kar and Kar, 2005; Kathiresan, 2005; Dahdouh-Guebas, 2006; Kerr *et al.*, 2006; Vermat, 2006). Kar *et al* (2005) were the first to point out the need for research on the beneficial role of mangroves in mitigating the tsunami. Kathiresan's work in 18 tsunami affected hamlets in Perangepettai (located along 25km of coastline in Tamil Nadu) showed that the hamlets protected by (located behind) mangroves and other coastal vegetation suffered less human death and loss of wealth. Danielson *et al* (2005) also pointed out that in Cuddalore District, Tamil Nadu the impact of the tsunami was significantly lesser in mangrove and *Casuarina* protected villages than in others. However, in response to Kathiresan's (2005) research findings, Kerr *et al* (2006) reanalysed their data and concluded that the mangroves and other vegetation did not have a significant effect on the impact of the tsunami. Instead, they stated that topography and distance from the shoreline were the major factors determining impact of the tsunami. Vermaat *et al* (2006) contributed to this debate by reanalysing Kathiresan's data and stated that the original conclusion of Kathiresan and Rajendran (2005) holds, and that mortality and property loss were actually lesser behind mangroves. Alongside the heated debate, there has been substantial work on bioshields in India after the tsunami. In this report, we attempt to assimilate information from the work on bioshields, the flaws therein from an ecological perspective and make a few recommendations.

Institutions involved

Both government and non-governmental bodies have contributed significantly to bioshields. The State Forest Department of Tamil Nadu for instance, has been planting Casuarina and mangroves under the category of bioshields post–tsunami. Various NGOs have also been involved in bioshields in the three tsunami-affected states. In the following section we present a brief overview of the Tamil Nadu Forest Department's post-tsunami initiatives representing government initiatives and present the efforts of NGOs working on bioshields. We also discuss the efforts of other international bodies either involved in or funding bioshields in India.

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1. Tamil Nadu Forest Department

Tamil Nadu has a recorded forest area of 22,871 sq. km and a total coastline of 1076 km (FSI - FSR, 2001). The Tamil Nadu Forest Department has been raising shelterbelt plantations along its coastline since 1960 (details attached in Annexures 1&2). As a result, about 2239 ha had been covered under shelter belt plantation prior to the tsunami under various plantation schemes like Tamil Nadu Afforestation Programme, National Afforestation Programme etc. These plantations broadly consist of mangroves and *Casuarina* spp.

Methodology

A team of research associates from ATREE (N. Mukherjee and B. Muthuraman) conducted interviews with Forest Department officials (mostly District Forest Officers) in five coastal circles in Tamil Nadu. Since Tamil Nadu was the worst affected state by the tsunami, we concentrated our efforts on this state. We were broadly interested in understanding the Forest Department's perspective towards plantations and bioshields, the type of activities carried out under various post-tsunami schemes and the causes of conflict, if any. The questionnaire is attached in Annexure 3. We procured maps and details of the post-tsunami micro plans of the Forest Department. We also visited some of their plantation sites to gain a better understanding of ground realities.

Results

Forest department perspective: The Forest Department strongly believes in the importance of coastal plantations and is in favour of bioshields. After the tsunami, the Forest Department continued its efforts to plant mangroves and *Casuarina* along the coast. *Casuarina* is a fast growing species which can grow even on nutrient-deficient soil and requires little care after establishment. The economic returns of *Casuarina* plantations are also considerably high. Mangroves on the other hand provide a considerable suite of ecosystem services besides timber.

i. **Area**: Immediately after the tsunami, the Forest Department conducted a rapid assessment to identify sites for further plantations. About 17,754 ha were found to be available along the coast for raising shelter belts "after leaving room for encroachment". Out of this total area, about 11,500 ha were found suitable for shelterbelts (*Casuarina* spp) and 6254 ha for mangroves. The categories under which all this land falls is not clearly specified.

ii. **Donors, funds and extent**: With the assistance of the World Bank, the Forest Department implemented two schemes: a) Emergency Tsunami Reconstruction Project (ETRP) b) National Cyclone Risk Mitigation Project (NCRMP). Under ETRP alone Rs. 700 lakhs were sanctioned for *Casuarina* shelterbelt plantation and Rs.100 lakhs for mangrove plantations. This amounted to 2000 ha for *Casuarina* spp. plantation and 400 ha for mangroves. The circle wise details of area and location of these plantations along with the preliminary maps were obtained. Various other international and national donor agencies have also contributed to tsunami rehabilitation but they are outside the purview of this report as the Forest Department received funds only under the above-mentioned schemes.

iii. **Species planted**: In mangrove plantations in the state, the widely used species is *Avicennia marina*. This species has a high salinity tolerance range and can establish itself much faster than other mangrove plants. In some places *Rhizophora* spp. is also used.

In the case of non-mangrove shelterbelts, *Casuarina equisetifolia* is planted on a large scale. According to most working plans a mixture of 90% *Casuarina* with 10% mixed species are supposed to be planted. This consists of *Acacia planifrons, Syzigium cumini, Holoptelia integrifolia, Bambusa arundinacea, Dalbergia sissoo, Thespesia populnea, Jatropha* spp., *Borassus flabellifer, Acacia curticulliformis* and *Cocos nucifera*. However, in most of the circles only *Acacia planifrons* is being used.

iv. **Other activities**: Apart from the forestry activities, the Forest Department has also taken an active interest in the social upliftment of people in and around their jurisdiction after the tsunami. A sizeable amount has been spent on:

a) Awareness programmes about the tsunami.

b) Rebuilding of fish landing centres under the category of "Entry Point Activities".

c) Construction and maintenance of tanks for rainwater harvesting for drinking water notably in Ramnanthapuram.

d) Construction of temporary sheds for shelter, notably in Nagapattinam.

e) Construction of schools and community halls, notably in Tuticorin.

f) Public Rural Appraisals.

g) Monitoring and evaluation of plantations.

v. **Problems faced by Forest Department**: In our discussions with the department officials, it became evident that they had to face several logistic challenges in their ongoing activities, primarily the availability of adequate skilled labour in the planting season. Most of the plantation activities are carried out during the onset of the north-east monsoon (October and November) which coincides with the agricultural sowing season; most of the locals prefer to work in agricultural fields as the wages are higher. Moreover, most of the people who are recruited by the forest department are primarily fisherfolk who are not skilled in planting activities.

Unavailability of funds on time is a major problem. Often work gets delayed or proper monitoring of plantations in subsequent years cannot be carried out due to lack of funds. Apart from these, grazing by cattle, illegal encroachments and the vagaries of rain add to the problems that the Forest Department has to deal with.

2. Non-Governmental Organisations' initiatives

Table 1 summarises the work done by the various Non-Governmental Organisations in Tamil Nadu, Pondicherry and Andhra Pradesh. Data could not be collected from Kerala for this study. A map showing plantation activities in Tamil Nadu is attached as Annexure 4.

Table1 Showing NGO initiatives related to bioshields in Tamil Nadu, Pondicherry and Andhra Pradesh.

State/ UT	Organisation	Place	Area	Species	Donor Agency
Tamil Nadu	M. S. S. R. F	Muzhkuthurai, Samiarpettai, Killai Panchayat and Madavamedu	Not available	*Rhizophora mucronata, Avicennia marina* in mangrove plantations and *Thespesia,* coconut and cashew along with *Casuarina*	DBT
	Anawim	Mangalavadi	2 ha	*Casuarina*	Green Coast
	Covenant Centre for Development	Rameshwaram	Not available	Not available	Not available
	SEEDS Trust	Rajakamangalam Kanyakumari	Established nursery with 15000 nos	*Rhizophora mucronata, Avicennia marina*	Green Coast
	PHCC	Kaatucherry Tarangambadi	4 ha	*Rhizophora mucronata, Avicennia marina, Bruguiera cylindrica*	Green Coast
	CAT	Manakudi Kanyakumari	3 ha	*Rhizophora mucronata, Avicennia marina*	Green Coast
Pondicherry	REEF	Thengaithittu	3 ha	*Rhizophora mucronata, Avicennia marina*	Green Coast
	CEAD	Veerampatinam	3 ha	*Rhizophora mucronata, Avicennia marina , Bruguiera cylindrica*	Green Coast
Andhra Pradesh	MSSRF	(i)Machlipatnam (Krishna District and (ii)Todangi (East Godavari District)	120 ha of mangroves and 40 ha of *Casuarina* respectively	*Avicennia marina, Avicennia officinalis, Rhizophora mucronata, Exocaria agallocha, Bruguiera cylindrica*	CIDA, IDRC
	Chaitanya Development Society	Chinnaganjam	50 ha	*Avicennia marina, Avicennia officinalis, Rhizophora mucronata, Bruguiera cylindrica, Exocaria agallocha*	AFPRO and CARE
	TREE	Gundamala Pathepallipalem Ongole	2 ha	Seed collection is being carried out for establishing nurseries. Awaiting the monsoon for direct seed transplantation and nursery raising.	Green Coast
	GARDS	Nizampattnam, Baptla	5 ha		Green Coast
	GGM	Baptla	2 ha		Green Coast
	DFYWA	Vishakapattinam	2 ha		Green Coast
	SNIRD	(i) Ulavapadu Mandal (Prakashan Dist) and Kavali Mandal (Nellore District) (ii) Kothapatnam Mandal (Prakasham District)	i) 80 ha of *Casuarina* (ii) 67 ha of *Casuarina*	*Avicennia marina, Avicennia officinalis, Rhizophora mucronata*	Christian Aid; DKA, Austria and NOVIB

State/ UT	Organisation	Place	Area	Species	Donor Agency
	Sravanti	Chollangi and Island Polavaram	30 ha	*Avicennia marina*	OXFAM and CEE
	Coastal Community Development Programme	Prakasham District	50 ha		ITC, CARE India,
	Sangamitra	Krishna District	260 ha (proposed)	*Avicennia marina, Avicennia officinalis, Rhizophora mucronata, R. apiculata*	DEA (Germany)

3. Other organisations

World Wildlife Fund: WWF in partnership with IUCN, Wetlands International, and Both Ends launched the Green Coast Program to provide environmental support across the tsunami-affected region. It is funded by the Netherlands Public Charity Funds through NOVIB (Oxfam Netherlands). In India, the Green Coast Programme has been supporting bioshields work by funding various local NGOs.

Food and Agriculture Organisation: The FAO held a workshop titled "Coastal protection in the aftermath of the Indian Ocean tsunami: What role for forests and trees?" in Khao Lak, Thailand, from the 28-31 August 2006, funded by the Government of Finland. The conclusive findings of the workshop were:

1. Forests and trees can act as bioshields protecting people and other assets against coastal hazards like tsunamis, but the extent of effectiveness depends on many factors.
2. Bioshields are not effective against all types of natural calamities.
3. Bioshields should be considered as a component of the disaster management strategies, which includes various other measures like effective early warning systems and evacuation plans.

International Union for the Conservation of Nature and Natural Resources (IUCN): Often it is imperative to assign a monetary value for natural resources to further strengthen their case for conservation. IUCN has recently conducted a field study for the economic evaluation of healthy mangroves. The study indicates that healthy mangroves have an overall use value of about US$ 8,000/household or US$ 15,000 / ha / household. The protective value adds up to approximately US$ 2,000 / household or US$ 3,500 / ha / household. The protection value includes the value of property (about 90%), livelihoods and infrastructure.

Microsoft Corporation: A project titled 'Microsoft Tsunami Contribution' has been sanctioned by Microsoft Corporation for a period of 30 months. One of the components of this project consists of developing bioshields in coastal villages.

Centre for Environment and Development: This project titled "Regeneration, Restoration and Eco-Development of Degraded Mangrove Areas with Community Participation in Kalliassery Panchayat of Kerala" is being implemented. Mangrove conservation through field appraisal and community involvement is the focus of the project.

Recommendations

A fruitful collaboration between management and ecological research is required for effective forestry activities. However, the two are often driven by conflicting goals. From the ecological and socio-economic perspective, we have the following suggestions:

1. Research and documentation: Adequate attention should be given to site selection with respect to the autecology of the species being planted both in the case of mangroves and *Casuarina*. Sites where remnant natural mangroves and patches of tropical dry evergreen forest are present should be identified and conserved a-priori to preserve the gene pool in them. The factors affecting natural regeneration of native plants in the plantation sites should be investigated so that both time and effort spent in plantations can be saved. A socio-economic analysis of the traditional ecological knowledge base of the local people and their dependence on natural resources would be of help prior to the plantation effort. After the plantation activity, the sites should be monitored on a long-term basis to understand the sustainability of such efforts.

2. Processes: In the case of shelter belts where *Casuarina* is being planted, the ratio of other mixed species can be raised. A host of tropical dry deciduous or dry evergreen species can be used (e.g. *Manilkara hexandra, Mimusops elengi, Diospyros ebenum*, *Strychnos nux-vomica*, *Eugenia* spp., *Drypetes sepiaria* and *Flacourtia indica*). In the case of mangrove plantations, restoration rather than afforestation should be addressed. Mixed species plantations should be encouraged rather than monoculture of *Avicennia marina*. In this context, the flora in the recent past in the plantation site could be of importance.

3. Social aspect: The natural resource use of the local people in the vicinity of the plantation site should be borne in mind before the choice of species is made. Their perception towards plantations and their need for the particular plantation (eg. fuel, firewood or bioshields) should be considered. The long-term viability of the plantations often depends on the attitude of the local people towards their utility. Therefore the participation of the local people and NGOs in the plantations should be encouraged.

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http://www.ashanet.org/projects/project-view.php?p=78
http://mssrf.org/nr/nl/November2005.pdf

Annexure – I

Present status of shelterbelt plantation in coastal districts of Tamil Nadu

Sl.No	Coastal districts	Year of Planting	Area (Ha)
1	Villuppuram / Cuddalore	1978	54.3
		1985	110
		1988	31.4
		1991	11.7
		1992	19.7
		2000	10
2	Thanjavur and Pudukottai	1988	30
		1999	16.5
		2001	450
		2004	150
3	Nagapattinam and Thiruvarur	1989	59
		1994	15
		1998	5.5
		2000	250
4	Ramanathapuram	1969	200
		1974	23
		1975	200
		1986	10
		1990	33
		1991	23
		1999	17.5
		2001	300
5	Tuticorin	1998	15
		1999	15
6	Tirunelveli	1974	30
		1975	30
		1990	2.5
		1992	5
		1997	0.5
7	Kanyakumari	1960-73	28

Annexure – 2

Present status of natural and man-made mangrove forest in Tamil Nadu

Sl.No.	Coastal districts	Location	Natural mangroves	Manmade mangroves	
				Year of planting	Area (Ha)
1	Cuddalore	Devanapattinam	60	1999	10
		Killai	326.61	1999	60
		Pichavaram	1144.71	1995	110
				1998	115
				2001	150
2	Nagapattinam and Thiruvarur	Thalanayar	7200	1993	10
				1994	8
				2002	0.75
		Muthupet	11635.56	1989	10
				2000	45
				2001	151
				2002	300
				2003	500
				2004	500
		Sethukuda		1999	4
		Maravakkadu		2001	149
		Panchanadikulam (Kodiakarai)		1999 2001	159 150
3	Thanjavur and Pudhukottai			2002	25
4	Ramanathapuram (Marine National Park Division)	Point Calimere		1998	3
		Kadaloor		1998	38
		Thiruppalakudi uppur		1997	45
		Kannamuani	3	1994	2.6
		Sambai		2000	59.19
		Rettaipalam		1997	54
		Monali	5	1999	5
		Hare Island	5	1995	5
5	Ramanathapuram (Social forestry Division)	Monaliputtali	2.34		
		Kundugal		1999	12
6	Tuticorin	Punnaikayal	12		

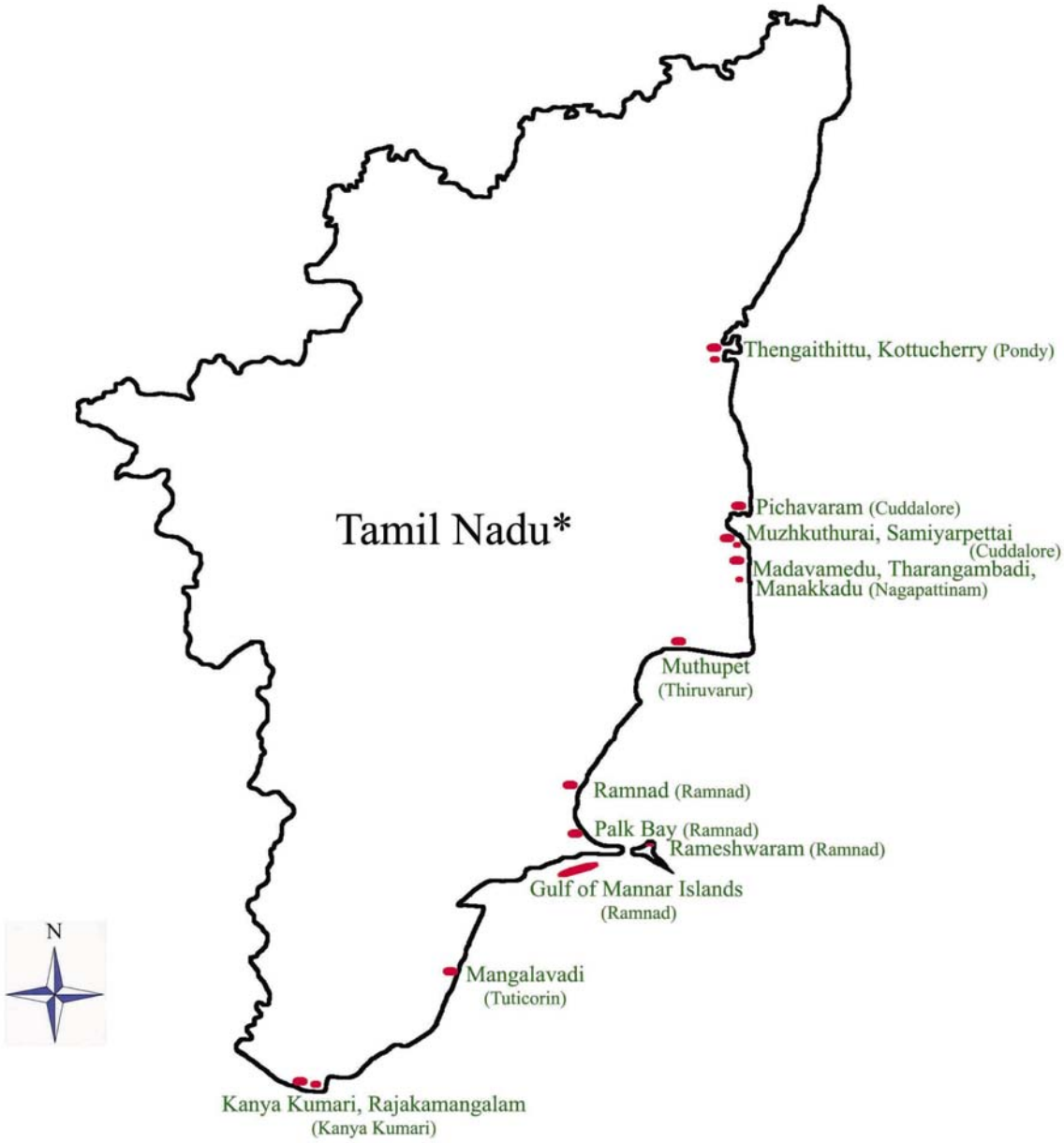
Annexure – 3

Interview schedule for Forest Department data

- List of ranges and divisions that fall in the coastal areas.
- How much area of forest land is on the coast?
- What are the various classifications of forest lands in Tamil Nadu?
- Are there special classifications of lands only peculiar to Tamil Nadu?
- Since when has the Forest Department been doing plantations in Tamil Nadu?
- What species has the forest departments used for plantations?
- Are mangroves given any protection by the forest department? What kind of protection?
- What has been the allocations and extent (money and area) invested in plantations since about 1990?
- What details are available at the Chennai office on the plantations on the coast?
- Any maps available of areas under plantations? Only coastal plantations –those that are within 500 m from the high Tide Line)
- Are there any jointly owned plantations?
- Under what laws are these plantations governed?
- Are there any sort of conflicts over the land use in these plantations?
- How much area on the coast is currently classified as scrub forest?
- How much area on the coast is currently classified as gomal land or village commons?
- Are there any 'village forests' as stated in the Indian Forest Act on the TN or Pondy coast? How are these areas governed?
- What is the status of biodiversity in these 'village forests' on the coast?
- Are there any post-tsunami plans for land cover changes in areas where the forest department has jurisdiction?
- Which are the exact areas where they want to plan bio-shields or other species?
- Are forest lands being given in any instance for tsunami rehabilitation?
- Do they know which are the areas where sea-walls are being planned?
- How much area is the Forest Department proposing to bring under bioshields under the World Bank assisted project or other grants?
- In what way is the Forest Department's current bioshields project likely to be different from earlier plantation work?

Annexure 4

Map showing areas of bioshield activities of NGOs in Tamil Nadu



Chapter 3b A brief assessment of sandy beaches on the south-east coast of India

A. Gokul[7] and Kartik Shanker[1]

Introduction

Much of the mainland Indian coast of over 6000 km is sandy. The coast is also extensively inhabited, with a number of coastal towns, interspersed with fishing hamlets nearly every kilometer or so. Consequently, most beaches along the coast, barring a few in protected areas, tend to be highly disturbed. There have been few studies on sandy beaches in India, a few on ecology (Trevallion *et al.,* 1970; Vohra 1971; Ansell *et al.* 1972b,c; McClusky *et al.,* 1975; Achuthankutty, 1976; Achuthankutty and Wafar, 1976; Achuthankutty *et al.,* 1978; Ansell *et al.*, 1978; Ansari *et al.,* 1986, 1990; Harkantra and Parulekar, 1986; Chatterji *et al.,* 1995) and a few on physical and chemical parameters (Ansell *et al.,* 1972a; Wafar *et al.*, 1980: Shankar and Shetye, 1999). Many of the ecological studies have focused on macro and meiofaunal assemblages at a few geographical locations and do not address the broader issues of sandy beach diversity and conservation (see Qasim, 1999 for a review).

Many of the studies of sandy beaches have been conducted in the context of the fact that these serve as nesting beaches for marine turtle species, mainly the olive ridley (*Lepidochelys olivacea*) on the east coast of India (see Shanker and Choudhury, 2006). Bhupathy and Saravanan (2001, 2006) provide a comprehensive account of nesting beaches in Tamil Nadu, including information on the habitat and threats. Similarly, Tripathy *et al.* (2006) provide an account of nesting beaches on the coast of Andhra Pradesh, suggesting that relatively undisturbed beaches near river mouths may be critical habitats for marine turtles. Kerala, in contrast, has few sandy beaches, as much of the coast has been walled (Dileepkumar and Jayakumar, 2006).

In the context of the recent tsunami, sandy beach systems, and sand dunes in particular have received attention for the role they may have played in protecting people and habitations. Sand dunes are mounds of sand lying behind the active part of a beach. Dunes are formed by the sand particles carried by the wind from the beach. Coastal sand dunes are present in almost all the maritime states of India. Along the Tamil Nadu coast almost all the coastal districts like Thiruvallur, Chennai, Kancheepuram, Viluppuram, Ramanathapuram, Thoothukudi, Thirunelveli and Kanyakumari have sandy beaches and dunes in their coastal area (EQUATIONS, 2006). The southern part of the Andhra Pradesh coast is largely sandy with dune systems and typical Psammophytes that helps in dune formation (Tripathy *et al.,* 2006). Dunes are highly dynamic topographic features, and may undergo rapid changes when not anchored by vegetation.

Both sandy beaches and dunes are subject to a variety of threats (see Choudhury *et al.*, 2003). The most direct threat is sand mining or removal of sand for construction, but habitat alteration by construction of resorts, residences and roads can have an equally damaging effect. Beach armouring has been a major threat to sandy beaches. Apart from affecting the areas where the seawalls and groins are erected, these lead to further erosion at adjacent locations. Ports, harbours, jetties exacerbate

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erosion and the need for armouring, thus resulting in further habitat loss. Plantations close the beach can also have detrimental effects on sandy beaches. In offshore waters, pollution, exploration for oil and gas and tourism activities can have negative impacts on sandy beach ecosystems. Aquaculture and agriculture practices along the coast have led to the loss of important coastal habitats.

Explicit legal protection is afforded to the Indian coastline by the Coastal Regulation Zone (CRZ) Notification, 1991, issued under the Environment (Protection) Act, 1986. As per the notification, all state governments were required to prepare Coastal Zone Management Plans outlining areas where sand dunes and other ecological features or CRZ –I areas would be marked. However, none of the CZMPs prepared by any of the state governments is a fully approved document. The Ministry of Environment and Forests (MoEF) only conditionally approved the submitted CZMPs Among the various conditions contained in this approval letter, the MoEF has stated that all sand dunes are to be demarcated as CRZ –I. The CRZ Notification also requires state governments to declare certain stretches as areas of outstanding natural beauty, to be accorded protection under CRZ –I areas. The MoEF letter giving conditional approval to CZMPs states that the state governments were to declare these areas based on the 'generally recognised perception of such areas'. By these means, several open sandy beaches and isolated coves along the west and east coast can find protection under this law. However, none of the state governments have done a complete and exhaustive identification of the CRZ –I areas (including dunes) and the maps still need to incorporate the MoEF's conditions and receive the final approval (Sridhar, 2005).

In India, though the dune systems are protected by CRZ regulations they still face many anthropogenic stresses (Mascarhenas 1998; Mascarhenas, 2002a; Mascarhenas, 2002b). There has been considerable amount of citizen action over the protection of sand dunes, particularly well documented in the states of Kerala and Goa. There are several criticisms levelled against the CRZ Notification specifically targeted at the abysmal implementation record in all coastal states. As far as sand mining goes, the CRZ as a protection measure has only been able to outline how the beach resources (present at certain locations) need to be safeguarded. The law is not able to prescribe appropriate or alternative building material, which will ensure that the demand for the resource is kept to a minimum. While there are many community-based sand dune protection measures, there is no space within existing legislation to promote such conservation or restoration measures.

As a part of phase 1 of the UNDP Post-Tsunami Environment Initiative, project partners carried out a field survey on the east coast of India, covering Tamil Nadu and southern Andhra Pradesh. During this survey, we carried out a preliminary short study to document and describe sandy beaches on the coast of Tamil Nadu and southern Andhra Pradesh. Beaches were characterised by physical features, biological features and human impacts. Apart from examining general features to characterise the beach from an ecological perspective, this survey attempts to quantify the degree of human presence and disturbance to this habitat along the coast.

Method

The survey was conducted along the coasts of Tamil Nadu and Andhra Pradesh. Sites were selected at various points along the coast and data was recorded on a range of physical, biological and anthropogenic parameters at these sites. At each site, data was collected at 2 to 12 randomly selected points along the beach.

The geographical location of the point on the shore was recorded using *Garmin 12 channel* GPS. The data sheet has six sections ie, general physical characteristics, background characteristics,

human impacts, offshore features and beach macrofauna. Beach width, colour and texture of sand, height and slope were recorded as general physical characteristics. Background characteristics included vegetation (composition and height) and dunes (height and length). The threats to the beach system were included in the human impacts. Qualitative scores (low, medium, high) were assigned for oil spills, boat and net repairing, human waste and other waste, foot traffic and lights. The presence of corals and seagrasses were recorded. Fauna included the occurrence of shore crabs, bivalve and gastropod shells.

Results

Beaches surveyed

In Tamil Nadu, Thondi, Adiramapattinam, Manora, Nagapattinam, Tharangampadi, Cuddalore, Pondicherry, Marakkanam, Kovalam, Neelangarai and Marina. In Andhra Pradesh, Pulicat, Uppada, Manginipudi and Meypadu were surveyed. A total of 137 points from 16 stations/beaches were surveyed. The maximum points were recorded at Nagapattinam (12) and the minimum at Thondi (2). The other sites include Adiramapattinam (5), Manora (11), Tharangampadi (10), Cuddalore (10), Pondicherry (10), Marakkanam (10), Kovalam (10), Neelangarai (10), Marina (10), Pulicat (11), Uppada (3), Manginipudi (9) and Meypadu (11). The survey ranges from south Thondi (Tamil Nadu) 9° 44' 30.0" N / 79° 01' 14.7" E towards north of the east coast to Uppada (Andhra Pradesh) 17° 01.217' N / 82° 17.539' E

General physical characters

The soil colour was generally brown and texture was coarse. The Manginipudi beach had glittering sand with blackish brown colour. The slope ranges between 0.1m (Kovalam) and 1.5m (Velankanni). The maximum beach width was recorded at Tharangampadi (246m) and the minimum at Thondi and Monara (9m).

Table 1

S. No	General Characteristics				Beach Characteristics				
	GPS		Total No of points	Towards	Habitat type	Slope (m)	Average width (m)	Sand colour	Sand texture
	From	To							
Thondi (3.7.06)									
1	9° 44' 30.0" N 79° 01' 14.7" E	9° 44' 25.9" N 79° 01' 11.9" E	2	South	Sandy	-	9	Brown	Coarse
Adiramapattinam (5.7.06)									
2	10° 18' 55.9" N 79° 22' 57.3" E	10° 18' 44.8" N 79° 22' 45.3" E	5	South	Muddy	-	13	Brown	Coarse
Manora (5.7.06)									
3	10° 15' 56.4" N 79° 18' 18.3" E	10° 15' 44.0" N 79° 17' 50.1" E	11	South	Sandy	-	9	Brown	Coarse
Nagapattinam (6.7.06)									
4	10° 45' 54.2" N 79° 51' 04.2" E	10° 46' 17.5" N 79° 51' 04.2" E	12	North	Sandy	1	158	Blackish brown	Coarse
Tharangampadi (8.7.06)									
5	11° 02' 15.1" N 79° 51' 17.6" E	11° 01' 35.8" N 79° 51' 23.2" E	10	South	Sandy	1	246	Black	Coarse
Velankanni (10.7.06)									
6	Not recorded	Not recorded	3	South	Sandy	1.5	147	Blackish brown	Coarse
Cuddalore (12.8.06)									
7	11°44' 17.0" N 79° 47' 14.0" E	11°43' 08.7" N 79° 46' 56.1" E	10	South	Sandy	0.7	82	Brown	Coarse
Marakkanam (13.8.06)									
8	12° 10' 57.4" N 79° 57' 43.0" E	12° 09' 51.7" N 79° 57' 05.7" E	10	South	Sandy	0.3	119	Brown	Coarse
Pondy (14.8.06)									
9	11° 56' 20.4" N 79° 50' 13.5" E	11° 55' 18.3" N 79° 50' 01.1" E	10	South	Sandy	3	18.3	Brown	Coarse
Kovalam (16.8.06)									
10	12° 47' 21.3" N 80° 15' 16.5" E	12° 48' 18.3" N 80° 14' 36.2" E	10	North	Sandy	0.1	52.5	Brown	Coarse
Neelangarai (17.8.06)									
11	12° 56' 31.9" N 80° 15' 38.7" E	12° 57' 41.8" N 80° 15' 51.6" E	10	North	Sandy	0.53	69.5	Brown	Coarse
Marina (18.8.06)									
12	13° 02' 20.4" N 80° 16' 52.9" E	13° 03' 28.6" N 80° 17' 09.8" E	10	North	Sandy	0.13	165	Brown	Coarse
Pulicat (20.8.06)									
13	13° 25' 18.4" N 80° 19' 46.9" E	13° 26' 37.5" N 80° 19' 35.2" E	11	North	Sandy	0.4	96	Brown	Coarse
Uppada (7.11.06)									
14	17° 01.217' N 82° 17.539' E	17° 01.513' N 82° 17.677' E	3	South	Sandy	-	167	Brown	Coarse
Manginipudi (11.11.06)									
15	16° 15.216' N 81° 14.842' E	16° 14.630' N 81° 14.413' E	9	South	Sandy	-	220	Brown	Coarse
Mypadu (14.11.06)									
16	14° 30.338' N 80° 10.783' E	14° 29.504' N 80° 10.710' E	11	South	Sandy	-	52	Brown	Coarse

Background characters

The maximum length of the dune was observed at Nagapattinam (594m) and minimum at Marakkanam (42) beach. The dune height ranges from 0.5 (Neelangarai) to 1.3 (Nagapattinam). Groynes have been built at Nagapattinam coast for dune formation and sand accumulation has been observed near the groyne. The common species on the beach is *Ipomea pes-caprae*, *Spinifex* and *Casuarina*. Palm and coconut trees dominated the background. *Prosopis* is also found extensively along the coast mixed with ground vegetation and background trees.

Human Impacts

The nearest domestic settlement was observed at Thondi. Approved houses were built along the coast at a distance of 14m from the high tide line. At Tharangampadi buildings were built at a distance more than 500m. Nagapattinam, Velanganni, Marakkanam, Pondicherry, Neelangarai and Marina beaches were observed to have buildings less than 500m from the high tide line. The boat and net repair activities were maximum at Thondi, Adiramapattinam, Nagapattinam, Velankanni, Uppada and Mypadu beaches and minimum at the rest. Streetlights were observed at Thondi, Nagapattinam, Velankanni and Marina. Foot traffic and waste dumping were observed in almost all the 16 beaches, but this form of impact was least at Pulicat, Marakkanam, Cuddalore and Manora beaches.

Table 2

S. No	Site	Dune		Ground Vegetation		Trees			Nearest settlement		Human impacts				
	From	L (m)	H (m)	Species	Avg Dist (m)	Species	Avg Dist (m)	H (m)	Type	Avg Dist (m)	Boats	Nets	Lights	Foot Traffic	Waste
1	Thondi	-	-	*Prosopsis pp.*(++)	7	*Palmyra spp.*(++)	10	15	Concrete house	14	++	++	++	++	++
2	Adiramapattinam	-	-	*Prosopsis spp.* (++) *A. marina* (+) *Pandanus spp* (+) *Spinifex spp.* (+) *Cyprius spp.*(+)	11	*Palmyra spp.*(++)	132	18	-	-	++	++	-	++	++
3	Manora	-	-	*Prosopsis spp.* (++) *Avicennia spp.* (+) *Sweda spp.* (+)	6	*Palmyra spp.*(++) *C. nucifera* (+)	10	22	-	-	+	+	-	+	-
4	Nagapattinam	594	1.3	*Casuarina spp.* (++) *Ipomea pes-caprae* (+) *Prosopsis spp.*(+)	92	*Prosopsis spp.*(++) *Cocos nucifera* (+) *Thespesia spp.* (+) *Pongamia spp.* (+) *Acacia spp.*(+) *Palmyra spp.* (+) *Casuarina spp.*(+) *Neem tree* (+)	190	15	Govt. Offices, Concrete house and huts	111	++	++	++	++	++
5	Tharangambadi	793	2	*Casuarina spp.* (++) *Prosopsis spp.*(+)	140	*Palmyra spp.*(++) *C.nucifera* (+) *Thespesia spp* (+)	88	13	Concrete house and Huts	>533	+	+	-	++	++
6	Velankanni	-	-	-	-	*C. nucifera* (++) *Thespesia spp* (+)	170	4	Concrete house and shops	51	++	++	++	++	++
7	Cuddalore	68	1	-	28	*Casuarina sp.* (++) *Prosopis spp* (+) *C. nucifera* (+) *T. populenea* (+)	67	3	-	-	-	-	-	-	-

8	Marakkanam	42	1	*I. pes-caprae* (++) *Spinifex spp* (+)	43	*C. nucifera* (++) *Thespesia spp.* (+) *Casuarina spp* (+) *Palmyra* (+)	46	4	Huts	30	+	+	-	+	+
9	Pondy	-	-	-	-	*T. populenea* (+) *C. nucifera* (+)	30	3.5	Govt. Buildings	34	-	-	-	++	++
10	Kovalam	-	-	-	-	*Prosopis spp* (+)	41	3	-	-	+	+	-	++	++
11	Neelangarai	80	0.5	*I. pes-caprae* (+) *Spinifex spp.*(+)	45	*T. populenea* (++) *Calotropis spp* (+) *C. nucifera* (+)	49	3	Resorts, Houses and Huts	90	-	+	+	++	++
12	Marina	-	-	-	-	-	-	-	Govt. Buildings	184	+	+	++	++	++
13	Pulicat	60	1	*I. pes-caprae* (+)	60	*Casuarina sp.* (++) *Palmyra* (+) *Cocos nucifera* (+) *T. populenea* (+)	84	3	-	-	-	-	-	+	+
14	Uppada	-	-	*Spinifex spp*(+)	60	*Casuarina spp* (++) *Prosopis* (+)	78	10	-	-	++	++	-	++	++
15	Manginipudi	65	3	*Spinifex spp* (+)	140	*Prosopis spp* (++) *Palmyra spp* (+)	199	2.4	-	-	+	+	-	++	++
16	Mypadu	>200	2	*I. pes-caprae* (++) *Spinifex spp* (+)	43	*Prosopis spp.*(++) *Palmyra spp* (+)	63	3	-	-	++	++	-	++	++

Offshore characters

Thondi, Adiramapattinam and Manora beaches had a fair diversity and distribution of seagrass species. The seagrass species include *Halophylla ovata, H. beccari, Cymodocea serrulata, C. rotudata, Halodule uninervus, Syringodium sp*. The offshore terrain was generally muddy and shallow.

Faunal indicators

Along the entire 16 beaches surveyed, shore crabs belonging to the family Ocypodidae were most abundant. The common crab species along Tamil Nadu and Andhra Pradesh coast are *Ocypode ceratophthalma, O. cordimana, O. macrocera, O. platytarsis, Scopimera proxima, S. pilula, Uca annulipes, Dotilla myctroides, Macrophthalmus depressus, Metapograpsus thukuar*. Bivalve and gastropod shells are scattered along the beaches, however, they were abundant along Adiramapattinam, Velankanni and Pulicat beaches.

Table 3

S. No	Site	Offshore Characteristics				Faunal indicators	
		Seagrass					
		Species	Avg Dist (m)	Height of the Bank (m)	Corals	Shore Crabs	Shells
1	Thondi	*Cymodacea serrulata*	10	-	-	-	-
2	Adiramapattinam	*Halodule spp.*	120	0.5	-	*Ocypode spp.*(++)	*Murex* spp.(+) Screw shells (+) *Meritrix* spp (+) *Anadora* spp (+) Broken Shells (++)
3	Manora	*Halophylla spp. C. serrulata Halodule spp.*	2364	1	-	-	-
4	Nagapattinam	-	-	-	-	*Ocypode spp.*(++)	Broken shells (++)
5	Tharangambadi	-	-	-	-	*Ocypode spp.*(++)	Broken shells (++)
6	Velankanni	-	-	-	-	*Ocypode spp.*(++)	Screw shells(+) *Murex* spp (+) *Babylona* (+) *Anadora* spp (+)
7	Cuddalore	-	-	-	-	*Ocypode spp.*(++)	Broken shells (++)
8	Marakkanam	-	-	-	-	*Ocypode spp.*(++)	Broken shells (++)
9	Pondy	-	-	-	-	-	-
10	Kovalam	-	-	-	-	*Ocypode spp.*(++)	Broken shells (++)
11	Neelangarai	-	-	-	-	*Ocypode spp.*(++)	Broken shells (++)
12	Marina	-	-	-	-	*Ocypode spp.*(++)	Broken shells (++)
13	Pulicat	-	-	-	-	*Ocypode spp.*(++)	Bivalves (+)
14	Uppada	-	-	-	-	*Ocypode spp.*(++)	Bivalves (+)
15	Manginipudi	-	-	-	-	*Ocypode spp.*(++)	-
16	Mypadu	-	-	-	-	*Ocypode spp.*(++)	-

Conclusions

Sandy beaches are the most widespread of habitats along the coast, and yet little has been done to understand their ecology or goemorphology. Along with sand dunes that often back these beaches, beaches are an important part of coastal ecosystems whose role in supporting diversity has not been adequately highlighted. Constantly subject to erosion and accretion, the effect of tide, storm surges, riverine floods, monsoon and other vagaries of the environment, sandy beaches tend to be highly dynamic systems. The exchange of sand between beaches and dunes serves to sustain both systems. Beaches can thus be very sensitive to onshore and offshore developments that affect these patterns. Sandy beaches can therefore serve as an important indicator of the level of anthropogenic disturbance on a coast.

On the Tamil Nadu and Andhra Pradesh coasts, sandy beaches were relatively wide, but few sites had dunes. Ground vegetation comprised Ipomea pes-caprae and Spinifex, while trees were largely planted species such as coconut and palm. Casuarina, an exotic, is planted extensively along the coast, and has had negative impacts on beaches elsewhere. Invasives such as Prosopis and Casuarina, were also widespread. While fauna were not quantified, Ocypode crabs and bivalve and gastropod shells were found at all sites, with variation in densities. It is possible that species composition and abundance can be used as indicators of ecosystem health. Seagrass were observed offshore at a number of locations. The presence of seagrasses at many such sites has not been comprehensively documented for this coast. There were high densities of boats and nets, foot traffic, lights and waste at almost all sampled sites. Almost all sites were within ~ 100 metres of human habitation.

The sandy beaches of the two states are already heavily impacted, but fortunately they still exist. Beaches have several important ecological and sociological values. For example, they serve as nesting grounds for marine turtles. In India, four species of marine turtles nest and the problems of sandy beaches have become synonymous with threats to these turtle populations. But beaches also offer safe landing sites for fishing boats, and provide space for fishing communities to store their boats and nets. When extensive stretches of the coast are walled for protection against erosion, it becomes difficult for fishermen to land their boats, and the boats and nets have to be kept at considerable distances from their homes.

However, they are clearly subject to a variety of threats. While policies such as the CRZ Notification attempt to protect sandy beaches and dunes, in practice the protection they offer is feeble. Like many other ecosystems, removal of threats often offers the best route to restoration. Most importantly, government and civil society need to recognise the importance of these systems. Dunes may well be able to offer protection against storm surges and tsunamis; in fact dune restoration is being attempted by communities at one site in Tamil Nadu in recognition of their importance.

Sandy beaches can be used for a variety of ecological friendly practices including fisheries, recreation and eco-tourism. It is important to highlight their ecological and economic value and devise policies and management strategies that can utilise the resource and conserve the ecosystem.

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Chapter 3c Measuring the impact of the tsunami on seagrass meadows in the Gulf of Mannar and Palk Bay

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Introduction

The tsunami of 2004 raised concerns of how near-coastal marine ecosystems such as coral reefs and seagrasses had withstood this catastrophic event. The tsunami caused large waves that hit shallow marine areas with high shear forces, potentially resulting in significant damage to benthic habitats (Kumaraguru et al. 2005). Beyond the force of the waves themselves, the turbulent ocean conditions caused by the tsunami waves could have resulted in short- to medium-term changes in sediment conditions. In seagrass ecosystems this could result in burial of entire meadows, or an increase of water turbidity causing major changes to the growth and photosynthetic potential of seagrass species (Cruz-Palacios & Van Tussenbroek 2005; Duarte 2002; Duarte *et al.* 1997). These losses could have serious consequences for the ecological and economic functions that seagrass ecosystems perform: they are efficient ecosystem engineers, are important agents of sediment accretion, contribute significantly to primary productivity in nearshore environments, and are highly diverse ecosystems in their own right (Duarte 2002; Harborne *et al.* 2006; Hemminga & Duarte 2000). Seagrass communities are also vital to the survival of green turtles and the near-extinct dugong and in supporting local fisheries, and the decline of seagrass meadows to a tsunami event could have far reaching implications not just for near-shore ecology but for local livelihoods as well.

Fortuitously, the vast majority of seagrass meadows along the southern Indian waters, are concentrated in the Gulf of Mannar and Palk Bay region and in enclosed bays along the coast (Jagtap 1991; Parthasarathy *et al.* 1991). The seagrass communities found in enclosed bays are dominated by relatively short-lived species with a very high turnover, making them unsuitable candidates to assess long-term impacts of the tsunami. Seagrasses found in these bays and estuaries are therefore not included in this analysis. The Gulf of Mannar and Palk Bay were afforded considerable protection from the tsunami by the landmass of Sri Lanka, and, while regions north and south of the Gulf of Mannar and Palk Bay reported significant losses of life and property as a result of the tsunami, these regions were spared the worst of the impact (See Chapter 1). Visual underwater surveys conducted in the aftermath of the tsunami appeared to confirm the fact that the seagrasses of the Gulf of Mannar and Palk Bay escaped the tsunami with minimum impacts (Kumaraguru *et al.* 2005; Patterson 2005). No significant breakage of seagrass leaves or rhizomes was noted, and no reports of meadow burial were reported from the regions surveyed (Kumaraguru *et al.* 2005; Patterson 2005). These initial studies were rapidly conducted and were, necessarily, not very detailed. Our objective was to determine if these initial results were supported by a more critical survey of the ecosystem.

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Sediment dynamics and seagrass ecosystems

Seagrass meadows are constructed by photosynthetic vascular plants, growing predominantly in sandy sediments. They ability to colonise these shifting sediments is based on their facility for rapid vertical rhizome growth, which protects them from burial in the sand, together with a root system that allows the plant to be firmly anchored in the benthos (Marbà & Duarte 1998). Well established seagrass meadows reach an equilibrium when sediment influx is balanced by vertical rhizome growth (Gacia & Duarte 2001). Sediment dynamics play a crucial role in the growth of seagrass meadows – too much sediment and the rhizomes are buried under sand, too little sediment, and the seagrass risks being uprooted from the meadow (Duarte *et al.* 1997; Gacia *et al.* 2003; Marbà & Duarte 1995; Sheridan 2004). Natural sediment regimes also play an important role by changing water turbidity and consequently regulating the photosynthetic potential of the meadow and can therefore control growth rates, productivity, and the depths to which they can grow (Terrados *et al.* 1998). Seagrass communities are highly vulnerable to disturbances deteriorating the light environment, potentially shifting their metabolism towards heterotrophy (Gacia *et al.* 2005). In highly turbid waters such as the Gulf of Mannar and Palk Bay, seagrasses restrict their growth to a within a few meters below the surface. Apart from natural sediment regimes, any event, natural or anthropogenic, that causes a change in turbidity and sediment regimes, can significantly impact the functioning of the seagrass meadow (Onuf 1994). Under high sediment regimes, seagrass meadows increase the vertical rhizome growth directly driven by the sedimentation. This prevents the burial of the apical stalk, which would otherwise kill the entire plant if buried. At their most dramatic, sedimentation can also lead to complete burial of seagrass meadows (Badalamenti *et al.* 2006; Cruz-Palacios & Van Tussenbroek 2005; Marbà & Duarte 1995). Recovery of meadows from such events is often protracted, and may be very difficult, particularly if the event, along with burying shoots, also resulted in the death of the meadow's seed bank, severely reducing the meadow's ability to restock itself (Campbell & McKenzie 2004; Cruz-Palacios & Van Tussenbroek 2005; Sheridan 2004; Whitfield et al. 2004). Often though, the results of changes to sediment regimes could be much more subtle and difficult to establish with perfunctory surveys.

The vertical growth of rhizomes can be used as a potentially useful indicator of sediment dynamics, and, with reconstructive methods (measuring the plastrocone interval) the age of the shoot may even be useful in tracking past disturbance events (Duarte *et al.* 1994; Gacia et al. 2003; Marbà & Duarte 1998). This method allows us to build up the past history of influences around which an individual shoot was subject to. In the absence of any baseline data on the extent of seagrass meadows, or on natural growth rates, this method is perhaps the best field method available to directly infer the potential impact of the tsunami on these systems.

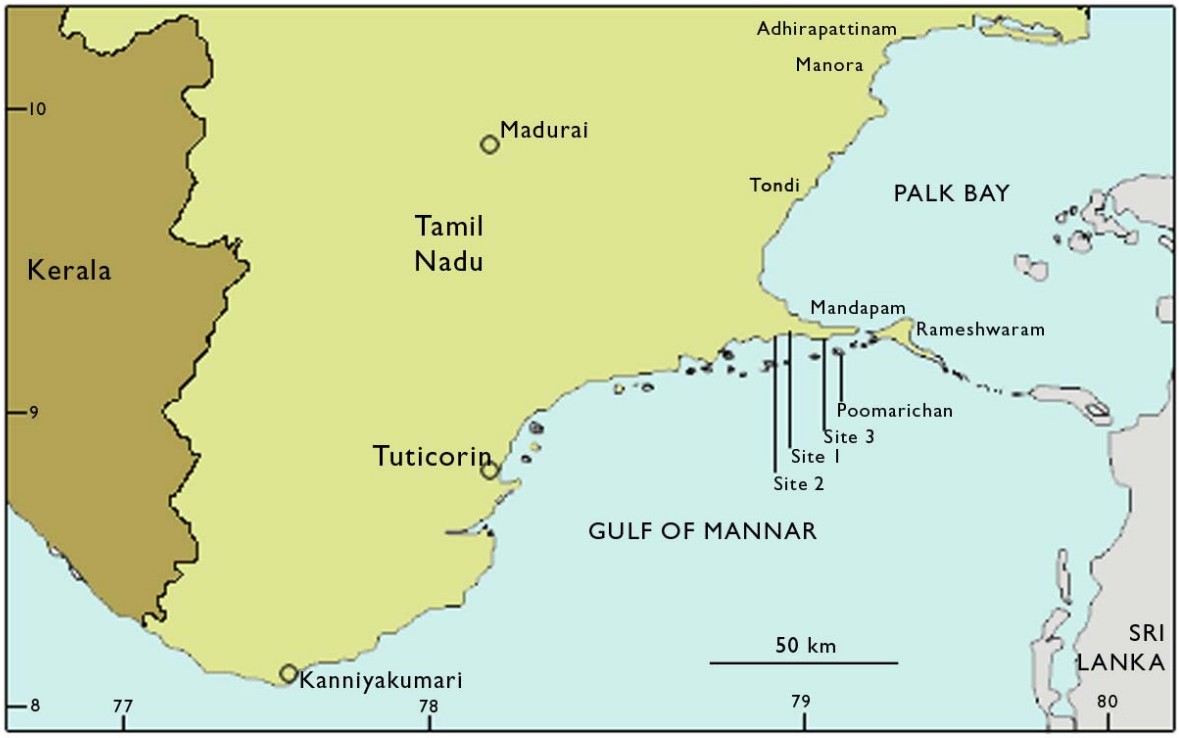
In this study, we attempted to determine if we could detect changes in growth rates in seagrass meadows of the Gulf of Mannar and Palk Bay, which could be directly and clearly attributable to the tsunami. Since more than 18 months had passed since the tsunami itself, we had to use relatively long-lived, widely dispersed species of seagrass as an indicator of tsunami impacts, and we chose *Cymodocea serrulata* for this study. One disadvantage of this method was that it does not allow us to study areas where *C. serrulata* was absent, precluding regions north of the Palk Bay from our analysis. The study also attempted to document the underlying natural variation in sediment regimes in this region, as an underlying trend against which to look for the impact of pulse disturbance events.

Seagrass Meadows of the Gulf of Mannar and Palk Bay

Seagrass species grow at scattered locations all along the south-east coast of India (Jagtap 1991; Parthasarathy *et al.* 1991). While elsewhere along the coast, seagrasses are largely restricted to river mouths and estuaries, fully formed seagrass meadows, dominated by long-lived seagrass species are at their most abundant in the Gulf of Mannar and the Palk Bay. These two areas combined enclose the largest meadow complex off the coast of mainland India. Seagrasses are not a phyletically rich group, with only 54 species worldwide, and, with 14 seagrass species, the Gulf of Mannar and Palk Bay region is among the most diverse regions in the world (Jagtap 2003). These meadows are important grazing areas for green turtles, and are the last remaining habitat of the globally threatened dugong that is virtually extinct in India.

The seagrass meadows of this region are restricted to fairly shallow waters. This is partly due to the shallow bathymetry of the Palk Bay and the Gulf of Mannar. Additionally though, these regions are characterised by high turbidity, potentially contributing to the shallow distribution of seagrasses. There are important differences in monsoonal and hydrographic influences between the Palk Bay and the Gulf of Mannar. The Gulf of Mannar is influenced primarily by the southwest summer monsoon (May to September), while the Palk Bay is influenced by the northeast winter monsoon (November to March). For more details on seagrasses, coral reefs, and mangroves of this region, please see subchapter 3a.

Figure 1 The Gulf of Mannar and Palk Bay with the sampling locations marked along both coasts



For this survey, we sampled a total of eight locations in the Gulf of Mannar and the Palk Bay (Figure 1). In the Gulf of Mannar, we sampled at three locations along the coast, and on one offshore island, Poomarichan. We sampled four locations along the Palk Bay coast, at Mandapam, Adhirapattinam, Manora and Thondi.

Reconstructing the past

Given the absence of any systematic monitoring of seagrasses in the Gulf of Mannar and Palk Bay, it is difficult to directly determine impacts of pulse events like the tsunami. This becomes all the more difficult if the impacts of this event are sublethal, causing subtle changes to demography or function. Our seagrass surveys were conducted 18 months after the tsunami, necessitating a technique that was sensitive to impacts sustained more than a year ago. The analysis of plastochrone intervals in seagrass rhizomes is a reconstructive technique that has been used very effectively in describing growth rates in seagrasses both in temperate and tropical waters (Brouns 1985; Duarte *et al.* 1994; Marbà & Duarte 1998; Patriquin 1973). This method is based on the fact that many long-lived species of seagrass leave behind scars on the vertical shoot as old leaves are shed. The distance between leaf scars (the Plastochrone Interval) is an accurate indirect estimate of time at interannual time scales (Patriquin 1973). There is also usually some seasonal variability in vertical rhizome growth, with alternating periods of increased and depressed growth. Periods of maximum vertical growth are often related to increases in sediment inputs in the meadows, and in tropical locations may often be related to monsoon-associated increases in sedimentation (Gacia *et al*. 2003; Marbà & Duarte 1998). In the absence of growth rate data, it is possible to use this seasonal trend as a first approximation of the number of leaves produced annually.

At all eight locations sampled, we snorkelled extensively in the seagrass meadows to determine the extent of the meadow, its species composition, and the maximum depth to which seagrasses were found in the meadow. *Cymodocea serrulata* was the dominant species in all the meadows we sampled. In each meadow, we collected shoots of *C. serrulata* which were visibly old, with plenty of nodal scars. In some meadows, despite extensive careful searching, it was difficult to find old shoots. Between 15 and 28 shoots were collected in each meadow.

For each shoot, we counted the total number of nodal scars in the vertical rhizome, the number of leaves in each shoot, the length and width of each leaf. The Plastochrone Interval (the distance in millimetres between nodal scars) was measured for each shoot. These measurements were used to track seasonal changes in rhizome growth, and to estimate the number of leaves produced annually. Among the parameters we measured included the maximum and minimum vertical growth in an annual cycle, the number of leaves between maxima, and the total cumulative growth in a given period. These measurements were used to compare seagrass growth between sampling sites, and between the Gulf of Mannar and the Palk Bay.

Comparing the Gulf of Mannar and the Palk Bay

Internode length between the Gulf of Mannar and the Palk Bay were strikingly different; maximum internode length was consistently higher in Palk Bay than sites in the Gulf of Mannar (Figure 2). Vertical rhizome growth in the Palk Bay varied considerably, showing distinct seasonality, while seasonality was not as well pronounced in the Gulf of Mannar (Figure 3).

To estimate the number of leaves produced within a single annual cycle, we averaged the number of leaves produced between successive maxima and minima across all shoots. On average, *C. serrulata* produced approximately a single leaf every month, and on average 12.3 (+/-0.95 SE) leaves per year. Growth rates between the Gulf of Mannar and the Palk Bay were strikingly different. Internode length was consistently higher in Palk Bay than sites in the Gulf of Mannar, as indicated by maximum internode length (Figure 2). Vertical rhizome growth in the Palk Bay varied considerably, showing distinct seasonality, while seasonality was not as well pronounced in the Gulf of Mannar (Figure 3).

Figure 2 Average values of maximum internode length at each sampling location across all shoots. Error bars are standard errors

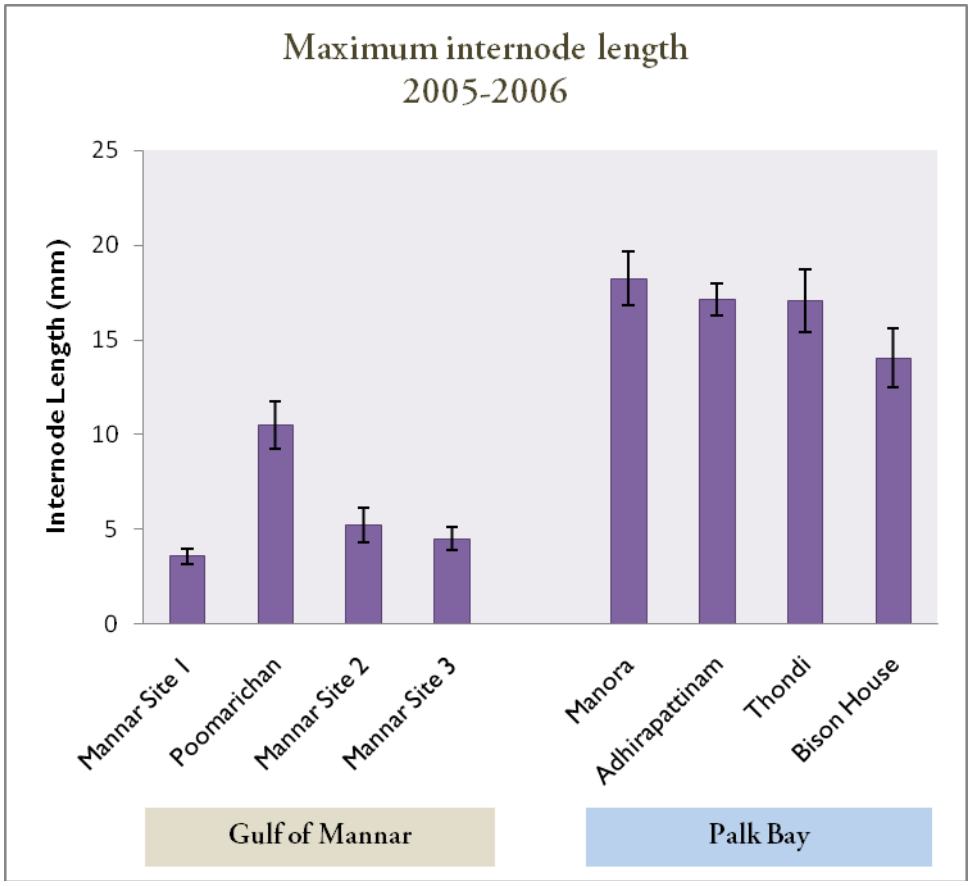
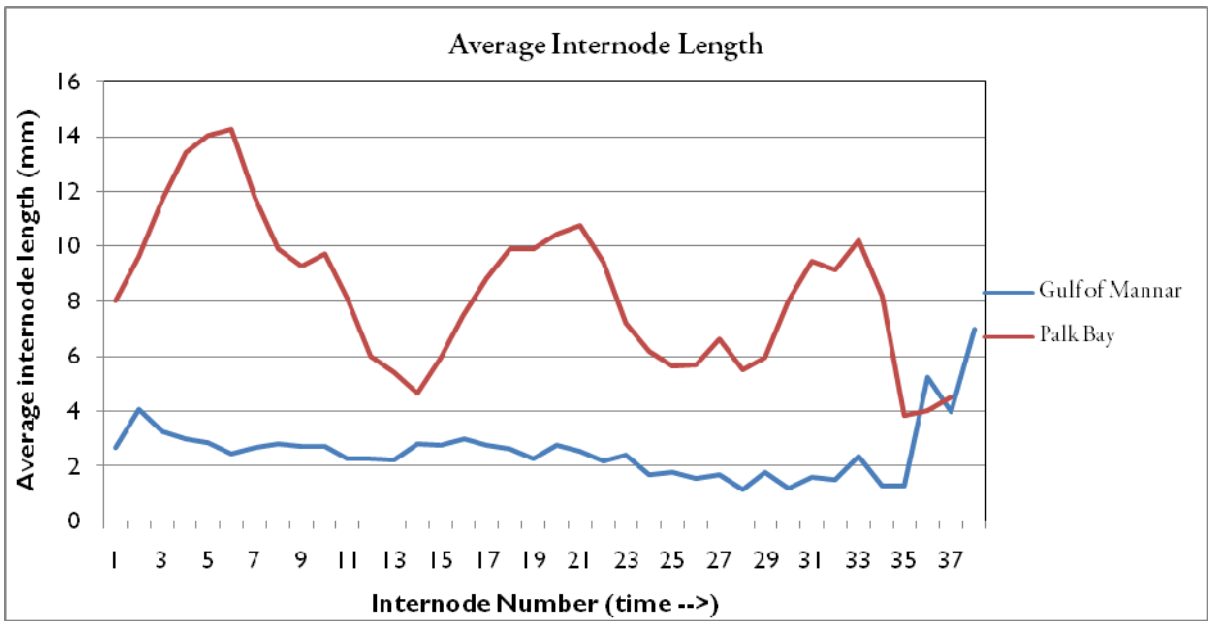


Figure 3 Internode length averaged across all sites in the Gulf of Mannar and Palk Bay through time



These differences between the Gulf of Mannar and the Palk Bay point to very different seasonal environmental conditions between these locations. The consistently higher growth rates in Palk Bay in comparison with the Gulf of Mannar suggest that seagrass meadows in the Palk Bay have to deal with a regime of high sediment flux. There is a strong seasonal element associated with this growth (see Figure 3), suggesting that the sediment conditions associated with the winter monsoons triggers a period of increased growth in Palk Bay seagrass meadows.

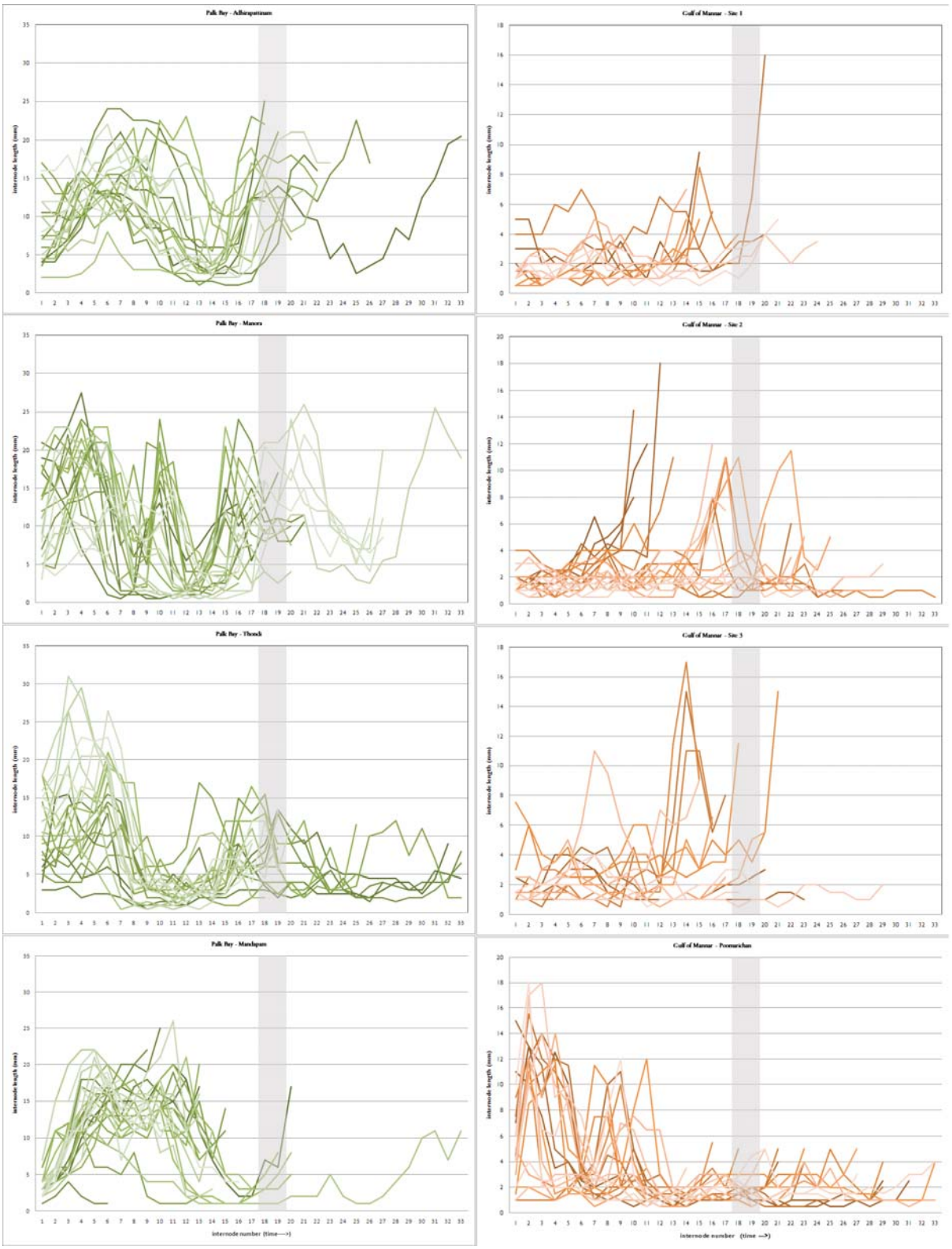
Detecting the impacts of the tsunami

Sudden changes in sediment flux could have important consequences for seagrass meadows. These changes could be triggered by storms and hurricanes, dredging or through sudden shifts in benthic sands as a result of coastal development (Badalamenti *et al.* 2006; Gacia *et al.* 2003; Marbà & Duarte 1995; Sheridan 2004). Traces of these events may be possible to distinguish as sudden changes in the vertical growth of the rhizome, as the plant tries to avoid being buried under sediment. Depending on how the event affected sediment dynamics, changes in growth rate could be almost immediate, or be preceded by a considerable lag.

While the immediate impact of the tsunami on seagrass beds may have been large-scale breakage of shoots, a longer-term sublethal consequence of the event could be a sudden change sediment conditions, not unlike a storm surge. We used the Plastochrone Interval method described above to determine the approximate time the tsunami occurred in relation to leaf growth. From our previous analysis, we determined the average number of leaves produced in a year by *C. serrulata* and used this value to determine the internode number around which the tsunami occurred. By these calculations, the tsunami occurred around internode number 18.47 (17.5 to 19.4 CI at alpha=0.05). We then examined trends in shoot growth at each site to assess if there were detectable deviations from background variability around, or slightly after, the tsunami. For this analysis, we used only a subset of the shoots, omitting any shoot with less than 15 internodes. Shoots with fewer internodes, in all probability, developed after the tsunami occurred, and would therefore not have experienced the event.

Although there was considerable variation in internode length between sites, temporal trends were fairly consistent within sites (Figure 4). The general patterns observed between locations (Figure 3) are visible at the site level a s well. Internode length varied in a much smaller amplitude at sites in the Gulf of Mannar in comparison with the predictable seasonal changes in rhizome growth evident in Palk Bay sites. Importantly though, at all mainland sites in the Gulf of Mannar (Site 1, Site 2 and Site 3), several shoots showed sudden, pulsed changes in vertical rhizome growth, deviating considerably from the background trend. This is clearest at Site 2 and Site 3, where several shoots show marked changes in growth either around the time of the tsunami or a few months after the tsunami event. While this analysis is not sufficient to prove conclusively that these peaks in growth were caused as a result of sediment changes caused by the tsunami, the trends are strongly indicative of pulsed local-level changes in sediment loads. Additionally, it has to be restated, that this technique is only sensitive to sublethal changes to seagrass meadows as a result of the tsunami.

Figure 4 Internode lengths of C. serrulata *showing the approximate time of the tsunami. Right panel: Palk Bay, Left Panel: Gulf of Mannar*



A more complete analysis of the impact of large-scale disturbance events would require a detailed mapping of seagrass meadows, regular monitoring of seagrass growth, and demographic information on meadows surveyed. This information does not exist for seagrass meadows in this region, and is a significant knowledge gap.

At Poomarichan, the only offshore island that was sampled, there is no peak evident around the time of the tsunami. The data suggests that the seagrass of Poomarichan experienced highly fluctuating growth beginning around July 2005, perhaps as a result of recent changes in sedimentation rates. These are unlikely to be the result of delayed tsunami impacts, but point to potentially dramatic changes in local environmental conditions.

In contrast, sites in the Palk Bay do not show any noticeable deviations from the background pattern of rhizome elongation around the time of the tsunami or beyond. If the tsunami had any impact on these meadows, its consequences to rhizome elongation were masked by seasonal changes in growth. Sediment inputs in the Palk Bay increased by several orders of magnitude directly after the tsunami (December 2004) in comparison with 2003 and 2005 (Kumaraguru *et al.* 2005), yet this did not appear to change vertical growth rates in *C. serrulata*. The sediment traps in this study were laid at two sites in Rameswaram and at Mandapam, whereas most of our sampling stations in the bay were further north, which were more protected than these southern sites. Perhaps the most parsimonious explanation for the trends observed in Figure 4 (left panel) is that the tsunami did not significantly affect seagrass meadows along the Palk Bay coastline. The landmass of Sri Lanka served to protect the bay from the full force of the wave. Although the Gulf of Mannar was also similarly protected from the direct force of the tsunami, the wave reflected off the island mass of Sri Lanka and impacted the Gulf of Mannar, the southern districts of Tamil Nadu and the southern districts of Kerala (see Chapter 1).

Seagrass meadows, sedimentation, and the hidden costs of development

Our analysis indicates that the seagrass meadows of the Palk Bay and the Gulf of Mannar survived the tsunami relatively unaffected. However, in the Gulf of Mannar, there appeared to be detectable changes in rhizome elongation either immediately following or within the first three or four months of the December 2004 event suggesting a sudden change in sedimentation inputs in these meadows. These signals portent the potential consequences of increased sedimentation levels in the Gulf of Mannar. Major developmental activities have been proposed and initiated in these waters, and it is important to consider the potential consequences of these activities on the seagrass meadows of this region. While the seagrasses may be able to respond to a single pulse sediment influx with increased growth, whether the meadows will be able to sustain major changes in sediment dynamics is highly questionable. Coastal and marine development often has a profound consequence on erosional and depositional patterns along the coast and can dramatically change sediment dynamics, with deleterious consequences for seagrass meadows (Duarte *et al.* 2004; Gacia & Duarte 2001; Gacia *et al.* 2003). While on the one hand, erosional processes can lead to bank instability in seagrass meadows, on the other, increased sediment deposition can result in burial and death of the seagrass bed (Duarte *et al.* 2004; Marbà & Duarte 1995). In this light, the planned dredging of this region for the construction of the Sethu Samudram Canal is likely to have long-term consequences for the seagrass meadows of the gulf and bay even if seagrass meadows are not directly dredged. The impacts of such dredging activity on meadows have been well documented and have resulted in major changes in the extent, structure and function of seagrass meadows (Duarte 2002; Nienhuis *et al.* 1996; Onuf 1994). Given the importance of these seagrass meadows to India, these consequences need to be more fully

understood so remedial measures can be taken and deleterious impacts can be minimised. It is crucial, above all else, to establish a monitoring programme that is sensitive to disturbances of this nature, and is based on ecological meaningful measures. Also vital, is a detailed mapping of the extent and present condition of seagrass meadows in the Gulf of Mannar and Palk Bay. More basic studies are urgently required to understand seagrass meadow dynamics, growth rates of seagrass species, and their responses to specific disturbance events such as sedimentation, turbidity and land-based pollution. While large scale natural disturbances like storm surges, cyclones and tsunamis will continue to affect seagrass meadows, the eventual decline of seagrass beds in the Gulf of Mannar and Palk Bay will be the result of a more human footprint.

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Chapter 4 An appraisal of Coastal Regulation Law in tsunami-affected mainland India

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Introduction

The Indian coastline is a contested space. Tremendous pressure drives development activities aimed at meeting livelihood requirements of coastal communities and the growth of a developing economy. Coastal and marine ecosystems are the backbone of a fisheries economy that supports livelihoods of millions directly and several more indirectly. The Indian coastline draws an increasing number of tourists both domestic and international driving the augmenting of tourist infrastructure each year. The location of ports and harbours makes the coasts a favoured location for situating industries attracted by transportation facilities. The country's burgeoning populations follow these coastal locations, Mumbai and Chennai having nearly run their course in being able to support more people. With different stakeholders contesting usage rights over the coast, official legislation has been introduced as proof of the State's resolution of the development-conservation stalemate.

The coast is governed by several official legislations that regulate 'development' activities including construction, industrial activity and coastal infrastructure. Some of these legislations have an explicit mandate to protect coastal ecology and available natural resources of the region. Other laws govern the establishment of projects and schemes that use these resources for the growth of the local and national economic growth. One such protective legislation is the CRZ Notification that was promulgated in 1991 using the provisions of the Environment (Protection) Act, 1986 and the Environment (Protection) Rules, 1986. Through such a notification, the coastline of the country was identified as an ecologically sensitive area, where development activities were regulated.

This report has been prepared as part of the Post-Tsunami Environment Initiative[1] (PTEI) to examine the functioning of the Coastal Regulation Zone Notification, 1991, introduced specifically to regulate development activities on the Indian coast. The coastal areas in the tsunami-affected states have been used over several years in a manner that has created lasting and significant impacts on flora, fauna and geomorphologic structures many of which may be irreversible (see Chapter 1). Anthropogenic activities on the coasts have resulted in loss of open beaches, degradation of mangroves and sand dunes, destruction of coral reefs and seagrass beds thus impacting fisheries and other marine life (See Chapter 3c). In addition, the coastline also faces natural phenomena such as cyclones, storm surges and tidal waves, which exacerbate risks to infrastructure and people's lives.

Post-tsunami interest in the CRZ Notification

Although the legislation came into force in 1991, the implementation of the law has suffered tremendously for reasons that this study explores. The problem of poor implementation is acknowledged each time a disaster occurs on the coast (Anon, 2005a). The 2004 Indian Ocean tsunami however, precipitated attention at national and international scales on the subject of implementation. Connections were being made between non-implementation and violations of the CRZ Notification and impacts on

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coastal areas in the face of the disaster.[2] The recently released Comptroller and Auditor General of India report states in paragraph 5.1.1, 'The Ministry of Environment and Forests did not enforce the Coastal Regulation Zone Notification effectively resulting in extensive destruction in coastal areas due to industrial expansion' (Comptroller Auditor General of India, 2006).

In Kerala, the tsunami impacted the districts of Ernakulam, Alapuzha and Kollam the most. For some years now, the Kerala state government is alleged to have vacillated on the CRZ Notification even claiming that it was not 'practical' for the state, in light of the high population density on its coasts. The government is known to have sought the dilution of the regulatory clauses as well as reduction in setbacks.[3] However, post-tsunami, there has been a re-think on this and an all-party meeting in January 2005 decided that rehabilitation would not be undertaken between the sea and coastal roads. In the post-tsunami context, the need for better implementation of the CRZ appears to have found agreement among the bureaucrats of the state as well as non-governmental organisations and trade unions.[4]

In Tamil Nadu, the tsunami ravaged extensive areas in 13 coastal districts with Nagapattinam, Cuddalore and Kanyakumari being the worst hit. It has been established that the impact of the tsunami was maximum in areas that are low and flat and devoid of any vegetation (Anon. 2006a). Low-lying areas such as Nagapattinam are prone to inundation by the sea. The Government of Tamil Nadu has set itself the task of enhancing protection to the coast and the coastal people through a series of measures including the erection of sea walls, 'bioshields', preparing coastal vulnerability maps, water quality monitoring, bio-remediation of coastal water bodies and capacity building for coastal management, and to implement the provisions of the CRZ Notification. The Tamil Nadu Government has begun the execution of some of these projects through the World Bank funded Emergency Tsunami Reconstruction Project (Anon, ibid).

While coastal areas in Andhra Pradesh did not experience the devastating impacts of the tsunami that Tamil Nadu did, it certainly sparked concerns about the implementation of the coastal law in this state. There were demands from sections of fisherfolk for pucca houses to be provided on the seashore for fishing communities and that larger violations of the CRZ should be tackled first instead of harassing fishing groups (Anon. 2005b). While fisher groups from other parts of the coast have echoed this sentiment as well, after the tsunami, civil society groups in Andhra Pradesh have continued to send petitions demanding the implementation of the law and opposing moves to dilute it (Anon. 2005c; Anon. 2005d). This analysis of the law tries to piece together the manner in which the CRZ Notification played a role in coastal protection in these states and the various reasons for this.

The Government of India embarked on making changes to the CRZ Notification even prior to the 2004 tsunami. However the content and direction of any legislative change mandates a thorough analysis of problems with the existing legal framework. This analysis provided here is a beginning in this direction.

Analytical framework and methodological notes

Several approaches are available to examine the functioning of laws and these vary with the theme under study. Within the nine-month project period, two simple aims were identified for the policy studies. The CRZ Notification was selected for a policy framework analysis in the affected states in the first phase of the PTEI. The first aim was to construct a scenario on the performance of the CRZ Notification in the tsunami-affected states of the Indian mainland, using available literature and through a round of interviews and discussions with key informants. The second endeavour was to make public, the available

information collected from dispersed sources, on the experience of CRZ implementation in the affected states, via the PTEI website (www.ptei-india-org).

The CRZ Notification can be regarded as an official 'conservation' law primarily since it is derived from the Environment (Protection) Act, 1986 whereby it regulates activities and use of coastal spaces, through a system of regulation, employing a specific approach of governance. In order to assess how the law performed as a conservation law, it was necessary to examine specific parameters related to environment protection / conservation, the overall governance design that it would employ and finally a closer examination of telling signs of its efficiency.

The questions of the study were related to the performance of the CRZ Notification, through the indices of **1) Environment Protection, 2) Governance and 3) Efficiency.** These questions directed the research effort and were guided by certain parameters that defined each of indices.

QI. How did the CRZ Notification in the affected-states function as an environment protection/ conservation law since its promulgation? The parameters examined were:

1. Genesis of the law:
    - Arguments, demands & public discussions from civil society, political representatives & people's groups.
    - Discussions in parliament and submissions to parliament.
    - Response from political leaders, correspondence between the central and state governments and civil society.
    - Discussions on draft legislations if any.
2. Stated objectives / disposition of the law:
    - What is the law's stated objective and purpose as identified from its clauses?
    - Problems or threats identified in the legal text, means to address these, clauses that promote or strengthen environmentally positive development / use practices on the coast?
3. Consistency and clarity of objective (as stated in specific legal clauses/ measures)
4. Flexibility and adaptability:
    - To address changing development needs on the coast
    - Growing scientific information on the coast
5. Scientific basis (socio-economic and ecological)
    - Extent to which information from social science informs decisions of implementing agencies, government committees and legislation review committees
    - Composition of committee members working on legal implementation
6. Approach and design for protection
    - What role does the committee envisage for various stakeholders in implementation, specifically for state agencies and for local communities?

QII. How was the implementation of the CRZ Notification conducted with respect to specific governance related parameters, namely, a) transparency, b) accountability, c) participation and d) capacity? The parameters examined were:

1. Transparency:
    - Policy drafts placed in the public domain
    - Access to relevant data, documents, and analysis on which draft policies are based

- Evidence of comments solicited from civil society
- Efforts made to incorporate views from vulnerable / disadvantaged communities
- Transparency in decision-making processes

2. Accountability
   - Provisions within the law to prevent conflict of interest
   - Existence of appellate redressal agencies in the implementation framework
   - Access to redressal agencies
3. Participation
   - Existing avenues and procedures therein for public participation
   - Degree of public involvement in decision-making, opportunities for hearings, feedback on results
   - Presence of non-official members in policy-making bodies
4. Capacity
   - Capacity within states to ensure the implementation of laws
   - Capacities with civil society groups to effectively participate in law-making
   - Assessments of skills and expertise among policy makers and implementers
   - Extent of information with and awareness of stakeholders regarding the law
   - Level of participation of stakeholders in policy implementation

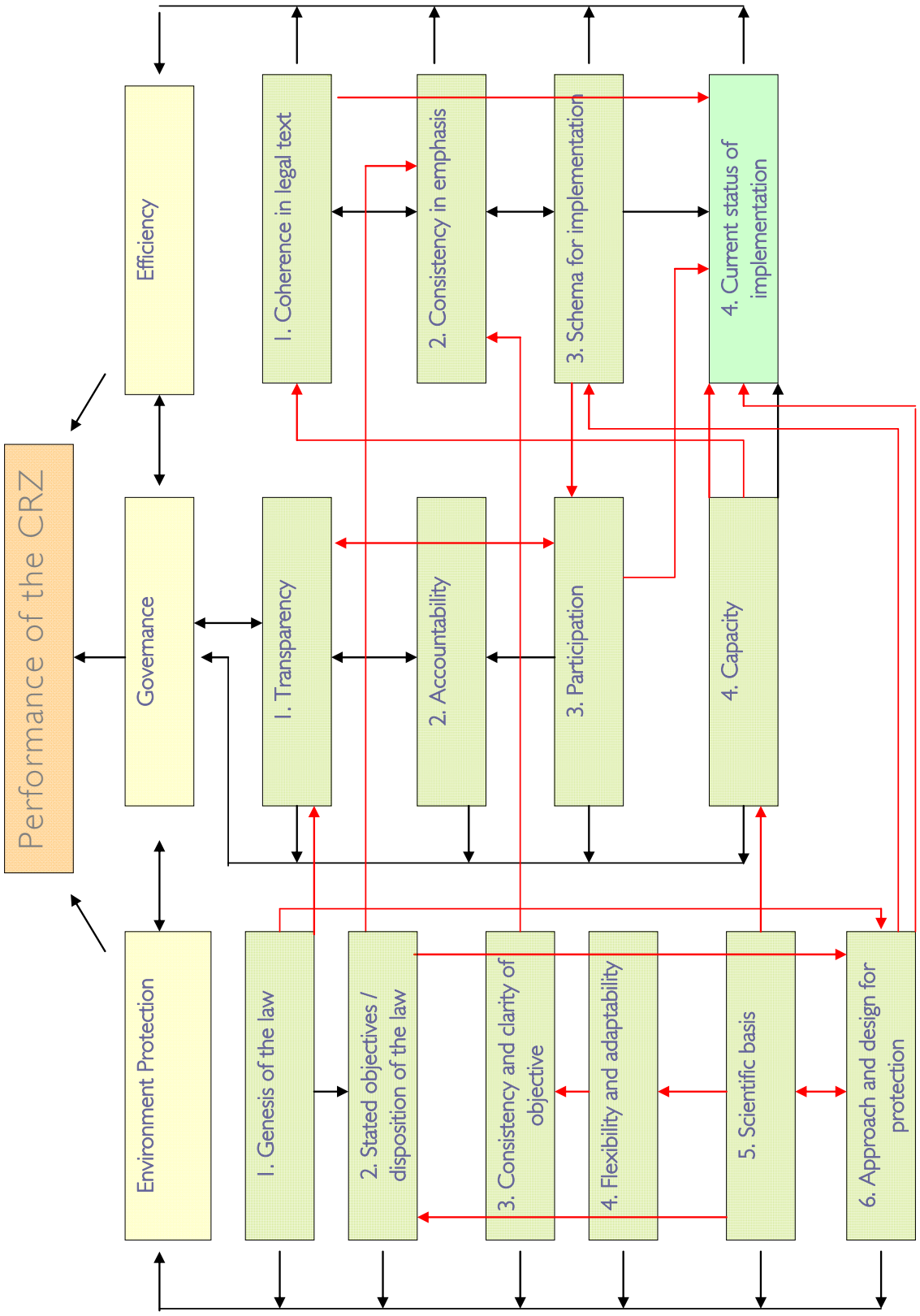
QIII. What were the provisions of the law and experiences in implementation that inhibited or contributed to its overall efficiency as a conservation law? The parameters examined were:

1. Coherence in legal text
2. Consistency in emphasis
3. Schema for implementation (including planned and actual implementation)
   - Financial allocations
   - Institutional arrangements
   - Monitoring and compliance
4. Current status of implementation

Diagrammatic representation

Figure 1 presents the analytical framework through a diagrammatic representation. The study design presumes that information on the parameters under the three indices of environment protection, governance and efficiency, would eventually illustrate the law's performance as a conservation law. These parameters also influence each other in certain straightforward ways, which were anticipated at the beginning of the study. For example, it was anticipated that the genesis of the law would determine its stated objectives. Similarly, greater transparency would signify greater accountability and vice versa. The black arrows in Figure 1 indicate the interplay of the parameters and indices, which the study anticipated and which are explicated in the analysis. Besides these linkages, the study itself brought to light certain other interactions between these parameters, which are indicated by the red arrows. The details of these interactions are explained in the different analytical sections of this document. The study was able to provide information on each of these factors, some in greater degree than others.

Figure 1: Diagrammatic Representation



Methods

Field trips were conducted only in the states of Tamil Nadu and Kerala for this study. Secondary data was gathered from the MoEF website, government departments, NGOs and individuals and from personal collections of the researchers. The data thus compiled included the primary notification and the amendments made to it from 1991 to 2005, committee reports on review of the CRZ Notification and recommendations made thereto, communication by NGOs to committees, ministries and government agencies regarding CRZ related issues, petitions filed by public interest groups and court orders and judicial documents. Recent media reports mostly dating from 2005 from internet sources were compiled and examined for the purpose of this report.

In addition to secondary information, primary data was obtained from key informants, comprising a selection of environmental NGO representatives, environment lawyers, and experts in the social and natural sciences. Discussions were also held with members of State Coastal Zone Management Authorities - the institutions set up to oversee the implementation of CRZ at the state level. Semi-structured interviews were conducted, and the data therein was matched with each of the parameters associated with the indices of environment protection, governance and efficiency.

Limitations

The study provides only a broad overview of how the CRZ Notification performed as a conservation law. However, in order to satisfactorily answer some of the questions outlined above, a more detailed and rigorous research design would be required, encompassing both qualitative and quantitative methods and would need to construct a detailed analysis of secondary and primary data on each of the parameters. The timeframe and resources available at the disposal of the researchers was not adequate to conduct a study of this scale. Nevertheless, this study makes a beginning for more detailed research and provides a useful framework to embark on.

Researching controversial subjects comes with problems that become inherent to it. The topics being discussed are not apolitical and have generated a fair amount of controversy, even prior to the tsunami. This directly limits the amount of information researchers are given access to, either in interviews or even by means of documents and records. The study therefore could not apply in its analysis the vast amounts of data contained in inaccessible government files, minutes of meetings of CRZ implementing agencies and importantly, the rich information revealed in interviews that were strictly off the record. The researchers have utilised information obtained by environmental groups in the country using the Right to Information Act, which has been valuable.

1. Environment protection by the CRZ

The crux of the Environment (Protection) Act, 1986 and its Rules from which the CRZ Notification is derived is that it substantially empowers the Centre [the concerned ministry being the Ministry of Environment and Forests (MoEF)] to take actions 'for the purpose of protecting and improving the quality of the environment and preventing, controlling and abating environmental pollution'. This includes the promulgation of specified notifications for this purpose. The CRZ Notification was issued under Section 3(1) and Section 3(2)(v) of the Environment (Protection) Act, 1986. These clauses outline the powers of the Central Government to protect and improve the quality of the environment and take preventive measures to control and abate environmental pollution. This includes the power to delineate areas where anthropogenic activities can be regulated and restricted (Sridhar, 2005). A copy of the notification compiling amendments until 24th July 2003 is available at www.ptei-india.org.

1.1 Genesis and initial objectives

Fishing communities and the CRZ

There is very little documentation on the genesis of the CRZ Notification and the roles played by fisher community leaders, NGOs, environmentalists, government agencies and politicians in this process. The information detailed below on the role of fisher groups in the drafting of this law is pieced together from discussions and interviews with fisherfolk representatives and from available secondary data.

There are no detailed studies that explain the relations between fisher communities and coastal lands that we could base further discussions or analysis on. Most studies on fisher communities only mention the absence of any official legal ownership rights for fishers over coastal lands (Kurien & Paul, 2001; Bavinck, 2001; Southwold-Llewellyn, 2006). Kurien and Paul, in their studies on social security of fisher communities in Kerala state, *'One of the paramount reasons for the poor quality of life and the sub-standard conditions of habitat of the marine fishing communities in Kerala State is the crowding of the whole community on a narrow strip of land along the length of Kerala's coastline. This is a result of the highly dispersed nature of the fishery resource and the consequent decentralised nature of fishing operations using beach landing crafts. Every fisherman prefers to live on the seafront near the point where he lands his craft and from where he can observe the sea. As a result the population density in marine fishing villages was around 2652 persons per square kilometre. This is in comparison to the state figure of 742 per square kilometre, which is already one of the highest in the country.'* (Kurien & Paul, 2000; Kurien & Paul, 2001: 12). They report that in the early 1980s, a large section of fisher households built thatched huts on land even beyond the cadastral survey. This would later have implications on whether their lands were considered 'authorised constructions' under the CRZ Notification or not. Kurien's brief comparison between the habitats of fishing communities and that of the rest of Kerala, is one of the few references in literature on the nature of fisher settlements (Kurien, 1995).

In general, the traditional occupation of fishing seems to demand a closer association with the sea than with the land. This general view was endorsed by T.S.S. Mani an activist representing the interests of fishing communities in Tamil Nadu and an advocate of several fisherfolk causes. He states:

> *The fisher people have been the traditional inhabitants of the coast. Their occupation of the land adjoining the sea was entrenched in their association with the sea. They never felt it necessary to prove their occupation of coastal lands through land pattas. In many areas they did not feel the need for this also because all their shore areas were in the trusteeship of temples or community institutions.*5

The insignificance that fishers accorded to land-based regulations began to affect them as coastal lands began to be taken over for development projects. Large commercial ports, harbours and industries were the first to be located on coastal lands in all the states. In 1968, the Slum Clearance Board was handed over the land belonging to Nochikuppam in Chennai. The slums were moved and small apartments were constructed for fisher families. It was at this time that the significance of having recorded rights began to be appreciated by the fisher leaders of this region. In subsequent years, other fishing hamlets further south of Chennai saw the establishment of the VGP and MGM beach resorts and entertainment complexes on community lands belonging to the fisherfolk. T.S.S Mani states that the hamlet panchayats in these regions were instrumental in facilitating the handover of these lands by the community.

There were several threats to the coastal lands around the time when the CRZ Notification came into force such as artificial shrimp farms, chemical plants, commercial harbours, power projects and the nuclear reactor at Kalpakkam. The people in this region and many other areas did raise concerns about

displacement and environmental impacts although they did not initially pose strident resistance or opposition against development projects per se.[6] These experiences made it evident to policy makers and other civil society groups that development projects had lasting impacts on both the coastal environment and traditional rights of the fisher people and therefore needed regulation.

While fisher peoples' organisations such as the National Fishworkers' Forum (NFF) have campaigned on various coastal environmental issues, details on their involvement in the demand for this coastal law or on the initial lobbying efforts could not be gathered from this study's interviews or in available literature.

Environmental activism and the CRZ

Since the early 1980s environmental lobbies in the country (distinct from the mass-based fisher organisations) have been strident in articulating the need to protect the coast and petitioned the Late Prime Minister of India, Mrs. Indira Gandhi who was well known for extending her sympathies on green matters.[7] This initiated the legislating process for coastal protection.

The concept of coastal zone management through the regulation of development activities was thus introduced in the country in 1981, when Mrs. Indira Gandhi, wrote to the Chief Ministers of all the coastal states to keep the beaches clear of all activities within 500m of the High Tide Line.[8] The intention was to prevent all kinds of unregulated development in the coastal areas. She was sensitive to concerns in industrial coastal cities and explicitly stated the need for a total prohibition on dumping of industrial waste in this environmentally sensitive area. That problems of coastal pollution from dumping continued long after Mrs. Gandhi's directive and even after the CRZ Notification was introduced[9] is telling of the chasm between legislating and implementing. However, many state that during Mrs. Gandhi's time, the directive was taken seriously and better respected, than the present CRZ Notification that followed it.[10]

Though the Prime Minister's directive had questionable legal backing, it still had considerable impact. Firstly, the *Environmental Guidelines for Siting of Industry* brought forth by the Ministry of Environment and Forests in 1985 stipulated that a distance of "at least ½ km from high tide line" be avoided for the location of industry. The *Environmental Guidelines for Thermal Power Plants (TPS)* brought forth in 1987 went much further. It stated, "*In order to protect coastal areas above 500 m. of the HTL, a buffer zone of 5 km should be kept free of any TPS".*

Subsequent to her letter, which was considered to be more in the nature of a directive, a seven member Working Group (later expanded to nine members) under the chairmanship of Dr. Nilay Choudhuri, Chairman, Central Board for the Prevention and Control of Water Pollution was appointed. The brief of the Working Group was to prepare appropriate guidelines for environmental management of beaches and development on or near beaches (Chainani, *unpublished*).

This Working Group noted that *"the Department of Environment has been advising the concerned States to prepare a status report in respect of 500 metres area (sic) and then follow it up with a master plan for development and control, along with a compatible development beyond the limits in the hinterland areas."* Regarding the direct impact of developmental activities on the land-sea interface they stated, *"adverse direct impact is possible within 500 metres from the high water mark or beyond two kilometres from it"* (Chainani, ibid).

Based on the findings of the Working Group, in 1983, the Central Government circulated *Environmental Guidelines for the Development of Beaches* to all coastal states and Union Territories

(Thomas, 2006). By the definition in the guidelines, beaches were inclusive of all coastal areas of the country. The Department of Environment also asked State Governments to get Coastal Zone Management Plans (CZMPs) prepared for their respective coastal stretches. The state governments did not respond; except for very few coastal stretches, no CZMPs were prepared[11] and it is speculated that this is possibly due to the absence of a statutory basis at that time (Chainani, ibid).

The period of the 1980s saw a lot of development planning for the Extended Bombay Metropolitan Region. Coastal protection efforts during this time, armed with Mrs. Gandhi's directive, was part of the planning agenda owing to the fastidious efforts of the activists from the Bombay Environment Action Group and responsiveness of several bureaucrats to these concerns. The experience gained by BEAG in this process was to set the tone for their active role in the promulgation of the notification.

When Rajiv Gandhi became Prime Minister, pressure mounted to relax Mrs. Gandhi's directive. Relaxations were especially requested for tourism facilities in areas such as Goa, Puri-Konark, Madras-Mahabulipuram and Trivandrum. In June 1986, the government set up an inter-ministerial committee to consider proposals for tourism projects within the 500 metres limit at the above locations. The Committee evolved certain guidelines of which the most important was that no construction would be permitted on the sandy stretches or within 200 metres of the high tide line (Chainani, ibid). Other safeguards were also recommended and these were to be factored into the CRZ Notification, which took shape in subsequent years. In this manner, various coastal issues came to enter the consciousness of law-makers and those lobbying for these legal protection measures.

There were repeated requests from states to relax the guidelines mainly for unhindered tourism development. Simultaneously, efforts were stepped up by environmentalists to legalise Mrs. Gandhi's directive by declaring areas upto 500 m from the HTL as a 'restricted area' under section 3(2)(v) of the Environment (Protection) Act, 1986. A draft notification was gazetted for the first time and opened for public comment on 27th July 1990, and instead of the usual 60 days prescribed by the Act, comments were solicited up till November 1st 1990. A public hearing was held on Nov 14th 1990 (Chainani, ibid). However, it is not known if detailed discussions were held with all state governments.[12] The notification was re-gazetted after being altered on 15th December 1990. More than 500 objections were received during the twin rounds of gazetting (Chainani, ibid). Ironically, this practice of inviting public comment on the notification was dropped in subsequent amendments of this law.

It was in 1991, between changes in the political parties in power at the centre, and bureaucratic reshuffling that the Ministry of Environment and Forests finally gazetted the Coastal Regulation Zone Notification.[13] The notification was designed to provide graded protection to regions based on zonation and the degree to which they were already developed. Areas which are categorised as CRZ I have the highest degree of protection, followed by CRZ III which are underdeveloped areas (both rural and urban spaces). CRZ II comprises all 'developed areas'[14] and requires a lesser degree of protection.

The period of the 1980's was also a time when the NFF and other fisher unions were slowly beginning to get organised. Chainani's detailed piecing together of the genesis of the CRZ notification does not make any indication of the participation of this constituency that was growing in strength, in the drafting process of this law. In fact there were other fisher groups who did not share the view that the CRZ was going to be a beneficial law for fishers. In Kerala, the National Fishworkers' Forum and the Kerala Swatantra Matsya Tozhilali Federation (Kerala Independent Fishworkers' Federation) strongly supported the CRZ. Their leaders state that at that time, all the other trade unions representing fisher

issues in Kerala, opposed it stating that the notification prevented fishers from building their residences on the coast. These other unions appear to have either not understood the provisions of the law or had adopted only a politically motivated position.[15] It was through awareness programmes and training sessions by groups such as EQUATIONS, Bangalore and the Coastal Action Network in Tamil Nadu in the early 90s that NGOs and community groups working on coastal issues understood the importance of the CRZ.

The CRZ Notification was a shot in the arm to civil society groups in Tamil Nadu, which were struggling against the impacts of development activities especially the shrimp industry. The resistance against the shrimp industry at the national level in India began in 1992 and gained momentum between 1993-94. Community groups came together under the banner of People's Alliance Against Shrimp Industries (PASI).[16] As a result of the growing movement against this industry, the High Court of Tamil Nadu issued a ban on all the shrimp farms violating the Coastal Regulation Zone (CRZ) Notification, which was later upheld by the Supreme Court of India in 1996 (also known as the 'Jaganath case').[17] In effect, all shrimp farm activities within 500m of high tide level (except those defined as traditional and improved traditional type) in the country were declared illegal.[18]

1.2 Subsequent changes in objective

The CRZ Notification specifically aimed at protecting coastal habitats through clauses that regulate or prohibit the use of these areas or resources in ways that could cause harm or destroy these habitats. Over time, changes through amendments and divergence in interpretation of these clauses diluted this original objective. The provisions of the notification for the protection of certain ecosystem components is detailed below:

Mangroves – The CRZ Notification does include mangroves in CRZ-I, and all states are required to demarcate these areas in their CZMPs. The MoEF in its conditional approval letter dated 27th September 1996, stated as one of its conditions that all mangroves having an area over 1000 sq.km should be considered as CRZ –I areas with a buffer area of at least 50 metres. Many State Governments interpret this as excluding all mangroves having an area less than 1000sq m from CRZ -I. Therefore many fringing mangrove areas find themselves excluded from the CRZ –I category.

Sand Dunes and Open Beaches - dressing or altering of sand dunes, natural features including landscape changes for beautification, recreational and other such purposes are prohibited by the notification. Extraction of sand, levelling or digging of sandy stretches except for the structural foundation of buildings is prohibited. Swimming pools are also not permitted for hotels, resorts within 500 metres of the High Tide Line in CRZ III areas. Mining of sands, rocks and other substrata materials except those rare minerals not available outside the CRZ areas and exploration and extraction of Oil and Natural Gas are not permitted (except in the Andaman & Nicobar Islands). The mining of rare minerals not found elsewhere is permitted. The upper time limit for the use of sand from the beaches for construction purposes has been repeatedly extended until 2003 in the Andaman & Nicobar Islands (ANI). This is otherwise a prohibited activity under CRZ.

Coral Reefs - The use of corals from the beaches and coastal waters for construction and other purposes is illegal in the CRZ. Dredging and underwater blasting in and around coral formations is not to be permitted in CRZ IV.

Coastal Forests – These are not mentioned specifically in the notification. However, if coastal forests were Reserved Forests located within the CRZ then they would be protected by the notification. Therefore the CRZ does not include forests on private lands or under other classifications.

Ground Water – Drawing ground water is completely prohibited within 200m of the CRZ. Within 200-500m manual drawing of ground water is permitted (exception for the ANI region).

One of the functions of the CZMAs is to identify areas, which are ecologically sensitive so that these can be demarcated in the CZMP and provided adequate protection under the CRZ Notification. However, interviews did not reveal whether the CZMA was at all involved in either identifying such areas to be included in the CZMPs or whether they undertook any other similar initiatives.

The disposition of the law was originally to protect the environment. The text of the law and the legal clauses from where it derives its powers make this explicit. In addition, this interpretation is also available in the 1996 judgement of the Supreme Court,[19] which explains the objective of the CRZ Notification clearly. It is meant to control ecological damage to coastal areas through pollution, maintain coastal livelihood security, uphold the traditional rights of fishermen and maintain the aesthetic value of the coast.[20] The literature analysing the CRZ legislation also ascribes similar objectives to the law. With subsequent amendments, the objective is no longer recognisable in the text of the law and the original purpose appears to be disposed off by these dilutions (See section 1.3 on Flexibility and adaptability of the law). The most striking change is that the original law envisioned permitting only activities requiring the waterfront or foreshore in the CRZ area, but each dilution permitted new industries (not necessarily 'coastal' in nature) into this sensitive zone (Goenka, 2000;[21] Divan and Rosencranz, 2001; Upadhyay and Upadhyay, 2002; Sridhar, 2005). Annexure 1 indicates the activities that can be allowed within the CRZ by obtaining permissions from specified agencies.

The earlier section on the objectives of the CRZ Notification alludes to the role the law played in effecting environment protection on the coast. However, it appears that the very spirit of the notification underwent significant transformation, and in its present form is unidentifiable from its text.

1.3 Flexibility and adaptability of the law

The CRZ Notification is a highly flexible legislation given the manner in which it is worded, and the fact that as a notification the MoEF can amend it. However, this flexibility has not at all been beneficial to meet environmental challenges and has seldom been used to respond to the need for changing protection and regulation needs. On the contrary, the notification's flexibility has been used significantly to allow for increasing developmental activity on the coastal stretch without any studies on carrying capacity or environmental damage on which to base these decisions.

There have been 19 amendments to the notification since 1991 and these have mainly been in the following areas.

- The clause stating that creeks and river bodies need to be at least 100 m was changed by the August 1994 amendment, which reduced it to 50m. This was later reverted to 100m by order of the Supreme Court dated April 1996.
- The NDZ was reduced in the Andaman and Nicobar Islands (ANI) and the Lakshadweep Islands for tourism. Building relaxations were also introduced with this amendment in July 2003.
- The demolition or reconstruction of buildings of archaeological/historical importance /public use was made permissible with MoEF clearance since the April 2003 amendment.
- Repeated extensions for sand mining in the ANI have been granted by the MoEF through amendments in January 1997, April 1998, September 1998, September 2000, October 2001 and January 2003. In the original notification, sand mining was to be phased out on a permanent basis making it a prohibited activity after a first deadline of 3st March 1998.

- Projects for power generation from non-conventional energy sources, desalination plants, airstrips, storage of non-hazardous cargo all became permissible with the amendment in October 2002.
- Non-polluting units such as Information Technology and other service sector units have been allowed in the CRZ of SEZs since May 2002.
- Department of Atomic Energy projects, pipelines and related constructions have been permitted; provisional permissions have been given to projects for the receipt and storage of petroleum products, LNG and facilities for regasification through the April 2001 amendment.
- Land reclamation in certain cases has been allowed since April 2001. The original clause allowed this only for anti-erosion measures/maintenance of waterways etc.
- Mining was allowed as part of Oil and Natural Gas exploration/extraction by the April 2001 amendment.
- Operational constructions for ports and harbours and light houses and constructions for activities such as jetties, wharves, quays and slipways, pipelines, conveying systems, transmission lines were added to the list of permissible activities that need MoEF clearance through the April 2001 amendment.

It should be emphasised that enhanced monitoring or impact assessments accompanied none of these relaxations. Nor did any of these amendments contribute to greater procedural clarity.

The only amendments that have been made to clarify issues that were ambiguous in the notification are the following:

- The December 1998 amendment made some effort at standardising the method for HTL demarcation and also provided a definition of the HTL. The May 2002 notification stated that the CRZ for rivers and creeks was to include areas up to the point in the river where salinity was 5ppt and above.
- The Central Government's rationale for introducing the 22nd April 2003 amendment was that large sized projects were being implemented without clearance from the MoEF and that this resulted in the destruction of mangroves, depletion of ground water and certain other activities involving ecological damage. However, there were other motivations for this amendment than what was stated. The amendment actually does little to stem the ecological destruction alluded to in its rationale. What this amendment merely did was include one more item on its list of activities requiring permission from the Centre. The amendment stated, that the demolition or reconstruction of buildings of archaeological or historical importance, heritage buildings and buildings under public use (defined in the amendment as including 'use for purposes of worship, education, medical care and cultural activities). This came at a time when the then Chief Minister Dr. J.Jayalalitha of the ruling All India Anna Dravida Munetra Kazhagam (AIADMK) party planned on demolishing the Queen Mary's College on the Chennai coast for the construction of a new government secretariat. The opposition party Dravida Munetra Kazhagam (DMK) is alleged to have orchestrated the introduction of this new amendment through the then Minister of Environment and Forests, T. R. Baalu who belonged to the DMK as well.22

1.4 Scientific basis (social and ecological)

Environmental and ecological basis

Various constituencies have questioned the scientific validity of the CRZ Notification at various times. The question of its scientific validity has been prompted by different motivations with environmentalists, industry even the Ministry of Environment and Forests raising this issue. In fact the constitution of the Swaminathan Committee to review the CRZ Notification was a barefaced admission by the MoEF that its

own notification could not stand the scrutiny of science. But the criticism of the law on these grounds is not fair without stating that the CRZ Notification was not designed to be a law grounded in the natural sciences. The section of the CRZ genesis earlier indicates that in its initial evolution, it was planned along the lines of zoning law with the idea of regulating known development threats (such as industry or tourism) here. The design of the law itself was perhaps guided by those who placed greater emphasis on firstly finding acceptance for the notification with the Ministry of Environment and Forests and using the political climate to apply this on the coastal states. Some analysts of the law opine that perhaps the current climate of coalition politics and development pressure would pose greater challenge for the acceptance of such a law by the states.[23]

The 500m distance from the HTL, which defines the CRZ area was arrived at arbitrarily. However, the zonation of areas into CRZ categories is left to the CZMP process. This process had it been undertaken in a well planned and participatory manner, could have produced a robust scientific document to guide development along the coast. The planning process could be supported by a series of assessments on the environmental sensitivity of specific areas, the carrying capacities for polluting activities, areas that are vulnerable to natural disasters due to their environmental (both natural and human made) characteristics. But this was not the case, and owes more to the factor of political will just drafting oversight.

There were seven committees set up by the MoEF to look at the CRZ Notification and suggest changes to it. Based on their recommendations, the notification went through a series of amendments. While the rationale for most of them can only be inferred from the content of the amendment, the few amendments for which a rational has been stated do not indicate any scientific environmental research guiding these changes. Although the ostensible reason for setting up the Swaminathan committee was to recommend changes to the regulation along scientific lines, reviews of this Committee report reveal that its recommendations also lack scientific rigour (Sridhar *et al.,* 2006). Notwithstanding the growing concern with the Swaminathan Report, it continues to drive legislative change and is telling of the MoEF's seriousness about science-driven management.

It is not clear whether projects located within the CRZ are themselves being undertaken following an adequate scientific understanding of impacts. The environment clearance process under the CRZ Notification, at the level of the MoEF, does not require that the impact assessment studies be made public. At the level of the SCZMAs, detailed environment impact assessments are not even expected. Therefore projects are cleared without a full understanding of their potential implications. If the experience with CRZ implementation were an indicator of the role of science in environmental decision-making, it would be assigned a marginal, and likely token, role.

Social science basis

The CRZ Notification is completely devoid of any understanding of the socio-cultural dynamics on the coast. The fisher communities who occupy the area governed by the CRZ Notification did not have any role to play in its creation as seen from the earlier section on its genesis. At the time when the notification came into force, they were being pushed to the margins by large-scale acquisition of coastal lands. Despite that, the notification did not make a clear statement regarding the protection of coastal lands for the well being of a community whose primary and in some cases sole dependence, was on the natural productivity of coastal areas.

This poor reflection of socio-cultural aspects of fisher communities and their modes of community organisation and economy resulted in a notification that was imposed upon them rather than

one which emerged from their needs. The simple statistics available about these communities such as number of fishing villages, settlement patterns, demographics, and other livelihood related data were not adequate for appropriate planning, as noted by their near absence in the Coastal Zone Management Plans prepared by state governments. As a result, the CRZ Notification governs areas that are community owned and under traditional governance institutions for managing occupations that evolved through generations. The lawmakers unfortunately accorded no role for these institutions and did not even attempt to understand the strengths and weaknesses of communities in coastal management.

1.5 Approach and design for protection

The discussion on the approach of the notification is limited by the fact that there was no clear articulation on this aspect, and much needs to be inferred from the experience of implementation. It can be argued that the intended approach was participatory, scientific and inclusive (if we use the CZMP processes as a reference), but the effected approach (evident from the text, its amendments and the implementation) tells another story.

The section on the genesis of the notification indicates the design that the notification adopted for protection. The CRZ Notification was meant to protect the coastal areas from industrial threats and, this is evident from Mrs. Gandhi's involvement in this matter. Industrial threats and unregulated development in urban areas followed by concerns for rural coastal environments, such as those in Maharashtra, provided the anvil for shaping this law. The above sections show that early in the drafting process itself, specific lobbies or interest groups (such as the tourism lobby) helped influence the regulations in this law. As seen from later amendments, the environmental lobbies that were responsible for the promulgation of this law were sidelined in favour of industrial and development lobbies (both private and governmental) that systematically steered the law's course. The notification outlines a series of dos and don'ts for the state governments to follow in their implementation. Without providing explicit space for civil society participation in its implementation or planning, the law assigned this task to the exclusive domain of government bureaucrats. The nexus that developed between sections of the bureaucracy and development lobbies (clear from the nature of amendments to the law) appears to have become impregnable to environmentalists and fisher organisations. The possibility to effect any intended approach of participation or inclusion also quickly dissipated over the years.

2. Parameters of efficiency in the CRZ Notification

The notification's text was examined against certain parameters that would indicate its potential to be an effective environment protection legislation. These are outlined below:

2.1 Coherence in legal text

The notification is ridden with ambiguous terminology such as 'traditional inhabitants', 'customary uses and rights'. The phrases and words used in the notification are common rather than legal terms such as 'roads' and 'buildings'. This leaves the clauses open to interpretation, which could have been avoided, had the notification used legally acceptable terminology. The CRZ Notification makes a rather unorthodox departure from the standard format employed by most legislations, doing away with definitions anywhere in its text.[24] Clear definitions could have prevented ambiguity and indecision, but a contrary situation resulted in enduring non-implementation and legal violations. For example, in the notification, the operation of regulations is based on the presence or location of roads. The word 'road' however has no definition in the notification. This would be an unremarkable observation, if not for evidence that there are at least two instances where the word 'road' has been interpreted to include even pathways or walkways close to the High Tide Line (HTL). In Kerala the Kochi Marine Drive had a

pathway close to the HTL that was indicated as a road in the CZMP and therefore all constructions on the landward side of this 'road' have been consequently allowed. There is also a contrary opinion, that leaving some of the clauses undefined actually assists in greater environmental protection since it provides space to make arguments based on specific cases rather than rely on a static definition of terms (T. Mohan,[25] *pers comm.*).

The notification has been amended 19 times since 1991 upto the July 2003 amendment.[26] Several clauses have been added and changes brought into existing clauses. Yet, the MoEF has not issued a consolidated notification with all the amended text incorporated in it, thus making reading the notification not just tedious but quite impossible to comprehend. Added to this are the multiple interpretations of certain clauses in various legal cases and by implementing authorities. This impacts implementation and also stymies the involvement and participation of NGOs and community groups in the monitoring process. It is well recognised that informal monitoring by community groups can lead to better implementation (Pargal *et al.*, 1997) but a protracted and ultimately confusing law inhibits legal awareness.

The CRZ is called a subordinate or delegated legislation as the MoEF drafts the notification.[27] The Parliament promotes delegating the function of drafting law to the bureaucracy when it believes it lacks adequate expertise in a particular subject. In such cases, even the Ministry of Law does not focus too much on the text of the notification but relies on the wisdom of bureaucracy.[28] Some of the problems with the text of the notification explicated in the earlier section, could have been avoided if it had gone through the formal law-making process, benefiting from the rigour of legal drafting.

2.2 Consistency in emphasis

This is assessed not just in the text of the original notification, but also through the various amendments made to it over the years. The very fact that there has been a drastic change in the spirit of the CRZ Notification through its 19 amendments (up to July 2003) seems to suggest a dramatic shift in the emphasis of protection in the law. There is however a consistency in some of the amendments though not necessarily towards protection. For example there has been a regular extension in the relaxations given for sand mining in the Andaman and Nicobar Islands amounting to 7 extensions in all (Sridhar, 2005).

2.3 Schema for implementation

2.3.1 Institutional arrangements

The notification involves a land zonation exercise and requires the states to be involved in critical aspects of implementation. In the initial years of the notification, the states were not interested in the implementation of this central law. It was only after the Supreme Court intervened in 1996 on the matter of non-implementation that special authorities called the Coastal Zone Management Authorities were set up at the national and state levels.[29] Today, the implementation of the CRZ Notification broadly depends on a three-tier hierarchical structure that comprises of the Ministry of Environment and Forests at the top, the National Coastal Zone Management Authority (NCZMA) occupying a lower rung although at the centre, and the State Coastal Zone Management Authorities (SCZMA) at the bottom.

While several critical responsibilities of planning, management, enforcement and monitoring are vested with the SCZMAs and the NCZMA, very little attention is paid to the constitution, composition and functioning of these authorities. The Kerala CZMA was first constituted in November 1998 for a

period of two years. Once this expired, a new CZMA was not constituted until the High Court of Kerala ordered that a new CZMA be appointed in response to a public interest litigation (Sahasranaman, et al., 2005). The new CZMA was established in November 2002. For the period between November 2000 and 2002, there was no functioning Kerala CZMA. It is not known if the CZMAs of Tamil Nadu and Andhra Pradesh also faced such time lags between the completion of the committee's terms and the constitution of new committees.

The CRZ Notification does not lay down any guidelines regarding the composition of CZMAs. Citizens have questioned the composition of the CZMA as it lacks adequate expertise from the environment field (NST, 2002; Sridhar, 2003).[30] John Kurien, a member of the present Kerala CZMA says that as the lone social scientist in the Authority, and with long agendas points at each meeting, it is almost impossible to pay adequate attention to the potential social impacts of each project that is presented for clearance. Without adequate human resources, expertise and time to appraise impacts of projects, the Authorities are in danger of becoming a 'rubber stamp' for clearances.

The composition of the CZMAs is grossly inadequate. The notification is presently characterised by numerous amendments, the possibility for multiple interpretation of clauses, the growing body of case law (comprising numerous orders and judgements passed in cases directly related to implementation of the notification) and the existence of other planning and development related laws overlapping this notification's jurisdiction. It therefore becomes essential that every CZMA have a person trained in environmental and planning law. Poor legal understanding especially of procedures and protocols despite the presence of technical expertise in the CZMAs led to the suggestion that the Authority should be headed by a judge.[31]

The composition of each Authority also points to the degree of autonomy that it functions with. In Kerala, the Authority is housed in the State Council for Science, Technology and Environment. In Tamil Nadu, it is under the State Department of Environment. The Kerala CZMA is seen as being free and unhindered in taking decisions since it is only housed within the Council for logistical purposes.[32] How this happens is not clear since the CZMAs include bureaucrats and officials from departments such as Ports and Industries, whose activities or projects are to be cleared by the CZMA, but who may have proposed or already given departmental permissions to these projects. This creates an environment for conflict of interest within the implementing agency itself.

There has also been a lot of criticism regarding the functioning of the CZMAs. A Kerala court order once mentioned that CZMAs are all about 'meeting, eating and cheating the public'.[33] In a Writ Petition filed by environmental lawyer P.B. Sahasranaman in 2005 to challenge the Kerala State Government's plans to rehabilitate tsunami-affected families in the No Development Zone (NDZ) of the CRZ, the Kerala CZMA has been called non-functional and also responsible for the degree of the tsunami impact on the coastal people of Kerala. He states in his interview that the Authority has a mandate to ensure that prohibited activities are not undertaken. It also has the duty of informing the public of these prohibitions though simple actions such as putting up boards mentioning CRZ areas, but the Kerala CZMA failed to pay any attention to the performance of any their duties.[34] In analysing the functioning of an Authority such as the CZMA, which has the responsibility of taking decisions regarding grant of clearance to projects involving substantial investments, a concern has been the extent to which the Authorities are influenced or limited by political pressures. Advocate P. B. Sahasranaman is

of the opinion that protection should be given to the CZMA as in the judge's protection code, so that they can take decisions objectively without fearing political or other pressures.

Ironically, though unsurprisingly, no CZMA member mentioned having faced any pressure to clear projects that were considered negative by the Authority in the interviews conducted. However, this does not discount such pressures from existing, and could only be a gap in the information shared with us officially. In any case, it is important to study carefully documents and recorded correspondence on decisions taken by the Authority on large development projects and actions directed by them for the implementation of the notification and against violations. This analysis was not possible since even minutes of CZMA meetings and related information was not available with the authority to share with the authors readily. Without an accurate plan and a robust authority to implement it, the mere legal structure of the CRZ Notification for coastal regulation/management is of no use.[35] The Coastal Zone Management Plan (CZMP) is the single document on which the entire implementation of the notification depends. Unfortunately, the quality of CZMPs that have been used until now has come under severe criticism, from NGOs and public interest groups as well as academics and institutions that have themselves been part of the process of their formulation. While several problems of the CZMPs can be attributed to the archaic mapping and documentation technology employed by these agencies, a significant reason for the poor quality of the CZMPs is also due to the processes followed in their formulation. The Tamil Nadu CZMP is a good case to understand this.

In its current form, all CZMPs are inadequate for planning.[36] Several areas that should have been demarcated for protection do not appear in the CZMPs. In Kerala, having identified some CRZ areas on the village level cadastral maps, the comparison of their depiction in the state CZMP shows that "all the mangroves demarcated in the cadastral maps are missing in the CZMP" (Anitha & Thomas, 2006). The zoning process itself has been faulty (for eg. all gram panchayat areas were identified as CRZ III other than those which were specifically mentioned as CRZ I) As per the requirements of the notification, the Indian coast should have 80% of its area under CRZ III, and 10% each under CRZ I and II.[37] The CZMPs have been criticised on the ground that they were done in a hurried manner due to which areas which should have been demarcated as CRZ I and having maximum protection have been listed as CRZ III, thus allowing industrial activities (Anon, 2004; Anon, 2005a; Sridhar, 2005).

The scale of maps in the CZMPs makes it impossible to use it as a primary document for the implementation of CRZ. The Plan must necessarily have plots identified by survey numbers if they are to be used for CRZ implementation. The alteration of the existing CZMP maps to include survey numbers is a tedious exercise that will require time and financial resources. Detailed CRZ maps in cadastral scale (1:4000) are being prepared for many development sites in Kerala following the guidelines in the CZMP (Anitha and Thomas, 2006). When considering the earlier fact mentioned by Kurien (Kurien and Paul, 2001) that several fisher settlements were located outside the cadastral limits, one finds evidence to corroborate allegations of poor drafting and design for implementation.

2.3.2 Financial allocations

The problems of the State having to implement a central legislation are felt most by the SCZMAs. They do not have adequate funds for various tasks that they should take up in order to create awareness about the CRZ Notification. Nor are funds adequate to undertake or commission independent studies for the effective implementation of the notification.[38] A scrutiny fee is charged by the KCZMA for the processing of applications for CRZ clearance.

Scrutiny fees in Kerala		Scrutiny fees in Tamil Nadu[39]	
Individual houses costing up to 10 lakhs or whose plinth area does not exceed 500 sq m	Exempted	Projects below 5 crores	Rs 50,000
Houses and projects costing between Rs 10 and 25 lakhs.	Rs 5,000	Projects below 50 crore	Rs 2 lakhs
Projects/houses costing between Rs 25 lakhs and 1 crore	Rs 50,000	Projects below 100 crore	Rs 5 lakhs
Projects costing between Rs 1 crore and Rs 2.5 crore.	Rs 1,00,000	Projects below 500 crore	Rs 10 lakhs
Projects costing between Rs 2.5 and 5 crore	Rs 2,00,000	Projects of 500 crore and above	Rs 20 lakhs
Projects costing between Rs 5 and 100 crore.	Rs 5,00,000		
Projects above Rs 100 crore	Rs 10,00,000		

The above information was collected during field trips. Data was not obtained for Andhra Pradesh since the state was not included for primary data collection in Phase I of the project. Data was not provided on whether the collections from scrutiny fees met the full expenses of the CZMAs. A response from the TN CZMA to a Right to Information application filed by a concerned citizen[40] on how these funds were utilised only states that the collections from this fee are utilised for conducting meetings of the CZMA, awareness programmes, funding research programmes, and travel expenses of the authority. Complete details of how these funds are utilised (such as list of research programmes undertaken or awareness programmes conducted) was not possible to obtain within the period of the field trips.

2.3.3 Schema for implementation: Clearance procedures

The CRZ Notification prohibits certain activities from being undertaken in CRZ areas. For other activities (Annexure 1), permission is to be sought from the concerned regulatory bodies before they are undertaken. There are three agencies that are responsible for granting clearance to projects proposed in CRZ areas. These are the NCZMA, the state CZMAs and the MoEF. The notification is silent on the process for granting clearance. It does not mention the minimum documentation furnished the project proponent should furnish, or the time frame needed for the entire clearance process. These critical aspects have been left to the agencies to decide and establish through practice. This has resulted in the absence of any standardisation whatsoever between the procedures followed by different agencies and by the CZMAs of different states. This appears to have encouraged ad hoc and whimsical decision-making. Ambiguous clauses make it difficult for public interest groups to challenge such decisions.

This review undertook a preliminary analysis of the procedures under the CRZ Notification. This contained a listing of permitted and prohibited activities, clearance granting procedures and clearance agencies as contained in the text of the notification. This is found on the website (www.ptei-india.org). The procedural analysis table was constructed using only the text of the notification, and the gaps in the columns on clearance procedures and questions indicate specific procedural aspects that are vague and those that are clearly outlined within the notification.

Administrative procedures for the implementation of legislation need not be outlined in the law itself. P.B. Sahasranaman opines that procedures could evolve from practice. However, they must certainly be documented formally by the concerned agency so that subsequent committees and authorities can follow them and build on them to improve these procedures. [41] During the interview with the Secretary of the Kerala CZMA, the researchers could not obtain any documents on the procedures

followed for clearance and had to therefore rely completely on the information shared in the interview on this subject.

Based on the information gleaned from several CZMA members in Kerala, the procedure for grant of clearance has been pieced together as comprising the following steps:

1. The proposal for projects in CRZ areas is considered by the State CZMA.
2. The proposals of projects that are to be cleared by the NCZMA or the MoEF are sent to them.
3. A presentation of the proposed project is done by private agencies. A status report is to be prepared by a consultant financed by the project proponent. A certified mapping of the CRZ area in question on a cadastral map is now a part of the clearance process.[42]

As of now all status reports are only available in the files maintained with the CZMAs. It was suggested to the authors that CZMAs could be put together on the website or a document so that CRZ related information collated so far is available to interested citizens.[43] Further enquiries on hurdles to implementing these ideas elicit responses that only point to inadequate financial and human resources, rather than any systemic problems, such as lack of political will and enthusiasm.

The Member Secretary of the Kerala CZMA stated that any activity within the CRZ needs clearance from the CZMA. The application form is to be sent to the Member Secretary, Kerala CZMA through the concerned local authorities (*Panchayat*/Municipality/Corporation). The documents that are to be submitted are the following: 1

1. Application in the prescribed format
2. Report from local authority on CRZ status
3. Building Plan
4. Site Plan
5. Building estimates and
6. Copy of the Possession Certificate.

In Tamil Nadu, the required documents and application form goes from the Member Secretary of the District Coastal Zone Management Authority who is the District Environment Engineer of the state Pollution Control Board. It is scrutinised by the district coastal zone authority headed by the District Collector. It then moves to the State Coastal Zone Management Authority, headed by the Secretary, of the Department of Environment. The Member Secretary of the CZMA is the Director of the Department of Environment. The papers move further to the MoEF if the project is one that requires clearance at the central level.

The documents that need to be submitted for the clearance of a project in Tamil Nadu are as follows (Anon, 2006):

1. Location map showing HTL, LTL, 200 m line, 500 m line and extent of coastal regulation zone, certified by the competent authority for this purpose.
2. Topographic map of the site (1:25000)
3. Confirmation from the state/UT government regarding classification of the area (as per the CZMP) and their observations/recommendations
4. Topographic map covering 10 km radius from the periphery of the site indicating mangroves and other ecologically sensitive features
5. General layout of the site (1:25000) showing already existing developments/infrastructure

6. Comments of the Chief Wildlife Warden
7. Plan of the area showing existing structure within one km.
8. Plan/Elevation of the proposed building
9. Approval of electricity connection and certification of supply
10. Layout of green belt
11. Approval of Tourism Department
12. No Objection Certificate from SPCB
13. No Objection Certificate from state Ground Water Board
14. Certificate from Water Supply Authority

Although the authorities later developed these procedures and requirements, the clearance process is hampered by the fact that reliable information on zonation is still unavailable in the absence of fully approved and accurate CZMPs.

2.3.4 Monitoring and compliance

The CRZ Notification does not lay down any procedures for the monitoring of CRZ implementation. Neither does it have any process in place for ensuring that there is regular and ongoing monitoring of projects that have been granted conditional clearance to operate in CRZ areas.

Questions to the CZMA members in Tamil Nadu and Kerala regarding monitoring of CRZ implementation led to vague references to 'some problems' in implementation. The researchers were not allowed access to minutes of CZMA meetings, which may have contained discussions on issues of compliance, by projects. The State CZMAs have also not undertaken any investigations or studies to arrive at a conclusion regarding the violations of CRZ and the degree of compliance by projects that are granted conditional clearance. The State CZMAs and the National CZMA are expected to submit six monthly reports on CRZ issues as per the CZMA notifications. However, these were not accessible to the researchers for analysis. A response from the Tamil Nadu CZMA to a Right to Information[44] application surprisingly states that the authority does not possess copies of the six-monthly reports and minutes, therefore making it difficult for researchers to assess their performance.[45]

Status reports are absolutely essential to understand the extent to which the CRZ has been implemented, the extent to which it has been violated and degree of compliance to conditions of clearance. Without this information, it is only logical to consider the CZMAs as 'clearance granting agencies' rather than management authorities.

Violations in Kerala include the Goshree project, which involved reclamation of 25 ha of land. The case was taken to the High Court and the first orders were issued in 1996. The final judgement came in 1998. Even the government has violated the CRZ Notification in Kerala. Facing the Central Marine Fisheries Research Institute in Cochin is a government multi-storied building built by reclaming part of the Cochin Port backwater area. In Thalassery, mangroves have been felled to accommodate hotels and resorts.[46] . In Tamil Nadu, there were reports of illegal sand mining/quarrying taking place on the Theosophical Society area beach in Chennai and the state government had been urged to restrict it in the interest of protecting the beach and minimize the impacts of cyclones and other calamities. Violations are also reported from Cuddalore where several industries are located in the SIPCOT area and are discharging effluents and extending their constructions into CRZ area.[47] These violations are only indicative of the situation on the coast and were the ones discussed in some detail by the respondents in the interviews. Several civil society groups such as Coastal Action Network, Nagarika Seva Trust, Bangalore, Bombay Environmental Action Group, EQUATIONS and the National

Fishworkers' Forum have highlighted violations of the notification in the past decade and have in some instances even compiled status reports of the notification on their own. Many of these groups have approached the courts seeking judicial intervention on matters related to the violation of the notification in the tsunami-affected states in the past. The Tamil Nadu CZMA in response to a Right to Information request stated that it has taken no suo moto action on complaints of violations.[48]

The power of the Authority to take action against violators is not clear. Although the notifications constituting the CZMAs state that they can take action against violators under the clauses of the Environment (Protection) Act,[49] it is held by members of the Authority as well as others that the Authority is a toothless body and cannot enforce the CRZ Notification. There is a need to examine the Environment (Protection) Act carefully to understand the powers of the authority. The CZMA has the power to prosecute under section 10 of the EPA but no officer is authorised.[50] In Tamil Nadu, the Chairperson of the Authority is the Secretary of the Department of Environment, a busy government official. The EP Act provides that the head of the authority created under its clauses is empowered to take action, the Member Secretary of the CZMA stated that it was not possible to draw the attention of the secretary on all small matters that would constitute 'action'.[51]

2.4 Implementation status

The implementation of the notification is comprised of various aspects, and is not judged by any one criterion alone. The functioning of the CZMAs, the level of participation of various stakeholders in its design and implementation, the preparation of various plans and the instances of violations are some of the aspects that provide information on how the notification was implemented. These are discussed in specific sections in this report. Several civil society and independent observations and analyses of the notification have commented on the poor status of implementation of the law (Chainani, unpublished; Sharma, 1996; Sridhar, 2005; Sridhar et al., 2006). The most telling comments on the status of implementation of the notification however are admissions made by the government itself.

The recently released report of the Comptroller Auditor General of India (CAGI) states that the CRZ Notification was not implemented at all by the MoEF (CAGI, 2006). The report states, 'The Ministry of Environment and Forests did not enforce the Coastal Regulation Zone notification effectively resulting in extensive destruction in coastal areas due to industrial expansion' (Paragraph 5.1.1 of the CAGI report). It further states, 'The States/UTs did not prepare coastal zone management plans' (Paragraph 5.1.2) and they 'did not review/amend zoning regulations and building byelaws after the tsunami' (Paragraphs 5.1.6, 5.1.6.1 and 5.1.7). The CAGI report recommends 'the Ministry of Home Affairs may coordinate closely with Ministry of Environment and Forests (MoEF) and the State Governments and ensure the enforcement of the Coastal Regulation Zone notification so that indiscriminate commercial and industrial expansion is not permitted.'

Similarly, the Swaminathan Committee constituted to review the implementation of the CRZ Notification, whose Member Secretary was a Joint Director of the MoEF has admitted that the implementation was nearly absent in all coastal states (Anon. 2005a). At the very first meeting of the Swaminathan Committee, it was observed that the coastal states had failed to prepare the Coastal Zone Management Plans for nearly 12 years, despite being ordered to do so by the Supreme Court of India. The Committee has also noted that there are rampant violations of the CRZ notification in every coastal state (Anon. 2004).[52]

The main concern with the newly proposed coastal regime is that there was absolutely no implementation of the earlier notification. Critics are sceptical whether the same MoEF will show any

keenness and political will to draft and later ensure the implementation of a stronger protection regime given the hostile response from the influential industrial and development lobbies operating today.

3. Governance issues with the CRZ Notification

An assessment of the CRZ Notification and its implementation was also done to understand its compliance with parameters of good governance such as **transparency, accountability, access to information and public participation.** These are discussed together in this section, to show the manner in which these factors interface with each other as manifested in the CRZ implementation experience.

The original notification was introduced in 1991 only after a period of 90 days was granted for citizens to comment on the draft notification and send their comments and suggestions to the MoEF (Chainani, *unpublished*). It was only after all the objections were considered that the final notification was made.[53] Following this, the CRZ Notification has been amended 19 times (upto July 2003) and out of these only three amendments allowed for public comment. All the others were introduced using clause 5(d) of the EP Rules. This clause states that in certain cases where the Central Government thinks it necessary, it can dispense with the requirement to call for public comments on draft amendments.

Table 2 below shows the various amendments to the CRZ Notification that utilised clause 5(d) of the EP Rules. The provisions or clauses that 16 amendments introduced or changed without any public participation were likely to have significant social and ecological impacts. Some of these are the permission for land reclamation for certain activities provided the purpose was not commercial purposes, permission for demolition or reconstruction of buildings of archaeological or historical importance, heritage buildings and buildings under public use and reduction of the NDZ area in CRZ –III to 50 m in the Andaman and Nicobar Islands and in the Lakshadweep Islands for tourism purposes. The draft amendments should have rightly been circulated widely and discussions held to obtain different viewpoints before finalising them.

Table 2 Showing the amendments to the notification that did not appear for public comment.

Date of amendment	Legal clauses
31st January 1997	S.O.73 (E) EPA 3(1), 3(2)(v), EP Rules5 (3)(a), 5(4)
9th July 1997	S. O. No. 494(E) EPA 3(1), 3(2)(v), EP Rules5 (3)(a), 5(4)
20th April 1998	S.O 334 (E) EPA 3(1), 3(2)(v), EP Rules 5(3)(a), 5(4)
30th September 1998	S.O 873(E) EPA 3(1), 3(2)(v), EP Rules 5(3)(a), 5(4)
29th December 1998	S.O 1122(E) EPA 3(1), 3(2)(v), EP Rules 5(3)(a), 5(4)
29th September 1999	S.O. 998 (E) EPA 3(1), 3(2)(v) EP Rules 5(4)
29th September 2000	S.O 900(E) EPA 3(1), 3(2)(v) EP Rules 5(3), 5(4)
12th April 2001	S.O 329(E) EPA 3(1), 3(2)(v), EP Rules 5(3)(a), 5(4)
3rd October 2001	S.O 998(E) EPA 3(1), 3(2)(v), EP Rules 5(3)& (4)
19th October 2002	S.O 1100 (E) EPA 3(1), 3(2)(v), EP Rules 5(3)& (4)
16th January 2003	S.O 52 (E) EPA 3(1), 3(2)(v) EP Rules 5(3), 5(4)
22nd April 2003	S.O 460(E) EPA 3(2)(1), 3(2)(v) EP Rules 5(3), 5(4)
30th May 2003	S.O.635 (E) EPA 3(1), 3(2)(v) EP Rules 5(3), 5(4)
30th May 2003	S.O.636 (E) EPA 3(1), 3(2)(v) EP Rules 5(3), 5(4)
24th June 2003	S.O.725 (E) EPA 3(1), 3(2)(v) EP Rules 5(3), 5(4)
24th July 2003	S.O.838 (E) EPA 3(2)(1), 3(2)(v) EP Rules 5(3), 5(4)

The Supreme Court had earlier, in its order of April 1996, severely criticised the use of the Central Government's arbitrary, "unguided and uncanalised" powers when it granted the relaxation of CRZ areas for all rivers and creeks thrOugh the amendment dated 16th August 1994. Despite this, it continues to be the preferred style of operation for the MoEF, which issued amendments to allow specific development activities along the coast without basing these decisions on scientific studies and detailed discussions with local fisher communities and several other constituencies who depend on a healthy coast for their survival. The amendment of July 1997 took place when the function of CRZ clearance for ports was handed over to the Ministry of Surface Transport and the July 2003 amendment that introduced the reduction of NDZ for tourism purposes was based on an ICZM study, even before the study was completed. This provides evidence of the callous attitude towards the law even with the principal regulatory agency and perhaps even a motivation that sought to undermine the CRZ Notification.

In July 1997, an amendment introduced the term 'local inhabitants' instead of 'traditional users'. With this change, the little emphasis in the notification on protecting the livelihoods of coastal communities along with environmental protection was lost. Also, whatever support had been built for the CRZ Notification among the fisher communities, stood threatened. The change in terminology saw stiff opposition from various quarters and this amendment was challenged in the High Court of Delhi by the Wildlife Protection Society of India in CWP 4198/97 (ironically the petitioners state that the matter has not come for hearing even once). This means that all categories of 'coastal' people are at the same level and there is no identification of the primary users of the coast.[54]

Several amendments were brought in with the justification that 'local people' had asked for these changes to be made on the grounds that it was hampering their development. For eg:

15. That local people of the Union Territory of the Andaman and Nicobar Islands are stated to face 'difficulties' – a justification that finds no other substantiation but which results in extensions to sand mining permissions.
16. The Central Government is stated to have had consultations with the State Governments to permit construction of dwelling units, infrastructure for the local inhabitants, housing schemes of Urban Development Authorities (approved prior to 1991), setting up of non-polluting industries in Special Economic Zones and salt harvesting in the January 2002 draft amendment.
17. The July 1997 amendment states that some State Governments had drawn the attention of the Central Government to the 'difficulties' being faced by 'local people' and subsequently construction of essential facilities in the coastal zone was introduced. Most of the 'essential facilities' in this amendment relate to large industries on the coast.
18. In response to the petition filed by Wildlife Protection Society of India challenging the July 1997 amendment to the CRZ Notification, the response of the MoEF stated, *"exploration and detailed and extensive discussions were held with the concerned departments and organisations. The views of an expert committee were also obtained regarding some of the provisions of the amending notification and the expert committee was also represented by non –officials members and had extensive discussion with various Governments, NGOs and public."* Table 2 shows that this amendment was introduced without soliciting public comment under 5(d) of the EP Act.

In all of the above cases, although the MoEF states that the changes have been brought about because of demands from specific areas, there was no way for citizens to find out who were actually involved in discussions with the MoEF, what were their concerns or grievances and was dilution of the notification's

provisions the only way to address these grievances. No evidence of any of these consultations is available from the MoEF or with NGOs.

The regular implementation of the CRZ Notification also suffers from lack of transparency. The minutes of meetings of the Coastal Zone Management Authorities, their process of decision-making, their monitoring reports and other critical documents are not accessible to the public. The implementation of the CRZ Notification will remain a problem unless voluntary disclosure of public interest information regarding the functioning of the Authorities as well as process and content of plans and other relevant documents is made mandatory.

Neither the notification itself, nor the MoEF as an implementing agency, provided for trainings or building capacity of the Authorities and other line departments in comprehending or implementing the notification. Unless this is explicitly stated in the notification itself or at least in the form of guidelines, it will be left to the state governments to undertake these activities at their discretion.

The CRZ Notification initially contained certain provisions that protected the interests of fisher communities whose livelihood depended on a healthy coast. If they are involved in the implementation of the notification and its monitoring, it could ensure the protection of coastal habitats as well as relieve the state government to a great extent, of the responsibility of having to be involved in the day-to-day implementation of the notification. Therefore, it was important for the notification to emphasise capacity-building and active participation of local governments and citizens in rural and urban coastal areas. In its present form, this is absent in the notification. Several traditional fisherfolk and coastal community institutions find themselves in varying degrees of disuse/redundancy. The notification does not recognise their presence or their potential role in coastal conservation. It would be useful to study how these community institutions can play a role in the implementation and monitoring of coastal zone management laws.

The level of participation of district and village level institutions in the implementation of the notification is ad hoc. While the Tamil Nadu Government has notified committees for the implementation of the notification at the district level[55], other states do not appear to have followed suit. Tamil Nadu also has a specific committee for the Chennai Metropolitan area comprising the Director, Department of Environment, the Member Secretary of Chennai Metropolitan Development Authority, a representative of the local body and a District Environmental Engineer of the State Pollution Control Board.[56] In Kerala, it was felt that if coastal conservation was to be truly achieved, then areas in the sea adjoining the coast would also need to be brought under some form of regulation. A suggestion was made was to demarcate a littoral zone upto 2 km into the land from the sea.[57] The *panchayats* could then exercise some control over pollution on land, which was affecting the sea.

The constitution of CZMAs needs more attention in the CRZ Notification. Presently, none of the Authorities include a professionally trained or experienced person from the field of environmental law. This study examined the composition of the committee members (see www.ptei-india.org for a table on the composition of the CZMAs.) The process for selecting members to the committee is presently done without any prior public information or notice. Thus it is not possible for citizens to provide any inputs for the constitution of the CZMA or even know if a new Authority has been set up after the expiry of the existing one. If done in an open and participatory manner it could ensure that experts from the most relevant fields are included in the Authorities. This may also ensure that there is no time gap between the expiry of the Authority and the constitution of a new one or reconstitution of the old Authority.

The process of formulating the Tamil Nadu CZMP is an example of the role of public participation in the planning process. Information about the process of finalisation of the CZMP reached local groups working on coastal issues through informal sources and not through a public notice. A copy of the CZMP worked on by the State Government was obtained and analysed by many civil society groups working on coastal issues in the state. Following this several letters were written by citizens to the MoEF, to the Coastal Task force that was set up to assist the Ministry in finalising CZMPs and to the State Government (Jairaj, undated; Sundararajan-Mathew, 1996a, b; Anon. 1996a, b; Rajah, 1998; CAG, 1998). They provided detailed comments regarding the zonation of ecologically sensitive areas, lack of information and in some cases faulty information in the CZMP about fishing villages and their population. However, due to the lack of transparency, it was not known whether these comments were considered before the finalisation of the CZMP and what the reasons were for excluding certain suggestions. In the case of Kerala, the CZMPs were made publicly accessible in all districts, but this was done only after the process of finalisation of the CZMP. Even then, the CZMP was not made available in Cochin, a rapidly developing area.[58]

4. CRZ in the post-tsunami context

As stated earlier, the understanding and the implementation of the CRZ Notification has been fraught with problems and its implementation in the coastal states has been at best, partial. There is even official opinion on how the lack of implementation has made coastal areas vulnerable to disasters (CAGI, 2006). Ecologically sensitive areas such as mangroves and coastal wetlands have been destroyed, sand dunes and beaches, which function as protective barriers, have been affected by intensive development activities. Industrial development along the coast has polluted ground and surface water sources. Traditional coastal dwellers have also been directly displaced by development projects or have had to move out due to pollution impacts. These conditions have led to the impoverishment of coastal communities. Due to the degradation of coastal areas and the poverty of coastal communities, impacts of natural disasters have been especially significant and long lasting.

The devastation caused by the December 2004 tsunami drew focus on the significance of setbacks. How far should residences and other infrastructure be located from the sea? The CRZ Notification mandated a minimum setback of 500m from the HTL, but not for all activities. As the notification was originally envisaged, only those activities that required foreshore facilities were to be allowed within the CRZ area. This was in addition to all the structures that existed in the CRZ prior to the notification. But subsequent amendments and absence of demarcation of the HTL or CRZ zones have resulted in more and more activities being permitted on the coast.

The rehabilitation measures post-tsunami were to be undertaken mainly in CRZ areas. The activities that were proposed in the rehabilitation phase, post-tsunami led to a great deal of confusion as the notification was unclear about the legalities of several of these activities. There was no help forthcoming from the Ministry of Environment and Forests on these issues either. The foremost problems were about where to locate the new dwelling units of the families whose homes had been damaged partially and fully. 'Move fishers beyond 500m' was the only simplistic and knee-jerk State response. In Tamil Nadu, the UN Team for Recovery Support co-organised a consultation on post-tsunami reconstruction on the 12th April 2005.[59] Prior to this, the UNDP commissioned a study on the CRZ and issues related to rehabilitation which identified several issues that needed to be clarified by the MoEF, prior to the tsunami-affected coastal states undertaking any construction (Sridhar, 2005). Despite issues such as these being raised at the April 2005 consultation, it is not known if the MoEF has been proactively monitoring or assisting in lawful reconstruction activities.

4.1 Housing within the post-tsunami CRZ

The Government of Tamil Nadu introduced G.O (Government Order) 172 on 30th March 2005 declaring that all government sponsored new houses would be constructed only 200 m from the HTL. With the stated objective of providing built houses in safe locations to the tsunami-affected families, the Government pledged assistance only to those who agreed to be relocated beyond 200 metres of the HTL. Those who intended to construct within 200 m would not be eligible for government assistance. The government also extended assistance to those whose homes were not damaged but who wanted to relocate nonetheless. The ambiguity of the Coastal Regulation Zone Notification led to the above interpretation, and it was deemed that no new constructions would be permitted within 200 m for all categories of the CRZ (Sridhar, 2006).

There was strong resentment towards G.O 172 from various quarters. Several fishworker groups and NGOs termed this a discriminatory order. They put forth various arguments against the G.O stating that fisher communities have a right to stay close to the shoreline and visibility of the coastal waters is important for their fishing activities. The lack of consultation with and participation of fishing communities in these shelter guidelines has also been severely criticised. Other arguments stated that this G.O would effectively remove fishing communities from the coast, and thus make it easy for the tourism industry and other real estate interests to occupy the coast (Sridhar, ibid).

In response to this, a meeting of federations of fishermen took place in Chennai on January 16, 2005 and passed strong resolutions where they claimed the coast as theirs. Under pressure from the fisher groups, on 25th March 2005, the Chief Minister announced in the legislative assembly, that the fishers should not be made to move away from the coast. Now within 200 m, new constructions would be allowed albeit informally.[60] Following this, the Government Order 172 dated 30th March 2005 was issued. It states, *"The areas so vacated because of new construction will be entered in the Prohibitory Order book and maintained for public purposes. Fisher people will be permitted to keep boats, nets etc. in these areas. Separate sheds, locker rooms etc. may be put up in these locations by Government/NGOs on a temporary basis as per CRZ guidelines"* (Government of Tamil Nadu, 2003). It needs to be confirmed if the Tamil Nadu State Government is indeed following this rule in the rehabilitation efforts. Despite this clause, there are fears that the lands freed up will be used for development projects, such as tourist facilities, which will result in environmental and social impacts on fisher communities and the coastal ecology (TISS, 2005).

The problem of identification of legal areas for rehabilitation without accurate CZMPs, remains. Also, the reconstruction of damaged structures in CRZ–I and in the NDZ of CRZ-III areas is impossible unless a way to ascertain if the damaged structures were legal and existed in the CRZ area prior to 1991 is found. Some indication of possible methods that can be followed is provided in the UNDP sponsored study on post-tsunami rehabilitation issues in Tamil Nadu (Sridhar, 2005).

It is seen that those agencies governing use and those stakeholders that have access to financial resources and political prowess exercise a more successful articulation over their rights and control on coasts than those solely dependent on it for their survival. The past few decades have witnessed fisher support groups such as the National Fishworkers' Forum, several NGOs and community groups working for the uplift of fisher communities demanding coastal area rights on behalf of communities. They have demanded that fishworkers and their families be given the first right over the coast. Some of them have coined the term 'sea tribes' to draw a parallel between their condition and that of forest dwelling tribal communities. Although this articulation is used to build a sense of unified identity among fishworker communities, a concerted effort at going beyond sloganeering is yet to be made.[61]

Fishing communities do not have pattas or land rights and title deeds in the majority of cases. However, the CRZ Notification only allows authorised constructions on the coast. The dichotomy has not been addressed yet till date (Sridhar, 2005).

Post-tsunami, in Kerala the government stated that construction would not be taken up in the same place if it is a CRZ area, but this is not being followed. A case was filed in the Kerala High Court because the government proposed to rehabilitate the tsunami-affected families in the same place. The petitioner argued that people will thus continue to face natural disasters and violation of CRZ will be condoned.[62]

The CAGI report states that though funds were made available to the A.P. State Housing Corporation in April 2005, no progress was made (March 2006) for completion and handing over the houses to the beneficiaries due to delays in acquisition of land and resistance on the part of beneficiaries to move out of the Coastal Regulation Zone. As of September 2006, 59 houses were completed (CAGI, 2006).

4.2 Coastal protection post tsunami - sea walls and bioshields

The immediate reactions of the state governments to the tsunami were to 'fortify' the coast by constructing sea walls across the coast. The state government rushed into declaring that protection works such as construction of sea walls, groynes, beach protection measures, shelter beds, mangrove plantations along the coastline would be undertaken. Specific projects such as sea wall construction around Kalpakkam township are reported to be under consideration in the Tamil Nadu.

The reviewers of the Swaminathan Committee Report point out that prior to the tsunami, the Tamil Nadu Forest Department was involved with the plantation of Casuarina along the coast, although largely on revenue lands. The data from various coastal forest divisions along Tamil Nadu shows that only Casuarina was being planted all along the coast and the entire exercise appeared to be devoid of any science (refer to the Chapter on initiatives of the Forest Department in Tamil Nadu). They have drawn attention to the fact that "the range of restoration activities currently being undertaken such as that of creating bioshields and coral reef restoration should be injected with a good amount of scientific rigour. They state that there is a range of socio-economic and ecological parameters that are to be considered in the plan for creating bioshields but these have not thus far been employed (Sridhar, *et al.,* 2005).

There have been several other concerns regarding CRZ implementation in light of tsunami rehabilitation efforts. In the initial period of relief, sand mining from CRZ areas was reported as NGOs and others involved in relief efforts did not know that it was a prohibited activity. The issue of maintenance of buildings and sanitation standards in the construction of temporary shelters and their dismantling has been a cause of concern too.

4.3 New legislation post-tsunami: Better or bitter fare?

The Coastal Management Zone

Even prior to the tsunami, a process had been undertaken by the Ministry of Environment and Forests to reform environmental regulations. These included the promulgation of a National Environment Policy, the reengineering of the environment clearance process[63] and the establishment of the M.S Swaminathan Committee to review the CRZ Notification and suggest changes for a new legislation. The Swaminathan Committee, headed by Prof. M.S. Swaminathan was constituted in July 2004 with the mandate to suggest an appropriate framework of coastal management. The report of the committee was submitted to the MoEF in February 2005.

The minutes of the meetings of the Swaminathan Committee refer to several activities that have been responsible for destroying coastal areas and also affecting the livelihoods of fisher communities, such as sand mining and sea walls. This study makes a comparison of the contents of these minutes and the recommendations in the final Swaminathan Report (available on www.ptei-india.org). Ironically, several suggestions made in the committee meetings (as seen from the minutes) don't match with the final recommendations of the final chapter of the Swaminathan Report.

The entire process of review of the CRZ Notification by this committee was criticised because it did not involve participation from public interest groups or coastal communities. The meeting minutes and reports of the Committee remained out of public access until an application under the Right to Information Act was filed seeking this information. The most astonishing aspect of this process was that even State Governments or State CZMAs were not consulted while drafting the report.[64]

The minutes of the meeting do not indicate any reference to an assessment of the degree of implementation of the CRZ Notification and the number of violations that exist in different states, although it merely states that the law was severely violated. The committee has not considered the various steps that may have been undertaken by state governments to implement the notification and the problems they may have faced in this process.

The meeting discussions imply that the committee considered the notification per se as being the problem and not the mechanisms for implementation such as the management authorities which are understaffed, short of funds and dealing with State Governments which may have no political will to regulate activities on the coast. The recommendations of the committee were used to develop a new notification called the Coastal Management Zone Notification in place of the CRZ Notification. But the new notification suffers from the lack of an institutional framework for implementation precisely because of the oversight of the committee regarding appropriate mechanisms for the realisation of coastal management.

Although the initiative taken to review the efficiency of the CRZ Notification, a fifteen year old legislation, in achieving coastal protection is appreciated and long overdue, the process of the review and the final product - the Swaminathan Committee Report, has not been accepted by several people concerned with coastal issues (Anon, 2006b[65]; Anon, 2006c[66]; NFF, 2006) The United Nations Development Programme (UNDP) commissioned a review of the Swaminathan Committee Report after the latter was released (Sridhar et al. 2005). The reviewers provide an exhaustive analysis of the Committee Report and have highlighted areas that need more working if a new framework for coastal management and protection of coastal livelihoods is to be achieved.

The draft CMZ Notification has been circulating since early 2006 (Anon. 2006d). While the MoEF has not formally called this its draft CMZ Notification, it needs no endorsement, as it is identical to the recommended notification in the Swaminathan Report. The reviewers of the Swaminathan Report have stated that the proposed notification was not based on any scientific principles and was in fact completely contrary to the positive elements contained in the first few chapters of the Swaminathan Report (Sridhar et al., 2005).

4.4. Efficiency of the CMZ Notification

4.4.1 Incomplete idea of the integrated planning process

The new notification and the Swaminathan Report hinge on the approach of integrated planning. While the Swaminathan Committee Report recommended several constructive measures to take forward the concept of Integrated Coastal Zone Management, the proposed notification does not seem to contain a

framework to implement this. Integrated planning and management is an extremely detailed and involved exercise that can only happen through political will, a sense of cooperation among departments and decentralisation of rights and responsibilities to citizens and officials at local levels. Plans once worked out have to be binding for a certain time period. Too much flexibility (or complete mutability as seen in the CMZ Notification) will surely be counter-productive.

The draft CMZ Notification relies heavily on Integrated Plans for appropriate development along the coast. The Integrated Plans for ports and harbours and for tourism in CMZ II are to be done by 'Port authorities or concerned agencies' and 'Ministry of Tourism and the State/UT Tourism Department' and these plans 'shall be approved by the Ministry'. This is far from even being a starting point for 'integrated' plans in the real sense. Integrated plans will need to be drawn up by special inter-disciplinary groups, representatives of different line departments, citizen-experts, scientists and others who may be able to contribute with their knowledge and understanding of the nature of the coast. Without such a process, the Integrated Plans will have no acceptance among all constituencies and therefore project proponents or those who undertake activities on the coast will find no incentive to abide by legal requirements. Besides it does not suffice that the MoEF approves these plans, if State Government departments do not accept them, as coastal lands are primarily under their jurisdiction.

4.4.2 Poor regulatory structure

While there is growing opinion from all quarters that an open system with the required checks and balances is more appropriate than a license system characterised by tedious clearance procedures, it is also to be borne in mind that some degree of regulation might have to accompany any management system in the country. Today, environmental protection still depends on whether a project proponent finds it a desirable outcome or not. A strong objective and set of regulations that are designed to prioritise the well being of communities and ecosystems and sustainable economic growth is absent in most laws and their implementation plans. The absence of any regulatory emphasis or structure for implementation in this new CMZ Notification is disturbing.

The CMZ Notification has passed by the positive elements in the Swaminathan Committee Report. For example, the Swaminathan Committee recommended an end to building more sea walls and sand mining as these were recognised as causing substantial damage through beach and dune loss, loss of protection to agricultural lands further inland, impacts on turtle nesting grounds and erosion of coastal lands. Sand mining, for instance, has been prohibited only in CMZ II areas and not in other regions. The notification states 'activities that may be permitted or prohibited on the seaward side of the setback line and agencies responsible is given at Annexure II'. Annexure II lists activities that can be permitted in CMZ II areas provided permission is obtained from the concerned authorities. It does not clarify whether these are activities that can even be allowed in CMZ III areas or whether all activities that are missing from Annexure II must be considered prohibited everywhere.

4.4.3 No procedural improvement over the earlier law

The CMZ Notification does not explicate clearance procedures for permitting infrastructure/development projects. Part VII of the CMZ Notification, which appears to be a section on process for grant of clearance only mentions the time period within which clearance decisions will made, its validity period and the possibility of transferring clearance. By this account, the CMZ is repeating the very same problems that hampered the implementation of the CRZ Notification. The initial years after the promulgation of the CRZ Notification saw no implementation whatsoever because no attention was paid to the process by which State Governments could carry out its ambitious aims. It was only after the CZMAs were established by order of the Supreme Court that the Authorities found mechanisms by

which to perform the function of grant of clearance at the state level. In the proposed CMZ Notification, responsibilities of clearance of projects have been divided between 'local/concerned authorities', the State/UT Authority and the MoEF. However the procedures to be followed for clearance are not mentioned anywhere. Logically, the Swaminathan Committee should have studied the clearance process practiced by different states and the MoEF and recommended changes armed with practical information from these agencies. It should have also described the process to be followed by the various agencies in the new notification. This exercise alone can go a long way in ensuring that laws such as this find flight.

The new notification contains no definitions in its current form, a feature it shares with the CRZ Notification. Areas which have the highest ecological significance are to be identified as CMZ I in the new law. The notification states that '*Integrated Management Plans for these sensitive areas shall be prepared by the Ministry of Environment & Forests through scientific institutions which will be implemented by the concerned State/Union Territory and monitored by the Coastal Zone Management Authority of (that) State/Union Territory. Necessary funding will be earmarked and provided by MoEF. Activities which are essential shall be permitted in these areas based on Integrated Coastal Zone Management Plans and after public hearing'.* Considering that the management areas in question includes extremely sensitive ecosystems such as mangroves, sea grass beds, turtle nesting grounds etc, the terms such as 'essential' warrant clear and stringent qualifiers so that ambiguity in definitions are not used to justify projects, schemes or activities that can damage these ecosystems.

The proposed notification lays down activities that are to be considered in CMZ II areas. This category is a strange mix of areas, falling under administrative categories such as, corporations, municipalities and *panchayats* as well as areas identified by certain kinds of economic activities, such as mining, industry and tourism. What is not clear is whether the areas to be identified under this category are *already* under certain kinds of use such as mining or tourism projects or whether they are *proposed* as mining or tourism areas. If it is the latter, then the identification process must take into accounts that in areas such as Kerala where coastal lands form a large percentage of the total area available for varied uses, housing and infrastructure required for fishing activities should be given priority. These uses should not be considered on par with economic activities like tourism and mining. Similarly, the idea that *'new houses and settlements shall be planned only on (the) landward of the setback line'* will be acceptable only if the priority rights for fisheries infrastructure and housing are established. The clause, *'activities requiring foreshore facilities and which are non-polluting in nature shall be permitted on the seaward side of the setback line subject to Environment Impact Assessment'*, is especially problematic since its restriction is to pollution-related impacts and also because the understanding of what constitutes 'non-polluting' activities is variable as seen in the present CRZ Notification.

The CMZ Notification has allowed for the identification of areas of particular interest from an economic point of view, and also heritage and archaeological sites. But it fails to accommodate the identification and special considerations that are needed for areas that have already been polluted beyond repair. This identification of critically polluted coastal areas is absolutely essential to ensure that such areas do not face any more pollution pressure. Areas such as the SIPCOT area in Cuddalore unless declared as 'no go' areas for any further industrial activity will cause severe and irreversible health impacts on the local population and natural resources. The CMZ Notification, by this oversight, will be responsible for violating the right to life of people in such areas. The Pollution Control Boards in some states had initiated a zoning exercise to assist in appropriate siting of industries. Such initiatives can be effectively linked with the CMZ Notification.

The management of CMZ II and III areas will be governed by the identification of setback lines based on the vulnerability of the coast to natural and man-made hazards. This is much needed as it will be based on the geomorphology of the coast and will go a long way in ensuring appropriate development on the coast. However, the identification of setback lines and decisions on siting of dwelling units for fisher communities will also have to be based on the livelihood needs of fisher communities. A sensitive balance will need to be struck between their need for proximity to the sea considering their livelihood needs, and protecting them from natural disasters. Emphasising the need for a setback that is responsive to new knowledge and events, the reviewers of the Swaminathan Committee report state *'guidelines and procedures for changes in the vulnerability line should be worked out. The provision for change of the vulnerability line should not be misused for dilution to pave for development activities in this sensitive area. The conservation spirit of the notification must consistently manifest in the text of the notification'* (Sridhar *et al.*, 2006).

4.5 CMZ and environment protection

The entire approach and design of the new notification is identical to that of the old law. It also adopts a dos and don'ts approach and is guided by similar concerns as the existing law. The present design of the new notification does not contain any procedural clauses or any other operational clause, which permits only a superficial examination of its content in this study.

Within the new notification, Integrated Management Plans will provide the framework and details of how CMZ I, II, III and IV areas are to be managed. The preparation of these management plans must be undertaken with adequate scientific input. Annexure 3 contains a description of the various provisions of the new notification. Having drawn from the experience of several natural disasters including the tsunami of 2004, the proposed CMZ Notification seeks to actively promote coastal protection through methods such as regeneration, restoration, stabilisation and protection. It states that:

In CMZ II areas, sufficient bioshields with local vegetation, trees including mangroves shall be planted on the seaward side; beaches shall be left free of any development, appropriate coastal protection structures be constructed wherever required on a scientific basis; Sand dunes being natural speed breakers in the event of hazards shall be maintained or regenerated by planting shrubs or through appropriate measures. Restoration and pro-active conservation activities rather than mere regulation finds a mention in these clauses of the new notification although it remains largely a land-use and zoning law. It is possible that coastal protection and conservation efforts will gain impetus through formal recognition under the Environment (Protection) Act, 1986. The introduction of these activities into the notification could potentially ensure central and state support in financial, logistical and technical terms.

However, regeneration and restoration activities must be preceded by adequate ecological and socio economic studies. The factors that must be known are: the characteristics of the area prior to degradation, the socio-economic factors that were the root causes of degradation, the best options for restoration, mechanisms to reduce or eliminate factors that may cause degradation again and mechanisms to create support among local communities and government agencies for the restoration initiative. The practice of defining restoration initiatives by targets only in quantitative terms - number of saplings planted and extent of area brought under plantation, should become a thing of the past. Since the notification does mention these conservation related activities, it may have been useful to elaborate these clauses with appropriate guidelines as annexes.

All Ecologically Sensitive Areas will be demarcated as CMZ I in the new notification. These areas are to be managed as per the Integrated Management Plans (IMPs) prepared by the Ministry of

Environment & Forests through scientific institutions which will be implemented by the concerned State/Union Territory and monitored by the Coastal Zone Management Authority of State/Union Territory. The CMZ Notification pays little attention to CMZ I areas considering the sensitivity of these habitats. Prohibition of all activities that have the potential to alter these ecosystems should have been laid down as the guiding principle to protect these areas. Establishment of buffer areas around the identified CMZ I areas should have also been made mandatory. While it can be argued that these aspects can be built into the Management Plans, mentioning these protective measures in the text of the notification has immense significance for the implementation of these measures.

The set of activities that can be permitted on the seaward side of the setback line are mentioned below. The notification does not indicate how decision-making will take place to permit these activities. It is important to remember here that even dwelling units will not be allowed in this region. The absence of IMPs as the basis of management of CMZ III does not seem deliberate and could just be due to an assumption that these activities are welfare measures for coastal communities or to support their livelihoods. However, shipping, tourism and recreational facilities and waste disposal are also listed here quite inexplicably.

Activities permitted by the local/concerned authorities on the seaward side

- Boating, shipping and navigation.
- Fisheries including traditional fish processing units and ice crushing facilities.
- Mariculture including hatcheries and traditional aquaculture.
- Agriculture and horticulture.
- Public toilets and rain/cyclone shelters.
- Repair of existing buildings including reconstructions.

Activities to be permitted with the approval of State/UT Authority on the seaward side

- Temporary construction for tourism facilities.
- Coastal protection: The approach shall be to avoid 'hard engineering', while 'soft engineering' options shall be preferred.
- Bunding for the purpose of preventing coastal erosion salinity ingress, maintenance of waterways.
- Saltpans – for making salt by solar evaporation of seawater.
- Water sports and recreation facilities.
- Discharge of treated effluents shall be permitted as per the State/UT Pollution Control Boards norms.
- Forest related activities.
- Boat building and repair.
- Boat re-fuelling facilities.

4.6 CMZ and governance

The CMZ Notification is a central notification like the CRZ Notification and may depend heavily on the State Government for its implementation. Although the implementing agencies are not categorically mentioned for each of the categories, the CZMAs at the state and national level have been identified as the monitoring and enforcing agencies in the CMZ Notification. This has been envisaged without any attempt at understanding the main causes of non-implementation of existing law. The notification must be lucid and will need to be acceptable to all State Governments and will require a prior commitment

from them in terms of allocation of funds and other logistical support for any implementation to take effect.

Quality of IMPs: The management of coasts under the CMZ Notification relies heavily on the quality and process of preparation of IMPs. The process of developing IMPs will require adequate training to all relevant agencies as most agencies so far have worked with little or no capacities or coordination. Superior quality IMPs can be ensured by insulating the drafting process from political pressure, vested interests of donors and carefully selecting the agencies/individuals entrusted with developing these plans. These should have been ensured through guidelines or specific clauses in the CMZ Notification.

Validity of IMPs: The CMZ Notification ought to have granted IMPs a formal administrative and legal status. Since the plans are to be the integral documents, governing activities and projects on the coast, implementation and compliance with the CMZ Notification will have to measure against these plans.

Public hearings: The notification does not lay down a transparent and participatory process for the preparation of IMPs. The notification mentions the use of EIAs and public hearings in the decision-making for certain projects. However, without a procedural framework indicating how these will be done and at what stages in the process they are to take place, these provisions can go easily unimplemented or be counter-productive. The CMZ states, *'Defence related projects shall be approved by the Ministry of Environment and Forests based on an Environmental Impact Assessment and public hearing'*. EIAs are to be done for non-polluting activities to establish them on the seaward side of the set back line, but the clauses of transparency and guidelines for public participation are missing here. Unfortunately. There is no link to the procedures followed in the EIA Notification, under the EP Act, which lays down procedures for granting clearance to development projects that have the potential to cause environmental and social impacts.

Procedures: No procedures have been laid down for monitoring and enforcement of this law. CZMAs are vested with this responsibility but again without any direction or attention paid to procedures. CMZAs are to be strengthened, the notification states while failing to mention how. There are no process guidelines for selecting members, CZMA composition and appropriate staffing and funding for logistical and technical support. There is also no mention of any process of reporting the compliance from different states in such a way that implementation levels can be assessed and used to improve coastal management.

Decentralisation: The responsibility of district and village level institutions in ensuring implementation, monitoring and enforcement should have been made mandatory, as they are already being practiced in the states of Tamil Nadu and Kerala. The role of community groups in monitoring and regulation should have also been encouraged and facilitated.

Transparency: There are no clauses of transparency and public access to information, anywhere in the notification. It also doesn't provide information, suo moto, about any aspect of coastal management, be it the IMPs, specific project related documents or meeting minutes of Authorities/ Committees.

5. Suggestions for the future

The suggestions on moving forward draw from the earlier work and suggestions provided by the authors and other civil society groups on the subject of coastal zone management.

That the Swaminathan Committee Report was timely is not disputed considering the implementation track record of India's principal coastal protection law. The resultant effects of non-

performance is demonstrated after every disaster on the coast and through increasing local action against environmental destruction. The terms of reference of the Swaminathan Committee were also more holistic that those of earlier review committees. Earlier reviews of the notification were specially intended to dilute the restrictions imposed by the legislation on development activities such as urban construction, sand mining and tourism facilities. These review processes resulted in amendments that only weakened the protective clauses of this environmental law, without suggesting additional conservation measures or governance procedures, although these changes were much needed.

As the only complete review of the legislation, the Swaminathan Committee report has significance and will help to put in place an appropriate regulatory framework for coastal management and regulation. However, a sound coastal management review process ought to pay equal attention to the process and content of the Swaminathan recommendations. The Swaminathan Committee's review process fell short on both these counts. Therefore, it is strongly recommended that the Swaminathan Committee's report be seen as the first step towards the review of CRZ Notification rather than the last.

5.1 Process related recommendations

- It is of tremendous value to involve a representative cross-section of the public at the planning stage before actual changes are made to legislation. There should be major public consultations/workshops inviting various NGOs and resource persons to present the findings of the Swaminathan Committee Report and to build on it. The Swaminathan Committee's findings need to be discussed widely with several sections of people especially fishworker communities, fisher trade unions, local governments, traditional governance institutions in coastal areas. These groups have either been involved with the implementation of the CRZ Notification or have faced the impacts of its faulty implementation. Their inputs will be critical in determining a sound regulatory process for coastal conservation and to facilitate their involvement in its execution.
- The Swaminathan Committee Report should be discussed with regulatory agencies that have been involved with the implementation of the notification at the state and central levels. The Swaminathan Committee failed to consult SCZMAs and district committees that were responsible for implementation of the CRZ Notification at the state level on a day-to-day basis. A sound regulatory framework cannot be developed unless the problems faced by these agencies are fully understood. Their problems are of a varied nature and range from the logistical to the political. If these are not addressed, any new legislation brought in place of the CRZ Notification may run into the same problems.
- A participatory process for developing changes to legislation can be established by holding consultative group meetings, establishing task forces and thematic groups and conducting trainings and workshops for stakeholders.

5.2 Content related recommendations

- The UNDP commissioned independent review of the Swaminathan Committee Report criticised the recommendations of the Swaminathan Committee as falling short on scientific grounds. The review recommends that "it is however possible to overcome this inconsistency and other discrepancies outlined in the Swaminathan Report, by launching a complementary set of studies, and planning exercises, which are truly national in scope and participatory in approach" (Sridhar, et al., 2006)
- The UNDP review has specifically recommended research and documentation of primary and secondary ecological, legal and sociological information relevant to coastal conservation, required to guide policy changes. All the un-addressed deficiencies with the CRZ Notification should be

collated. There are several studies and reports done by institutions and NGOs that can be referred to as well as various letters, memoranda and petitions highlighting these deficiencies.

- It is also essential to commission a study to understand coastal management policies and tools followed by other countries and identify suitable best practices. This would also include their policy/ legislative responses to coastal hazards and development challenges.
- A mechanism to grant usufruct rights of fishers over coastal areas with appropriate conservation conditions must be devised. These must be formally incorporated into the coastal management framework. The framework for coastal management must be firmly based on the priority given to fishworker communities as having the first right to coastal areas.

Some aspects listed below need to be incorporated in any new legislation proposed for coastal conservation and management.

- Incorporation of hazard and risk management and flood plain management and wetland drainage design in the overall coastal management mechanism and in the designing of the vulnerability line.
- Flexibility in the concept of the vulnerability line with proper guidelines and procedures for changes. The provisions for change of the vulnerability line should not be misused for dilution to pave for development activities in this sensitive area.
- A detailed set of guidelines for the identification of the Ecologically Sensitive Areas and the degree of protection they require.
- A review of the utility and effectiveness of bio-shields must precede plantation work on the coast. These reviews should be supplemented with complete impact assessment studies, identification of alternatives and assessments of particular species as actual bio-shields.
- The legislation should contain a specific list of projects for each zone on the coast for which Environment Impact Assessment procedures are mandatory (notwithstanding any list prepared under other legislations). These must employ rigorous BACI (Before-After-Control-Impact) designed studies that are ongoing processes, lasting as long as the development activity is being conducted.

The MoEF proposes to replace the present CRZ Notification with the draft CMZ Notification. The draft is an outcome of the Swaminathan Committee report but has unfortunately passed by all the positive aspects of the report. It is only termed a 'management' notification, but in actuality has little more than the old zonation approach of the CRZ Notification. Even in this, it fails to prohibit activities with established negative impacts. There are no procedures outlined for enforcement and monitoring in this law. It will be useful to start the process of drafting legislation for coastal management after a thorough process of consultation is undertaken as mentioned above. It must also be ensured that groundwork on the CMZ Notification is not begun until a new legislation is debated. A time frame of two years may be given to all State Governments to undertake the necessary groundwork for the implementation of the new notification.

Until the new legislation is ready, and all the groundwork for this is done, the existing CRZ Notification must be implemented. In order to make this possible, the MoEF must immediately redress several long pending areas of confusion, vagueness and arbitrariness of the CRZ notification. The most significant of these issues are:

- The multiple interpretations of CRZ clauses by various MoEF orders and legal judgements.
- The lack of definitions of terminology used in the CRZ Notification.

- Specific mention of the agencies responsible and elaboration of the process for the grant of clearance for various activities listed in the notification.
- Guidelines for development / rehabilitation activities in the tsunami affected states in the context of the provisions of coastal laws.
- Preparation of detailed geo-referenced maps to be publicly available and accessible, for the entire coast to facilitate a GIS-based approach to coastal zone management.
- Specific mention of the punitive measures and guidelines for taking action against violators of the CRZ Notification in the text of the notification.
- Introducing into the notification appropriate clauses of transparency and public access to all documents, minutes and decisions of all the regulatory agencies and authorities involved in the implementation of the CRZ Notification.

It is essential for the MoEF to state categorically that violations of the present notification will not be overlooked once the new notification becomes applicable. If this is not done, the message to violators will be that the present and future violations will be regularised in time. This is bound to set a very poor precedent and will make future implementation of any coastal conservation law impossible.

The two-year transition period could be used by the regulatory agencies to commission status reports on the implementation of the CRZ Notification and the violations that exist until a cut off date. This is essential to initiate the implementation of the new notification with base line information of the present violators and to ensure that the list of defaulters does not get longer. Appropriate action against violators must be initiated during the transition phase.

Changes to current coastal management approaches and legislation are indeed the need of the hour. An understanding of the root causes of non-compliance and non-implementation of the CRZ Notification will be essential to identify the shape that new legislation should take. This report attempted to piece together the experiences with one such legislation. Similar studies on other relevant coastal management legislations should also be undertaken.

Annexure I

Activities prohibited within the Coastal Regulation Zone

1. Manufacture or handling or storage or disposal of hazardous substances as specified in the Notifications of the Government of India in the Ministry of Environment & Forests. No. S.O. 594(E) dated 28th July, 1989 (Hazardous Wastes), S.O. 966(E) dated 27th November, 1989 (Hazardous Chemicals) and GSR 1037(E) dated 5th December, 1989 (Hazardous Micro Organisms Genetically Engineered Organisms Or Cells)
2. Setting up of new fish processing units including warehousing
3. Setting up and expansion of units / mechanisms for disposal of wastes and effluents
4. Discharge of untreated wastes and effluents from industries, cities or towns and other human settlements - existing practices to be phased out in 3 years
5. Dumping of city or town waste for the purposes of land filling or otherwise - existing practices to be phased out in 3 years
6. Dumping of ash or any wastes from thermal power stations
7. Land reclamation for commercial purposes such as shopping and housing complexes, hotels and entertainment activities
8. Mining of sands, rocks and other substrata materials
9. Harvesting or drawal of ground water and construction of mechanisms therefore within 200 m of HTL
10. Construction activities in the CRZ -I
11. Dressing or altering of sand dunes, hills, natural features including landscape changes for beautification, recreational and other such purposes
12. Construction of buildings on the landward side on any new roads except roads approved in the Coastal Zone Management Plan, which are constructed on the seaward side of an existing road
13. In ecologically sensitive areas (such as marine parks, mangroves, coral reefs, breeding and spawning grounds of fish, wildlife habitats and such other areas as may be notified by the Central/State Government/Union Territories) construction of beach resorts/hotels
14. In CRZ-IV ANI, corals from the beaches and coastal waters shall not be used for construction and other purposes
15. In CRZ-IV ANI dredging and underwater blasting in and around coral formations shall not be permitted
16. In CRZ-IV LK, corals from the beaches and coastal waters shall not be used for construction and other purposes
17. In CRZ-IV LK dredging and underwater blasting in and around coral formations shall not be permitted

Annexure 2

Activities permitted (under conditions) within the Coastal Regulation Zone

1. Industries directly related to waterfront or directly needing foreshore facilities.
2. Projects of Department of Atomic Energy.
3. Non-polluting industries in the field of information technology in SEZs.
4. Other service industries in the Coastal Regulation Zone of Special Economic Zones (SEZ); Specified activities / facilities in SEZs.
5. Facilities for generating power by non-conventional energy sources.
6. Desalination plants.
7. Construction of airstrips and associated facilities in the islands of Lakshadweep and ANI.
8. Transfer of hazardous substances from ships to ports, terminals and refineries and vice versa, in the port areas.
9. Facilities for receipt and storage of petroleum products and Liquefied Natural Gas as specified in Annexure III appended to this notification and facilities for re-gasification of Liquefied Natural Gas, may be permitted within the said Zone.
10. Expansion of fish processing units.
11. Hatchery and natural fish drying in permitted areas.
12. Setting up and expansion of units / mechanisms for disposal of wastes and treated effluents into watercourse.
13. Storm water drains.
14. Setting up and expansion of units / mechanisms for treatment and disposal of wastes and effluents arising from hotels and beach resorts located in Coastal Regulation Zone areas.
15. Setting up and expansion of units / mechanisms for treatment and disposal of wastes and effluents of domestic or municipal sewage in the Union territories of the Andaman and Nicobar Islands and Lakshadweep.
16. Land reclamation, bunding or disturbing the natural course of sea water required for conservation or modernisation or expansion of ports, harbours, jetties, wharves, quays, slipways, bridges and sea-links and for other facilities that are essential for activities permissible under the notification or for control of coastal erosion and maintenance or clearing of waterways, channels and ports or for prevention of sandbars or for tidal regulators, storm water drains or for structures for prevention of salinity ingress and sweet water recharge.
17. Mining of rare minerals not available outside the CRZ areas.
18. Exploration and extraction of Oil and Natural Gas and associated activities and facilities.
19. Sand mining in ANI.
20. Harvesting or drawal of ground water in the 200-500m area.
21. Harvesting or drawal of ground water in the 50-200m area.
22. Harvesting or drawal of ground water in areas within 200m or the CRZ whichever is less.

23. Construction activity for facilities for carrying treated effluents and waste-water discharges into the sea, facilities for carrying sea water for cooling purposes, oil, gas and similar pipelines and facilities essential for activities permitted under this Notification.
24. Defence requirements for which foreshore facilities are essential such as slipways, jetties, wharves and quays.
25. Operational constructions for ports, harbours and lighthouses and construction activities of jetties, wharves, quays, slip ways.
26. Constructions or modernisation or expansion of jetties and wharves in the Union territory of Lakshadweep for providing embarkation and disembarkation facilities.
27. Foreshore facilities for transport of raw materials facilities for in-take of cooling water and outfall for discharge of treated waste water / cooling water of thermal power plants
28. Housing schemes in CRZ
29. Weather radars for cyclone movement and prediction by IMD
30. Demolition or reconstruction of buildings of archaeological or historical importance
31. Demolition or reconstruction of heritage buildings
32. Demolition or reconstruction of buildings under public use including those used for purposes of worship, education, medical care and cultural activities.
33. All other activities with investment of five crore rupees or more
34. Other activities with investment less than five crore rupees
35. All development and activities within the CRZ other than those covered in para 2 and para 3 (2)
36. Pipelines and conveying system including transmission lines
37. Facilities that are essential for activities permitted under CRZ -I
38. Construction of trans-harbour sea links
39. Construction of dispensaries, schools, public rain shelters, community toilets, bridges, roads, jetties, water supply, drainage, sewerage which are required for traditional inhabitants of the Sunderbans Bio-sphere reserve area of West Bengal, on a case to case basis
40. Salt harvesting by solar evaporation of sea water
41. Storage of non hazardous cargo such as edible oil, fertilizers and food grain within notified ports
42. Housing schemes of the State Urban Development Authorities
43. Reconstruction of the authorised buildings to be permitted
44. Repairs of existing authorised structures for permissible activities under the notification including facilities essential for such activities
45. Agriculture, horticulture, gardens, pastures, parks, playfields, forestry
46. Construction of dispensaries, schools, public rain shelters, community toilets, bridges, roads and provision of facilities for water supply, drainage, sewerage which
47. Construction of units or ancillary thereto for domestic sewage treatment and disposal
48. Tourism in the ANI

49. Construction of hotels/beach resorts for temporary occupation of tourists/visitors subject to the conditions as stipulated in the guidelines at Annexure-II
50. Construction/reconstruction of dwelling units
51. Reconstruction/alterations of existing authorised buildings
52. Construction of non–polluting industries in the field of information technology and other service industries, desalination plants, beach resorts and related recreational facilities essential for promotion of SEZ
53. Buildings in CRZ-IV -ANI
54. Construction of buildings in CRZ-VI in Lakshadweep and small islands
55. Tourism in the Lakshadweep

Annexure 3

The schema of the CMZ Notification

CMZ I	CMZ II	CMZ III	CMZ IV
Description of Zone			
All ESAs as mentioned in CMZ Notification 2006	Coastal Municipality/Corporations and Coastal *Panchayats* with population density more than 400/sq km; ports and harbours, tourism areas, Declared Tourism Areas, Mining sites, Approved Industrial Estates, Special Economic Zone, Heritage areas, Archaeological sites, Defence areas /installations, Atomic/thermal/other power plants	All open areas including coastal seas but excluding those areas classified as CMZ-I, II and IV	Andaman and Nicobar and Lakshadweep.
Agency responsible for site identification			
Sites to be identified by MoEF	Site to be identified by relevant departments; Heritage areas & archaeological sites to be identified by MoEF, concerned Ministry & ASI.	NA	NA
Basis of management			
IMPs to be prepared by MoEF through scientific institutions	IMPs to be prepared by prepared by local bodies/concerned agencies/scientific institutions and approved by MoEF for *panchayats*/municipalities /corporations. To be prepared by Ministry of Tourism and the State/UT Tourism Department for tourism sites. No IMPs for other activity areas under this category		Integrated Coastal Zone Management plan prepared by the MoEF.
Implementation agency			
Implemented by the concerned State/UT	-	-	-
Monitoring agency*			
Monitored by the CZMA of State/Union Territory.	-	-	-
Funds			
Necessary funding will be earmarked and provided by MoEF	-	-	-
Agency to grant clearance for activities			
-	MoEf to grant permission (based on EIA) for: mining of placer minerals, oil & gas, other minerals found in coastal & offshore areas; activities requiring foreshore facilities & which are non-polluting; Defence related projects (based on PH).	Activities that may be permitted on the seaward side of the setback line to be permitted by local body/ state or UT (with EIA only for jetties and fishing harbours) /MoEF (with EIA)	-

* A general statement about monitoring and enforcement agencies in the CMZ Notification is *"For the purpose of monitoring and enforcing the Coastal Management Zone Notification the Central Government will strengthen the existing National and State/UT Coastal Zone Management Authorities constituted under Environment (Protection) Act 1986."*

Notes

[1] The PTEI is executed by UNDP and implemented by the Ashoka Trust for Research in Ecology and the Environment, Citizen, consumer and civic Action Group and the Nature Conservation Foundation (www.ptei-india.org). The project aims to understand coastal vulnerability and resilience in the face of such natural disasters within the Indian context, establish participatory ecological and community monitoring systems, critically analyse developmental policy with respect to coast, and develop management models for key sites along the coast.

[2] Anonymous. 2005. States request more stringent Coastal Regulation Zone guidelines. *The Hindu, 10th January*.

[3] Interview with P.B.Sahasranaman, environment lawyer, who had filed a petition in the High Court of Kerala on the post-tsunami constructions within the CRZ in Kerala (W.P. (C). No. 883 of 2005). August 2006.

[4] Interviews conducted in the course of this study seemed to indicate that the need for implementing the CRZ, post-tsunami was appreciated by government bureaucrats, fishworker leaders and NGOs.

[5] Interview with TSS Mani, a human rights activist and advisor to FIMCOTN, a fishworkers association in Tamil Nadu, October 2006.

[6] Ibid 5

[7] See Rangarajan, 2006 for an account of Mrs. Gandhi's involvement in environmental struggles and her motivations.

[8] The complete quotation is worth mention here as it signifies the idea of coastal protection she was approached with – "I have received a number of reports about the degradation and mis-utilisation of beaches in our coastal states by building and other activity. This is worrying as the beaches have aesthetic and environmental value as well as other uses. They have to be kept clear of all activities at least upto 500 metres from the water at the maximum high tide. If the area is vulnerable to erosion, suitable trees and plants have to be planted on the beach sands without marring their beauty. Beaches must be kept free from all kinds of artificial development. Pollution from industrial and town wastes must be also avoided totally. Please give thought to this matter and ensure that our lovely coastline and its beaches remain unsullied."

[9] Anon. 1993. Seas become rubbish dumps. Pollution in coastal areas increasing. *Indian Express*, June 12.

[10] Interview with Bharat Jairaj, Environment Lawyer, CAG, Chennai. October 2006.

[11] Supreme Court Order dated 18th April 1996 in W.P.(C) No.664 of 1993 issued in the petition filed by the Indian Council for Enviro-Legal Action.

[12] Chainani's chapter on the CRZ mentions that a meeting with held with the Govt of Maharashtra on Nov 20th, 1990, wherein environmentalists from the state also participated.

[13] A detailed step-by-step account leading upto the gazetting of the CRZ Notification is available in Chainani's chapter on CRZ, perhaps the only such document of its kind.

[14] For the purposes of the notification, "developed area" is referred to as that area within municipal limits or in other legally designated urban areas which are already substantially built up and which have been provided with drainage and approach roads and other infrastructural facilities, such as water supply and sewerage mains.

[15] Interview with T. Peter, Kerala Swatantra Matsya Tozhilali Union, August 2006.

[16] PASI was led by community leaders and environmentalists such as S. Jagannathan of the Land For Tillers movement, Tamil Nadu, Jacob D. Raj of the NGO 'Prepare' in Andhra Pradesh, Shri. Banka Behari Das representing the Orissa Krushak Mahasangha, Vandana Shiva of the Research Foundation for Science and Ecology, New Delhi and Claude Alvares from The Goa Foundation, Mapusa, among others.

[17] Vide Order dated 11th December 1996 in W.P (C) No. 561 of 1994 in the matter of S. Jagannath v. Union of India

[18] The Supreme Court in its order stated that all aquaculture industry/shrimp culture industry/shrimp culture ponds that were illegal should be demolished before March 1997.

[19] Ibid 11

[20] These objectives were identified by Dr B Baba and Dr John Kurien who are members of the present Kerala Coastal Zone Management Authority and also by environmental lawyer P.B Sahasranaman in interviews conducted in August 2006

[21] Also available in http://www.india-seminar.com/2000/492/492%20d.%20goenka.htm

[22] Interview with Bharat Jairaj, October 2006.

[23] Ibid 22

[24] Ibid 22

[25] T. Mohan is a Chennai-based environmental lawyer, who has argued many cases on the CRZ Notification and environmental matters in Tamil Nadu.

[26] For the purposes of this study, amendments upto 24th July 2003 alone have been considered since there is some ambiguity with the subsequent two notifications' clauses.

[27] Parliament enacts laws from time to time by way of Central "Acts" and these Acts are implemented by the various Ministries/Departments of Government of India, that is, the Executive. It is a well-recognised principle that the law enacted by Parliament cannot be comprehensive enough so as to visualise each and every eventuality that may arise during the course of its implementation and make a provision for it in the Act in anticipation. In order to cover for such contingencies, the Central Acts generally contain a provision authorising the Central Government to frame rules/regulations, etc. in certain specified areas to enable Government to carry out the objective of the Act. These rules/regulations framed in exercise of the powers conferred by an Act of Parliament is termed as "Subordinate Legislation". In a similar manner, framing of Subordinate Legislation is also contemplated in the Constitution of India. (http://rajyasabha.nic.in/com_sub_legis/coslbrief.htm)

[28] Ibid 22

[29] Ibid 11

[30] The Coastal Watch Programme of Equations, an NGO based in Bangalore for example, organised a strategic meeting of organisations and individuals on "Coastal Zone Management Authorities" on June 20, 1999. The issues highlighted at the meeting were the ambiguous roles of the authorities, the presence of multiple agencies with overlapping roles, the profile and composition of the SCZMAs and the NCZMA, and the unclear role of the local bodies in this decision-making mechanism. The problems with the SCZMA composition were mentioned in interviews with P. B. Sahasranaman and Dr. John Kurien, member CZMA and Professor, Centre for Development Studies. August 2006.

[31] Interview with P. B. Sahasranaman, Kerala based environmental lawyer, Cochin, August 2006.

[32] Interview with Dr. K. Kokkal, member CZMA and Principal Scientific Officer, Kerala State Council for Science, Technology and Environment, Thiruvananthapuram, August 2006

[33] Ibid 31

[34] Ibid 31

[35] Interviews with Dr. John Kurien, Bharat Jairaj. August and October 2006

[36] Interviews with Dr. B Baba, Director, Centre for Earth Science Studies and Dr. K.V Thomas, Scientist, Centre for Earth Science Studies, August 2006, Thiruvananthapuram.

[37] Interview with Dr. B. Baba, Centre for Earth Science Studies, Thiruvananthapuram, August 2006.

[38] Ibid 32

[39] Letter No 18123/EC.3/2000-1, dated 14.8.2000

[40] Letter from the TN CZMA to Mr. Dharmesh Shah's application dated December 2006.

[41] Ibid 31

[42] Interviews with Dr. B Baba, Dr John Kurien, Dr. K. Kokkal, August 2006

[43] Interview with Dr. K. Kokkal, August 2006

[44] Ibid 44

[45] The RTI response letter states that the six-monthly reports and minutes are submitted to the MoEF and hence copies are not available with the authority.

[46] Ibid 31

[47] Interview with Mr. Nityanand Jayaraman, Corporate Accountability Desk. October 2006.

[48] Ibid 40

[49] Clauses ii (a) and iv of the notifications for the setting up of CZMAs.

[50] Ibid 31

[51] Interview with Mr. Neelakanthan, Member Secretary of the TN CZMA, October 2006.

[52] The minutes of the Swaminathan Committee were obtained through a Right to Information application in December 2006.

[53] Ibid 13

[54] Ibid 10

[55] Via G.O. MS. No 165, Environment & Forests (EC –III) Department dated 9.6.98.

[56] Via Government Letter MS No 35 (EC –III) dated 15.3.2005.

[57] Interview with Dr. John Kurien. Professor, Centre for Development Studies, Thiruvananthapuram, August 2006.

[58] Interview with P. B. Sahasranaman, 2006 and Dr. K. Kokkal. August 2006.

[59] Consultation on "Reconstruction of Shelters and Community Infrastructure" in collaboration with UN Team for Recovery Support in Chennai on 12-04-2005 at the Indian Institute of Technology, Chennai.

[60] Ibid 5
[61] Ibid 5
[62] Writ Petition (C) No. 883 of 2005. Association for Environmental Protection vs State of Kerala and others
[63] The reengineering process resulted in a new Environment Impact Assessment notification 2006 despite severe criticism from NGOs and project-affected communities.
[64] Interviews with members of the Kerala and Tamil Nadu CZMAs.
[65] Also see http://www.thehindubusinessline.com/2006/06/28/stories/2006062802451200.htm
[66] Also see http://www.hindu.com/2006/06/27/stories/2006062718720300.htm

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Chapter 5 A preliminary socio-ecological review of post-tsunami ecosystem-derived livelihoods and rehabilitation efforts

Sudarshan Rodriguez[79]

Introduction

There has been a very limited focus on socio-ecological, socio-environmental and environmental aspects of the tsunami and the subsequent reconstruction & rehabilitation. The spatial database developed in this project captures and analyses a range of the various impacts of the tsunami and the subsequent rehabilitation quantitatively. However, some of the process level details and socio-ecological aspects of the tsunami impact and rehabilitation efforts can be reviewed and understood only qualitatively due to absence of either quantitative data or due to the lack of spatial uniformity in information. This chapter aims to review this literature and carry out a preliminary analysis of the same and make recommendations.

The first part of this chapter deals with the impacts of the tsunami and the subsequent rehabilitation of ecosystem-derived livelihoods. One of the major impacts of the tsunami other than loss of lives and infrastructure was the immediate and long-term effects on livelihoods. The major ecosystem derived livelihoods were fisheries and agriculture. The other livelihood source though not directly ecosystem derived, is aquaculture, but is linked to both agriculture and fisheries in the aspects of land use (spatial location next to estuaries, areas of conversion of mangroves and agriculture land), resource use (brackish water, sea water) and production. This sector, in addition to being linked to ecosystem-derived livelihoods, has also been plagued with environmental and social problems in the past (and continues to be so) and hence is reviewed here. The second part deals with all other socio-ecological and environmental aspects of rehabilitation and reconstruction activity in the affected areas.

Under fisheries aspects of the analysis of rehabilitation, over capacity and the resumption of fishing post-tsunami and its different contexts is reviewed. An attempt to understand the underlying causes of rehabilitation and over-capacity through the existing literature and analyses of secondary data is made. It also looks at the data and literature on asset base, catch effort, fish catch and income data, post-tsunami to understand the current situation of fisheries and the current gaps in knowledge/data. Further, two aspects in fisheries are also reviewed namely, the studies on community perceptions of changes post-tsunami and the unique contexts of the cases of group ownership in the pre and post-tsunami scenario.

Under agriculture, an overview of some of the studies of the impacts, especially on soil and water is done. Some of the background trends and coping mechanism of farmers are highlighted. One of the other important and often neglected resources of the coast is the groundwater. It is a scarce and vulnerable resource which in many coastal areas has already been severely impacted/ affected due to a wide variety of factors. The impact of the tsunami and implication of rehabilitation efforts on this vital resource is reviewed and analysed.

The second part of the chapter reviews the environmental and socio-ecological implications of rehabilitation. Here livelihood related issues in re-location and housing layout are examined and the environmental issues and concerns in planning of housing reconstruction such as groundwater, sanitation,

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site selection, wetland drainage etc. are highlighted. The interventions of hard engineering options and bio-shields, both major initiatives of the post-tsunami reconstruction, are examined revealing social, ecological, livelihood implications.

Finally, based on the observations of gaps, opportunities, issues and needs identified above a set of recommendations are made.

PART I- ECOSYSTEM-DERIVED LIVELIHOODS

Fisheries

The stagnation of fish production in the tsunami affected areas especially Tamil Nadu coupled with increase in craft and gear over the last two decades, warrants the need for a combination of management measures, precautionary approaches and livelihood strategies towards restoration and rehabilitation of fisheries in the affected districts post-tsunami. The fishing community, in particular, known for their self-reliance rarely sought assistance from outsiders or the government. Post-tsunami they were not interested in merely being passive recipients of relief and rehabilitation efforts, but instead wanted to get involved and take responsibility for relief and rehabilitation. Many communities were finding creative ways to take their own initiative in the restoration of their livelihoods (Kannam, 2005). This along with their remarkable trademark of independence and self-reliance is a strong indication of their resilience.

Resumption of fishing

One of the key questions that comes up when one enquires or explores the resilience of the fishing community in the light of the tsunami, is how soon communities are able to resume fishing or restore status quo in terms of their livelihood. One would of course, also need to analyse the factors and the context that influenced the resumption of fishing or restoration of the status quo.

As a result of the damage and loss of craft and gear, for at least three months there wasn't any fishing in the traditional sector and up to seven months in the mechanised sector in severely affected areas.[80] In some cases, fishing did not resume till over 6 months (TRINet, 2005c). The delay was mainly due to repair of boats, engines and procurement of new nets (Thaddeus, 2005a). The issue of compensation disbursement also played a role in the resumption of fishing (TRINet, 2005c). For eg., in Nagapattinam District, Arcottuthurai was the first fishing hamlet that resumed fishing after the tsunami. The fisherfolk in this village all belonged to the Padayachi (Vanniyar) community, which had no traditional interactions and links with other fishing hamlets in the district and their feeling of solidarity with the Pattinavar hamlets was weak. They neither waited for other fishing hamlets to take a collective decision nor waited for the District Administration to declare its fishery compensation policy (unlike the case of the Pattinavar hamlets, which waited for the policy and only then resumed fishing). This hamlet wanted to resume fishing as early as possible and was mentally prepared to do so. By 21st March, 2006 they ventured into the sea, while the other fishing hamlets were struggling to prepare themselves. The *Panchayat* in this village showed a special interest in sending the fishermen to sea as early as possible as they felt that earning an income was very important in a crisis. They also felt that going to sea would reduce tension within the village (Thaddeus, 2005a).

In some villages, in the initial stages, when there was a shortage of craft, the NGO intervention in craft donation was limited in scale, and the population of fishermen without craft was large. Studies mention that 6-7 persons were assigned per FRP boat instead of the normal 4-5 in order to share the

[80] It may be noted here that there is also a 45 day fishing ban for this sector between, 1 April and May 15, hence a postponement of repair of boats happened.

income of fishing among more families (Thaddeus, 2005a). This adaptation is perhaps a good indicator of socio-ecological resilience. However, no information exists on the duration of this practice or the prevalence of this among all the tsunami-affected villages.

In many hamlets, especially Pattinavar villages, there was a general rule that fishing would not resume till all members had seaworthy craft (Gomathy, 2006; TRINet 2005). This aspect of the sense of unity, social justice and equity within the community (in terms of assets and resources) is indeed worth exploring in studying its implications for socio-ecological resilience, even though it actually resulted in a delay in the resumption of fishing. In some cases, NGOs had asked communities not to resume fishing. Furthermore, the villages in Karaikal and Nagapattinam followed the 64 village cluster kinship system, with a head village for each clusters of 8, 16, 32 and 64 villages, in which villages resumed fishing only they received a letter issued by the head of the village permitting them to start fishing (Gomathy, 2006 ; Thaddeus, 2005a). It should be noted here that before the official resumption of commercial fishing, subsistence fishing (documented at least in Nagapattinam) on Kattumaram and FRP Boats had resumed in February 2005 itself (TRINet, 2005c). There is no systematic data and information for all the affected villages on this aspect as well. It is believed that in the stretches close to urban centres such as Chennai, i.e. Kanchipuram and Villupuram Districts, fishing resumed much earlier.

Another reason for the delay in resumption of fishing that was mentioned in one study was that when the crafts were repaired /replaced, suitable nets were not available for a long time and in some cases boats were received/replaced but not engines and this resulted in many of the boats lying idle (Salagrama, 2006).

Some micro level studies also cite that there was a fear of the sea in the fishermen's psyche. Fishermen were scared and tried to avoid going to sea, even in conditions similar to what they were used to earlier. This has been reported by many studies, but systematic quantitative data on the same is absent (Thaddeus, 2005a; Thaddeus, 2005b; Salagrama, 2006; Gomathy, 2006; TRINet, 2005c). One study points out that in some cases the fear of the sea had gradually transited into idleness. Many fishermen simply preferred being on land and the extended relief assistance and the compensation they received in cash made them cling on to this idleness (Thaddeus, 2005a).

A summary of the various factors that influenced the resumption of fishing is summarised below:

Box 1: Summary of the factors that influenced resumption of fishing

- Lack of craft
- Lack of suitable nets, engines and gear
- Waiting for Government policy on compensation
- Waiting for restoration of rehabilitation to pre tsunami numbers (till all members had seaworthy craft)
- Waiting for instruction of head village
- Poor quality of boats and frequent repairs
- Non provision of correct nets
- Conflicts –in group ownership
- Unable to adapt to gear /craft
- Fear of the sea
- Fear of the sea transiting into idleness

It is clear from the above that a multitude of factors influenced resumption of fishing; they include internal factors such as culture, caste, equity, community institutions, demography, community cohesiveness, internal conflict, and conflict resolution, as well as external factors such as government policy and NGO rehabilitation interventions. Furthermore, some of these factors in particular contexts actually led to a delay in the resumption of fishing and thus one would need to analyse these factors and contexts. However, there is no systematic data on this available from Kerala, Andhra Pradesh, or Pondicherry and there is only some scattered information in Nagapattinam in a few studies that briefly mention these situations and factors.

Impact of rehabilitation and over-capacity

Immediately about 4 months after the tsunami, it was increasingly becoming evident that in the artisanal fisheries sector the total craft numbers would exceed pre-tsunami levels. This trend would prove counter productive, as fish catches from Tamil Nadu had stagnated for the last few years, and would not result in increased catch or income. This situation would actually lead to over capitalisation, uneconomic operations and even resource depletion (NCRC, 2005e; M. Kasim 2005, pers. comm.). Despite many workshops, recommendations and advocacy efforts regarding the above, this trend was not addressed (SIFFS, 2005; Thaddeus, 2005a). Fortunately this trend did not occur in the mechanised sector.

There have been studies that have analysed the reasons for the above situation and they are again only confined to Nagapattinam. Their conclusions highlight the failure of civil society organisations (CSOs), the government policy environment and traditional *panchayat* institutions. Basically, the initial agreement between CSOs and the Government was to have a 50 -50 contribution of Rs 75, 000 each for replacing FRP boats and that any boats repaired by NGOs would not be eligible for compensation. This agreement was not followed by either of them and neither did the traditional *panchayats* want this. There was a big rush by NGOs to distribute boats and the traditional *panchayat* wanted to get as many as possible from the Government and CSOs (Thaddeus, 2005a; Thaddeus, 2005b; TRINET 2005c). However, the main principle of the traditional *panchayats* was to ensure that all those who had lost craft and gear were compensated adequately and only then were all surpluses to be distributed among other members (Gomathy, 2006).

There were also cases of NGOs donating boats and setting up group ownership with the crews. This was due to the entry of organisations that had no prior experience of working with fishing communities and applying an agrarian understanding/analysis (equating fishing labour to landless labour) to these communities in post-tsunami rehabilitation (Mathew, 2005a). Some studies mention that the NGOs were looking for reasons and ways to distribute boats, even though the government packages would have adequately covered and compensated all damages (Salagrama, 2005).

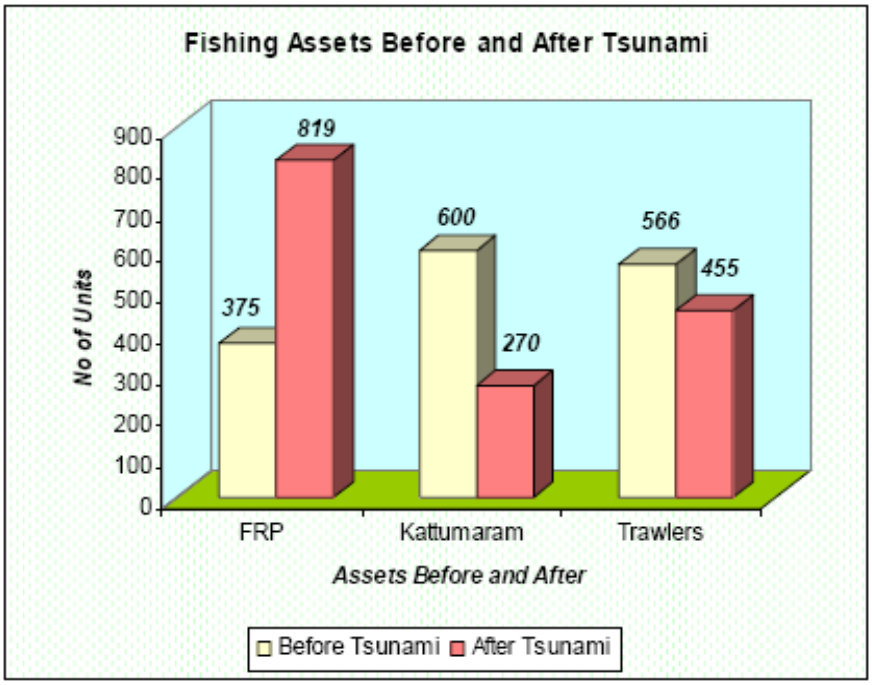
Asset base

When looking at composition of the asset base in the traditional sector there was an initial decrease in the number of catamarans which were replaced by the FRP boats. This was because in Tamil Nadu, catamaran damages and losses were paid in full and proof did not have to be attached. In fact, a study cites the reason for this situation compensation being in excess of the pre-tsunami levels (Salagrama, 2006). However, very few wooden catamarans were replaced and most fishers shifted to FRPs. One of the reasons was due to the immediate non-availability of wood (in terms of scale) and that replacement and provision of FRPs were much easier than catamarans. Secondly, there was also a lack of interest among fishermen in owning a catamaran and most opted for an FRP instead (Thaddeus, 2005a; Thaddeus, 2005b; TRINET 2005c). This was a background trend even pre-tsunami, especially in the nineties with

many catamaran fishers switching over to FRPs popularly attributed the competition from the trawlers (Banerjee, 2005; Thomas, 2005a).

In fact one study reveals that in Nagapattinam alone, FRP boats saw a 2.18 times increase (in number) along with upgrades in capacity (engine capacity from 6-7 HP to 10 HP) while catamarans had a 55 % decline. The graph below shows changes in assets base before and after the tsunami:

*Figure 1: Fisheries asset before and after tsunami**



*Source: Thaddeus, Koriya P. 2005a

It is interesting to note that the number of trawlers had reduced. This is due to the fact that many trawler owners did not reinvest but diversified into FRP boats, as they considered trawling no longer viable (Thaddeus 2005b; Salagrama, 2005). A hamlet wise asset worth gives a better picture of the situation, two examples from a study are given below to illustrate the situation:

*Table 1&2: Total net worth of fishing assets- before and after tsunami**

Fishing Hamlets	Total Worth of Assets before Tsunami	Total Worth of Assets after Tsunami	Change in Net worth after Tsunami
Arcotturhurai	150636000	165470000	14834000
Akkarapettai	323085000	339330000	16245000
Tharangambadi	72870000	79170000	6300000
Nambiar Nagar	94059000	42510000	-51549000
Total	**640650000**	**626480000**	**-14170000**

*Source: Thaddeus, Koriya P. 2005a

Total Net Worth of Fishing Assets in Tharangambadi- before and after Tsunami

Craft Types	No of Units before Tsunami	Total Worth Before Tsunami	No of Units after Tsunami	No of Units Repaired/ Undamaged	Worth of Repaired/Undamaged Assets	New Units	Worth of New Units	Total Worth of Assets after Tsunami
FRP	168	15120000	295	160	14400000	135	20250000	34650000
Kattumaram	100	2100000	20	20	420000	0	0	420000
Trawlers	53	55650000	42	42	44100000	0	0	44100000
Total	321	72870000	357					79170000

Total Increase in Value of Asset – 6300000

It is felt that actual numbers of craft are definitely more than the official figures. It must be noted here that getting data by any agency on over capacity, gear and fleet strength is difficult and sensitive (even for NGOs working with communities). Comparing with pre-tsunami levels is virtually impossible as many of the boats pre-tsunami were not registered and it is not known if all of the boats have been registered post-tsunami.

In the case of nets another study reveals that there is no significant change in the average number and weight of nets being used post-tsunami (Bhalla, 2006). The same study also mentions that there is a significant increase in the mesh size of nets being used for which the reasons are not known. But this may actually be a shift in the preference to the type of nets being used of which data was not collected or also due to the fact that sampling was restricted to a single season (use of nets vary with season). There are also reports of the increase in the use destructive of fishing gear such as mini seine nets ("surukuvalai") and drag nets post-tsunami. However, the extent of this is not known (Bhalla, 2006; Bhalla, 2007).

In the case of hook and line fishing the average numbers of fishers pre and post –tsunami remains the same, but there is a significant increase in the average length of the line used. The number and capacities of the engines have also both increased significantly with shift of the brands being used (Bhalla, 2006).

In the case of crew size, the earlier theory was that the increase in number of boats would create a shortage of crew. The study by Green Coast shows that this is not the case and that both the average crew size as well as number of active fishers have increased post-tsunami (Bhalla, 2006).

There has been some stock taking of these aspects of asset base only in Nagapattinam, but not in any of the other affected districts. Below is a summary of crafts used pre and post tsunami showing the increase. It is likely that the actual numbers would exceed those shown below.

Table 3: Available boats (Non-mechanised) pre-tsunami & post-tsunami

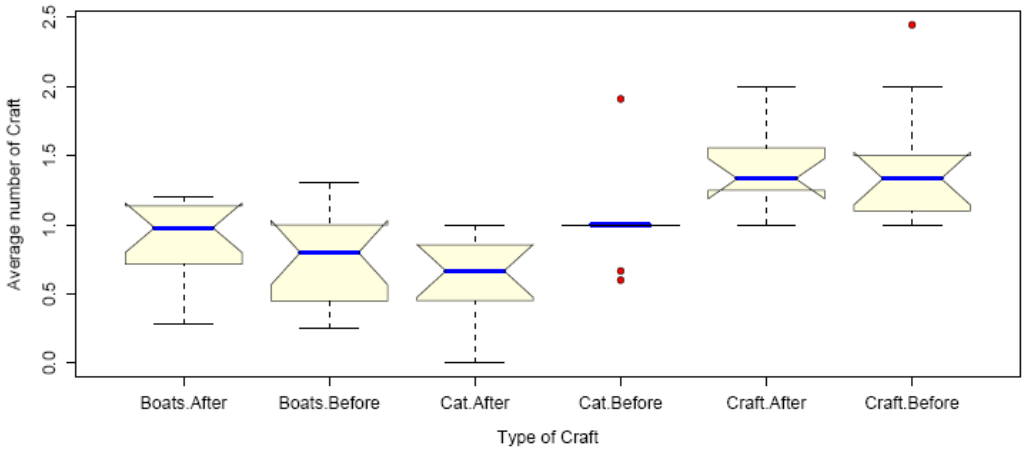
Name of the village	Catamaram Pre-Tsunami	Catamaram Post-Tsunami	Difference Catamaram	Vallam Pre-Tsunami	Vallam Post-Tsunami	Difference Vallam	Total change in no. of craft post tsunami (Vallam +Catamaram)
Kodiyampalayam	107	86	-21	135	156	21	0
Pazhayar	241	236	-5	186	144	-42	-47
Vanavanmadevi	135	120	-15	122	107	-15	-30
Madavamedu	137	110	-27	57	87	30	3
Kottaimedu	52	42	-10	68	94	26	16
Cinnakottaimedu	46	68	22	5	16	11	33
Koolaiyar	227	193	-34	16	75	59	25
Thoduvai	147	140	-7	88	158	70	63
Thirumullaivasal	371	321	-50	53	94	41	-9

Name of the village	Catamaram Pre-Tsunami	Catamaram Post-Tsunami	Difference Catamaram	Vallam Pre-Tsunami	Vallam Post-Tsunami	Difference Vallam	Total change in no. of craft post tsunami (Vallam +Catamaram)
Keelamooverkarai	79	64	-15	5	26	21	6
Keelamooverkarai	256	238	-18	66	113	47	29
Savadikuppam	69	55	-14	3	33	30	16
Nayakarkuppam	145	118	-27	6	58	52	25
Madathukuppam	145	116	-29	9	57	48	19
Pudukkuppam	158	128	-30	22	57	35	5
Poompuhar	750	685	-65	65	92	27	-38
Vanakiri	237	190	-47	97	99	2	-45
Cinnamedu	144	115	-29	22	49	27	-2
Cinnangudi	162	122	-40	41	78	37	-3
Thalampettai	105	95	-10	45	71	26	16
Pudupettai	257	228	-29	59	127	68	39
Perumalpettai	187	150	-37	65	158	93	56
Vellakovil	45	38	-7	41	73	32	25
Kuttiyandiyur	207	187	-20	101	176	75	55
Tharangampadi	347	281	-66	220	230	10	-56
Chandrapadi	227	181	-46	65	63	-2	-48
Cinnurpettai	24	19	-5	18	3	-15	-20
Nagore	245	216	-29	131	197	66	37
Samanthanpettai	133	121	-12	184	269	85	73
Nambiyar Nagar	142	127	-15	100	158	58	43
Nagaiariyanattu Theru	105	100	-5	112	117	5	0
Keechankuppam	60	53	-7	85	215	130	123
Akkaraipettai	179	119	-60	97	196	99	39
Kallar	137	110	-27	15	99	84	57
Velankanni	88	125	37	27	84	57	94
Seruthur	180	155	-25	231	310	79	54
Kameswaram	115	94	-21	51	100	49	28
Vilundamavadi	106	160	54	61	94	33	87
Vellapallam	245	196	-49	75	142	67	18
Naluvethapathy	90	72	-18			0	-18
Pushpavanam	78	74	-4	53	44	-9	-13
Areattuthurai	371	335	-36	66	252	186	150
Maniyantheevu	53	43	-10	5	53	48	38
Kodiyakadu	1	1	0	8	35	27	27
Kodiyakarai	6	4	-2	143	129	-14	-16
Pannal	0		0	26	29	3	3
Seruthalaikadu	45	36	-9	38	67	29	20
Annapettai	0		0	26	26	0	0
Voimedu	0		0	3	3	0	0
Cinthamanikadu	0		0	13	13	0	0
Kovilthavu	0		0			0	0
TOTAL	**7386**	**6467**	**-919**	**3230**	**5126**	**1896**	**+977**

Data based on book released by the District administration on 26/12/05 Basic Raw Data/Table Available at http://www.ncrc.in/fish_compensation.php

Though there has been an increase in the combined total number of craft in the traditional sector, it is not significantly/statistically higher than the pre-tsunami level (Bhalla, 2006). The same is shown in the figure below.

Figure 2: Number of craft pre and post-tsunami*



*Source: Bhalla, 2006

However, when seen in the light of capacity of engine and nature of craft (shift towards FRP boats), the changes in numbers could be significant with implications for catch effort and fisheries.

Catch effort

Thus from the previous table and section, it is clear that the number of craft in the non- mechanised sector (*vallam* and catamaran) has increased, but not alarmingly. Still some feel that the problem now lies with over-capacity and over fishing within the non-mechanised sector (as opposed to the earlier situation of the enemy being trawlers) (Salagrama, 2006). However, when one looks at the number of boats engaged in fishing, one gets a very different picture as not all of them are being used in fishing. This is illustrated by the tables below which show that around 26 % of the *Kattumaram* and 21% of the *Vallams* are not involved in fishing as of February 2006.

*Table 4: Status of resumption of fishing - taluk wise in Nagapattinam, March 1 - 15, 2006**

Status	Taluks	Kattumaram	FRP Boats	Trawlers	Total
Units doing Fishing	Sirkali	870	824	207	1901
	Tharangambadi	370	91	14	475
	Nagapattinam	360	590	427	1377
	Kilvelur	25	235	0	260
	Vedharanyam	114	248	0	362
Units not Fishing	Sirkali	227	43	6	276
	Tharangambadi	119	13	3	135

	Nagapattinam	0	173	2	175
	Kilvelur	17	200	0	217
	Vedharanyam	247	161	7	415

* Source: NGO Co-ordination and Resource Centre (NCRC). 2006c.

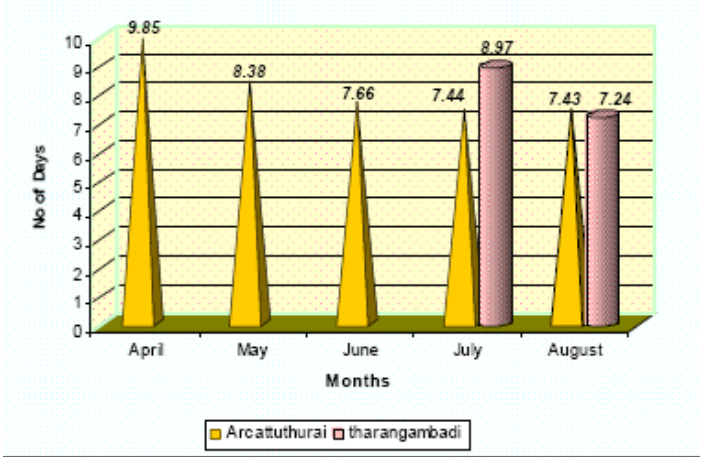
*Table 5: Status of resumption of fishing in Nagapattinam, March 1 – 15, 06 **

Status	Kattumaram	%	FRP Boats	%	Trawlers	%	Total	%
Units doing Fishing	1739	74.03	1948	78.68	648	97.3	4335	78.95
Units not Fishing	610	25.97	528	21.32	18	2.7	1156	21.05
Total	*2349*	*100*	*2476*	*100*	*666*	*100*	*5491*	*100*

*Source: NGO Co-ordination and Resource Centre (NCRC). 2006c.

There have been many reasons attributed to this situation, the main ones being the non-availability of crew for the increased number of craft and the change in owner-crew relations. Thus, in some cases the number of fishing days per boat had reduced (Salagrama, 2006). Many of the boats were also sold and recycling of boats meant that the number of boats were actually less than those reported by NGOs (Salagrama, 2006). The other reasons have been that the quality of boats was poor and they had to be frequently landed for repairs. Some also felt that this could be due to fishing operations becoming unviable (Salagrama, 2006). A FRP boat pre-tsunami that used to do 15-25 trips per month was now doing only 10 trips a month (as of August 2005) (TRINet 2005c) . The figure below illustrates this for some of the months in 2005.

*Figure 3: No. of fishing trips per month in Arcottuthurai &Tharangambadi**



* Source: SIFFS Society records from Thaddues. 2005a

Given below is a summary of the possible reasons for reduction in the catch effort/ utilisation of boats.

Box 2: Summary of the possible factors for reduction in catch effort

- Lack of Labour
- Poor quality of boats
- Non provision of correct nets
- Resale of boats
- Poor economic viability of operation
- Conflicts in group ownership
- Inablity to adapt to gear /craft
- Increased competition for fishing grounds

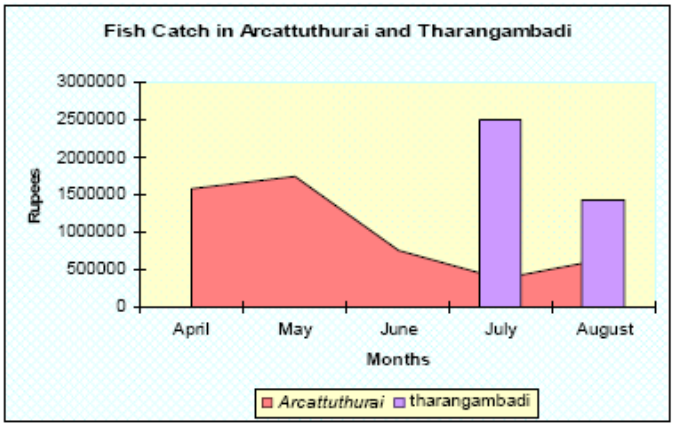
Another important point to note is that despite the average increase in engine capacity, the fishing range and grounds of these boats still remains the same (Bhalla, 2006). The stabilisation of fishing might take place when people adapt to new craft and gear, change in fishing grounds, target species. It is also felt that the number of boats will stabilise after a year with excess boats that remain idle being sold. From personal observations, it does seem that new catamarans have been bought since May 2006. This means there is a likelihood of the nature, composition and quantum of the asset base changing and stabilising with time. It is clear from this that increased fleet size, crew size (no. of active fishers) and engine capacities may not have necessarily increased the catch effort in the same direct proportion but may have increased nonetheless. One needs to study and analyse the reasons for the levels of catch efforts, stabilisation of fleet capacity as well as the adaptations made by the community in fishing operations in various regions.

It must be noted here that this kind of monitoring of craft use and catch is being done only in Nagapattinam and not in all the other affected districts/states. Furthermore, the parameters are dynamic and need to be continuously be monitored for the next few years in order to get a better picture of the trend as well as the underlying reason for them.

Fish catch and income

There is very little information on the monitoring of income and fish catch (pre and post-tsunami) and whatever little is available, is sketchy. Some experts like Dr. Kasim of the Central Marine Fisheries Research Institute (CMFRI) were of the opinion that short-living (in terms of life cycle) invertebrates such as prawns would recover faster and that the gap in fishing for about 4 months post–tsunami coupled with monsoon fishing ban would initially result in an increased catch for the non-mechanised sector when fishing resumed, but would not last very long (in TRINet 2005c). Some records kept by the SIFFS fishermen societies do show this trend as given below showing average catch per unit in income.

*Figure 4: Fish catch data for Arcottuthurai and Tharangambadi**



* Source: SIFFS Society records from Thaddues (2005)

The reason for the initial increase in catch/income could be attributed to the gap in resumption of fishing. The drop in income/catch in the subsequent months after May was reported to be 60-70% of the previous months. Other parameters are being monitored by the NGO Co-ordination and Resource Centre (NCRC) but they do not give details of the catch but show a 28 % decrease of fish catch by weight as seen in table 6 below:

*Table 6: Average fish catch per day and percentage per day **

Pre-Tsunami	7386 x 50 kg	369,000
	3230 x 150 kg	484,500
	948 x 500 kg	474,000
Total		1327,500
After Tsunami	6467 x 35 kg	226,345
	5126 x 110 kg	563,860
	459 x 350 kg	160,650
Total		**950,855**

* Source: NGO Co-ordination and Resource Centre (NCRC), Nagapattinam

Continuous catch data will need to be monitored along with details of species and incomes. This will need to be correlated with the catch effort, running cost etc. to get a clear picture of the status of resources, incomes and fishing patterns post tsunami.

Community perception of changes post-tsunami

There has been very little work on traditional ecological knowledge (TEK) of fishers till date. Post - tsunami some investigation qualitatively investigated the community perceptions of post-tsunami changes in the ecosystem. However, they are quite contradictory as they are actually spatially spread over a large area and hence are not able to capture region/area specific observations.

One study post tsunami, apart from documenting the classification of the winds, currents, and the fishing grounds also indicates the factors influencing the decision to fish and the perception of Nagai fishermen on the impact of the tsunami (Benchila and Prabhu, 2005). The main changes reported are unpredictability of winds, changes in currents, rise in water level at shore, poor catches, appearance of new species such as white fish (after 20 years) (Benchila and Prabhu, 2005). They did not report any changes in the sea bed.

Another study indicated that fishermen, particularly in Kancheepruam, reported changes to the sea bed, its rock formations, areas of sand and slime (contrary to the previously mentioned study) (Gomathy, 2006). As in the previous study this also mentions the erosion of the coastline/shoreline or change in the HTL and refers to the fisher's inability to predict winds, currents resulting in disorientation in fishing as well as gauging safety. The community believes that it will take 4-5 years to understand the fish patterns and chart/map their grounds again to avoid damage to their nets and (Gomathy, 2006).

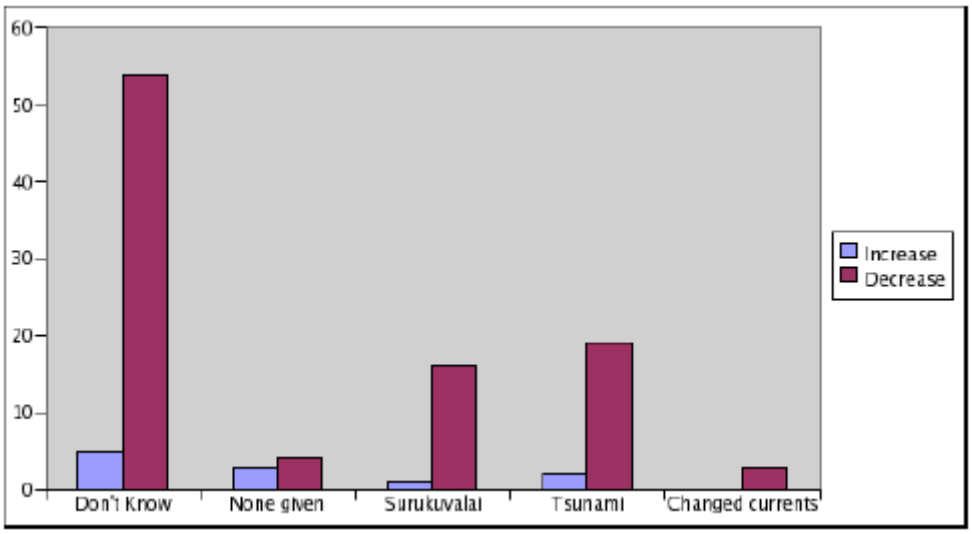
The changes in shoreline in some places such as Anumandai Kuppam in Villupuram are significant and are as high as 40 m. Koonimedu Kuppam in the same district reported changes in the beach quality from clayey to sandy soil (and the other way round in some other locations) (Salagrama, 2006). There were also reports of changes in the depths in some of the fishing grounds by some communities (Salagrama, 2006). As the beaches are very dynamic ecosystems, the stabilisation will take some time. Whether there will be a return to some of the earlier characteristics will be known only with time by monitoring and further studies. A summary of all the different observations and perceptions of the community of post-tsunami changes is summarised in the box below:

Box 3: Summary of perception of fishers on the impact of the tsunami

- Changes in HTL (also observed as increase in sea level)
- Erosion of beaches
- Changes in wind pattern
- Changes in currents
- Changes in sea bed (some villages/regions claim no changes)
- Inability to predict weather patterns
- Inability to predict fish aggregation
- Inability to gauge safety
- Poor catches
- Changes in fishing grounds
- Changes in beach quality and characteristics

A majority of the fishermen in one study reported a decrease in the fish catch and attributed this to the use of *surkuvalai* and the tsunami (Bhalla, 2006). The responses to the questionnaire from the study are shown below:

Figure 5: Reasons for changes in the fish catch *



*Source: Bhalla, 2006.

Most of the above studies on TEK and community perceptions of the tsunami impact are too broad and qualitative. A region specific study in detail would have given a better picture (along with an indication of the fishing grounds that the particular hamlets use for fishing).

Case of group ownership

Group ownership of boats has failed in the past and many fishworker groups and advocacy platforms have discouraged the same. It is well known that in certain areas such as Nagapattinam and Kanyakumari the concept of individual ownership is very strongly rooted in the culture. However, in some districts such as Villupuram, Cuddalore, and Pondicherry, group ownership did exist pre-tsunami (Salagrama, 2006). In all the 4 states many boats were given on group ownership (Salagrama, 2005). The extent of group ownership pre and post-tsunami is not known and quantified. However, there have been reports of cases of conflicts and disputes in the initial stages due to group ownership in rehabilitation (TRINet 2005c).

Various mechanisms to cope with group ownership emerged within the community. In Nagapattinam, one of these was that a written agreement between the traditional *panchayat* and each of the groups that there will be no compensation for any member exiting the group and that the boat could not be sold by the group. The dissolution of the group meant that the custodian of the boat would be the *panchayat*. This was done to discourage possible split up of the group (Thaddeus, 2005a). Another model was the setting of shares within a group and the option of selling or buying out shares for boats (Salagrama, 2006).

It is not fair to write off the concept of group ownership as it was already prevalent in some regions. The areas where it failed post-tsunami were those in which the practice was initiated without any thought or mechanisms in place (or the areas had no history of group ownership). To suggest it will not work implies that the fisherfolk do not have the spirit of cooperation and collectiveness inherent in them, which is unfair and definitely not true (Salagrama, 2006). In fact many fishermen had suggested the role of traditional *panchayat*s in facilitating group ownership with a feeling that this would lessen, ease and facilitate any possible friction. They also believed that eventually a balance could be established and any strife would be worked out (Salagrama, 2006) .

The above does indicate elements of adaptation and resilience. A study to understand the history, origins and reasons of group ownership pre-tsunami as well as the context of how and why they have failed in some areas, while succeeding in other areas would give a better understanding to the socio-ecological resilience in the communities.

Agriculture

Unlike the fisheries sector, the agricultural sector faced immediate and longer term damage of their assets namely soil and water sources. It is felt that this has not drawn any kind of attention that it deserves, perhaps partly because the damage to agriculture was not as visible and dramatic as in the case of fisheries even though about 26,000 hectares of agricultural land was affected by the tsunami with standing crops almost completely destroyed. (Centre for Indian Knowledge Systems, 2006; Das, 2005).

However, the assets like soil and water as mentioned earlier unlike the fisheries sector are different. Their damages are more permanent in nature and have to be either reclaimed or rejuvenated. The time scale of damage and recovery is also much longer than the case of fisheries. Moreover, individual farmers cannot reclaim agricultural fields on their own, as costs involved are prohibitive and activities quite complex (Das, 2005). Thus in reality, the damage to agriculture is indeed actually quite dramatic and drastic.

The impacts of the tsunami can be classified into four major categories:

- Sand/mud casting on the land.
- Salinity in the agricultural land.
- Contamination of water sources (surface and groundwater).
- Damage to the natural resources in the area (standing crop loss, plantations, livestock.

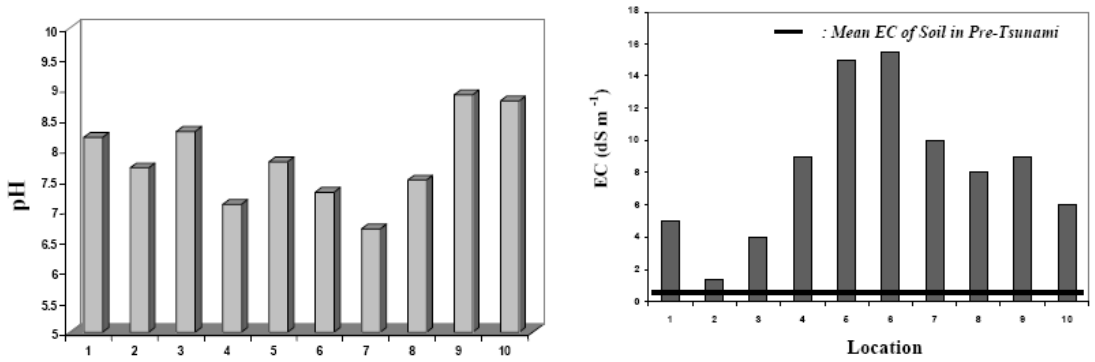
Poor drainage in most areas resulted in water that inundating fields and staying for some time before it drained away thus causing the salts to percolate into the soil as well as groundwater (TRINet 2006a). Initially, the NGOs working on rehabilitation in the agriculture sector couldn't get any useful help or information even in terms of technology when they approached the government departments and had to find ways of desalination and soil reclamation by interacting with farmers. There was also a lack of clarity and coordination between the various departments that were involved in agriculture based livelihood

rehabilitation. Thus there was no comprehensive picture available to specify the programmatic content of rehabilitation in the context of the agricultural land affected by the tsunami (NCRC, 2005b).

Ecological impacts

The full scale effects of the ecological impacts of the tsunami are yet to be understood, but there are definite effects on the land and water resources. The impact on trees and vegetation around was significant. Cashew and mango trees were badly affected by the physical force and the accumulated salts in the soil. Though coconut & palm have withstood the salinity for many months after the tsunami, farmers felt that the effects on them will be known only after more than a year (Green Coast, 2006b). One study of the soil shows the EC levels had increased from 5 to 15 times and the soil pH increased beyond 8 in about 40% of the samples (the pre-tsunami average pH was around 7) (Chandrasekharan et al, 2005). The result are summarised in the table below:

*Figure 6: Variations in EC and pH of soil samples from tsunami-affected areas in coastal Tamil Nadu**

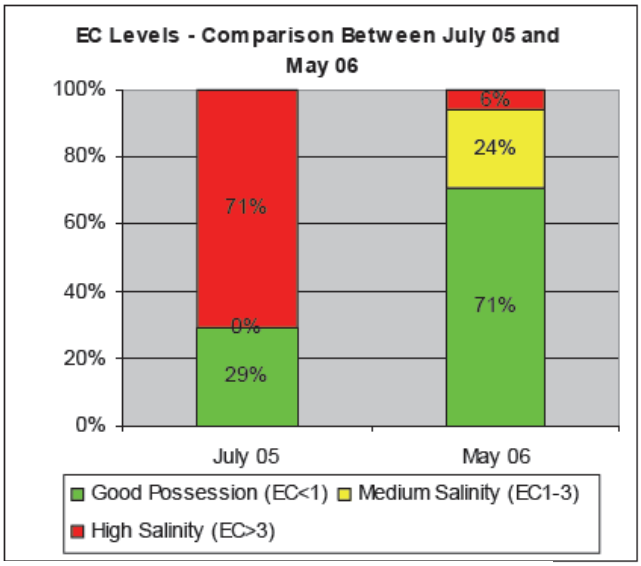


1, Serudhur-I; 2, Serudhur-II; 3, Prathabaramapuram-I; 4, Prathabaramapuram-II; 5, Vellapalam (Vedaranyam); 6, Neithavasal; 7, Manikkapangu; 8, Khozhaiyur-I; 9, Khozhaiyur- II; 10, Erukattancheri.

* Source: Chandrasekharan *et al.*, 2005.

The study points out that remediation of such soil cover is difficult, especially when deterioration has occurred due to sea-water ingress. The study concludes that as the affected areas will receive adequate freshwater to leach out the salts, only during the subsequent monsoon season (July/August 2005) and that the next crop of rice was also likely to be affected in these areas. One study done in 2005 and 2006 shown below shows major improvements in the soil quality in terms of reducing salinity (NCRC 2006c).

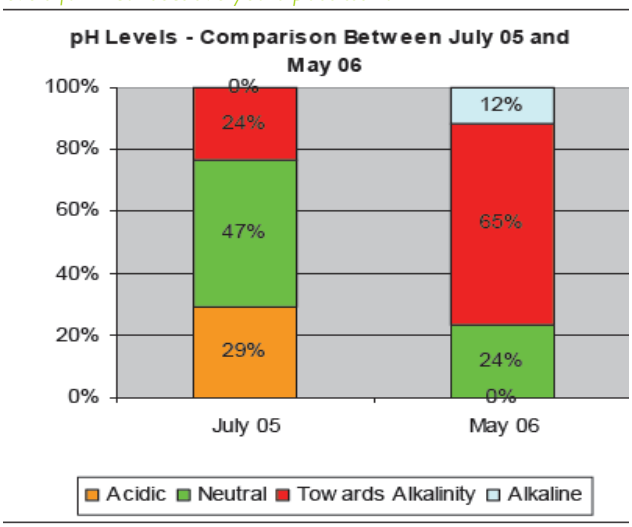
Figure 7: EC levels in soil for two consecutive years post-tsunami



* Source: NGO Co-ordination and Resource Centre (NCRC). 2006d

In the case of pH values, it shows some increase in proportion of samples moving towards the alkalinity range after reclamation. This shown below in the graph below:

*Figure 8: Changes in soil pH levels for 2 consecutive years post-tsunami**



* Source: NGO Co-ordination and Resource Centre (NCRC). 2006d

Water bodies and management

The impact on water bodies was caused by the intrusion of saline water both by inundation and ingress. These were managed by the farmers themselves, with some support for pumping out the accumulated water and desilting the physical slurry (NCRC, 2006d). Many habitations reported that traditional physical structures (bunds, etc.) for drainage and water management had not been maintained over the years due to lack of cooperation, ownership among the communities as well as government support for the same (NCRC, 2006d). During the heavy rains of October-November 2005 in Nagapattinam, in some villages rain water stayed on the fields due to the lack of maintenance of traditional water management and drainage structures (NCRC, 2006a). In some cases the drainage channels, which were reclaimed and desilted all along the coast as a relief work by various agencies and NGOs, were instrumental in the immediate drainage of excess water from the rains (TRINet, 2006a). Thus, there is a need for maintenance of water management and drainage structures, safe disposal of water, harvesting excess water and recharging the ground water in all the affected areas.

The Coramandel coast is known to have traditional water harvesting, soil conservation and watershed management techniques which have now eroded (Sangati CPR Working group). Two known cases are illustrated below:

*Box 4: Traditional techniques to reduce the salinity content in water and soil**

The farmers in Naluvethapathy in Nagapattinam district have traditionally used cake prepared from neem seeds, tamarind leaves, and mowa seeds (also known as 'iluuppai arappu' in Tamil) to remove water salinity. They applied these materials whenever the seawater entered into agricultural land during monsoon. The farmers mix the neem seeds, the tamarind leaves and the mowa seeds in equal proportions (200 kgs of the mixture is required per acre) and then mix them with the soil. However, nowadays they find it difficult to collect sufficient quantities of the materials.

Besides, mixing the materials and applying them to the soil consumes a lot of time. Garlic plants and jute plants are grown in the field, and then they are cut and left to decompose in the field. The land is then tilled 2 to 3 times. This action helps reduce soil salinity. Most of the farmers have knowledge of application of gypsum to reduce the salinity, but they are not confident of it effectiveness. Most of them feel that heavy rain would possibly reduce the impact of salinity in the land. In the month of April 2005 the region received some heavy showers and the farmers feel that these have removed some of the soil salinity. The ponds however remain to be desilted and cleaned.

*Box 5: Stabilization of sand dunes and soil conservation **

South Poigainallur is situated about 10 km south of Nagapattinam along the Tamil Nadu coast. The village has two kinds of lands mainly, that is, lowlands and uplands. The interesting aspect of the lands in South Poigainallur is that almost every piece of land is part lowland and part upland. This is a natural occurrence and the farmers do not try to change it. There is no river or canal irrigation in the village. During the rainy season, the village faces water flooding. The water is therefore channeled through these canals up to the sea. Ponds are dug on each one's own piece of land, and are used for irrigating crops. People use the common ponds known locally as *mandua* when more water is required. There is no discrimination in the usage of these common ponds, and the villagers share in the water equitably. There have also been no conflicts regarding the water of the common ponds.

South Poigainallur is very well known for its sand dunes along the seashore at a height of 30-40 feet. Sand dunes are found on the seashore at a distance of 15 meters from the sea. The height of the sand dunes is about 30-40 feet from the ground level. The dunes start at the northern side of South Poigainallur near Kallar which is ½ km from South Poigainallur and ends near Vailankanni (near Pookara street) and extends to a length of 6.5 kms. In order to protect crops from the waves and institute soil conservation measures (to prevent deposit of sea sand in their fields) the people erected fences using palm leaves along the seashore and planted palm trees along the fence. The people claim that the high tides brought sand to the shore carried on the waves which was then cast along the fencing lines along the seashore. They are of the view that since sand travels easily on the wind, the accumulation has been easy and the height of the dunes has grown over time. Moreover, the community have observed that during the season of the North winds (Winter season—November and December) a lot of sand accumulates on the seashore. The dunes from time to time were then stabilised by various vegetation of cashew, tamarind, and Spinifex. The back dunes with vegetation cover do not show any considerable seasonal variation and the fore dunes with less/no vegetation show a greater degree of seasonal dynamics. The dunes and this vegetative fencing prevented soil erosion and sand casting onto the agriculture fields. This is how they claim they have enhanced the formation of the famous sand dunes in their village. They claim that 500 years ago, the height of the sand dunes was only 5-10 feet, whilst now they are 30-40 feet. The people believe that the sand dunes have protected them from natural disasters such as cyclones and high tides. The dunes have in fact been largely responsible for minimizing the number of deaths in the village during the tsunami. The community have resisted the outsiders and prevented digging of sand from the sand dunes by presenting a united front. After the tsunami, the *panchayat* passed a resolution to protect the sand dunes and banned outsiders digging sand from the sand dunes.

Sources: Praxis. 2005k. South Poigainallur: Village level people's plans: Realities, Aspirations, Challenges. Praxis, Delhi.

Balakrishnan, R. 2006. Presentation at Workshop on Ecological Restoration of Degraded Ecosystems in Tamil Nadu: Planning and Implementation, 19 December 2006, Chennai, organised by Tamil Nadu Forest Department, Nature Conservation Foundation, and UNDP Post-Tsunami Environment Initiative, Nature Conservation Foundation, Mysore.

Background trend in agriculture

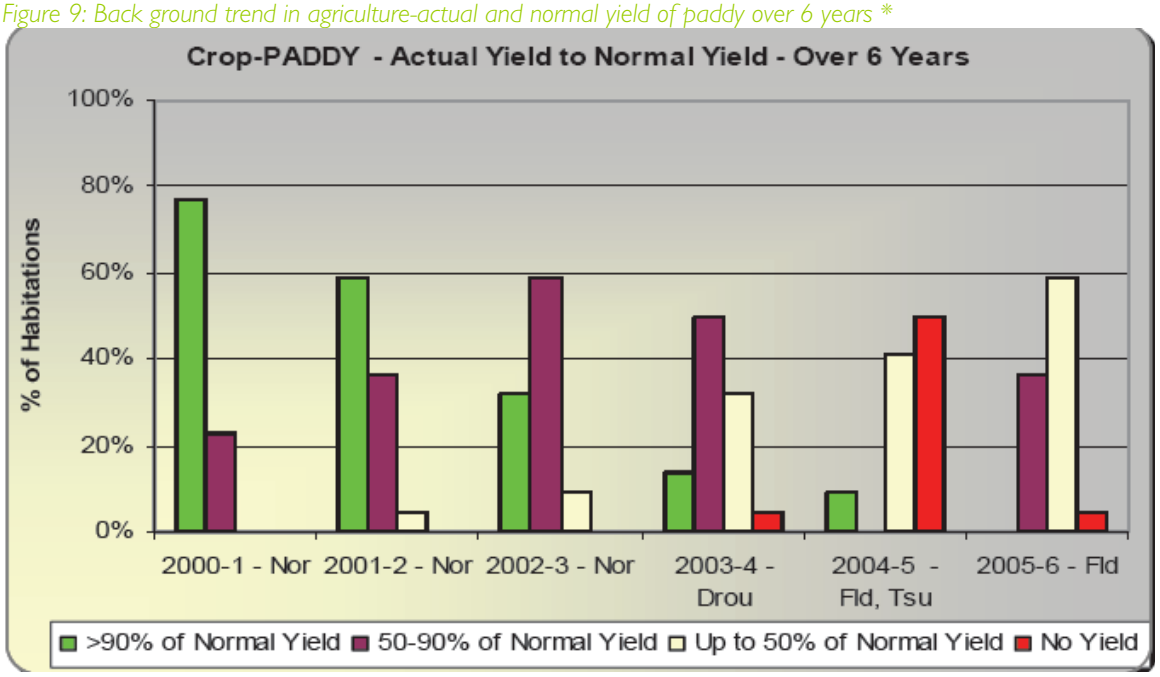
Analysis of past crop data in Nagapattinam district show a background decreasing trend in the yield over the years (even during normal years), which is an area of concern. The studies indicated that the salinity and lower fertility in the soil (indicated through NPK values from soil test) as the main factors contributing towards this trend (NCRC, 2006d). This background trend is similar in both dry and wet lands as well as for the other major crop, groundnut, with the proportion of habitations reporting 90% and above yield coming down to 14.30% (in 2005-06) from 85.70% (in 2000-01) (NCRC, 2006d).

There has also been an increasing occurrence of disasters in the Nagapattinam region in the past few years. Flood and drought have been the main disasters in the region and their impact have been reduced or total loss of production from the particular season, and reduced productivity of land due to salinisation or lack of irrigation (during droughts) (NCRC, 2006d). In some villages in Nagapattinam, agriculture was actually abandoned due to a combination of reasons - lack of irrigation, salinisation of

groundwater, continuous monsoon failure, and the inflow of seawater during the cyclones (Praxis, 2006b; Praxis, 2006e; Praxis, 2006f).

The responses to these disasters from government and other agencies have seemed to be adhoc, temporary and reactive.

*Figure 9: Back ground trend in agriculture-actual and normal yield of paddy over 6 years **

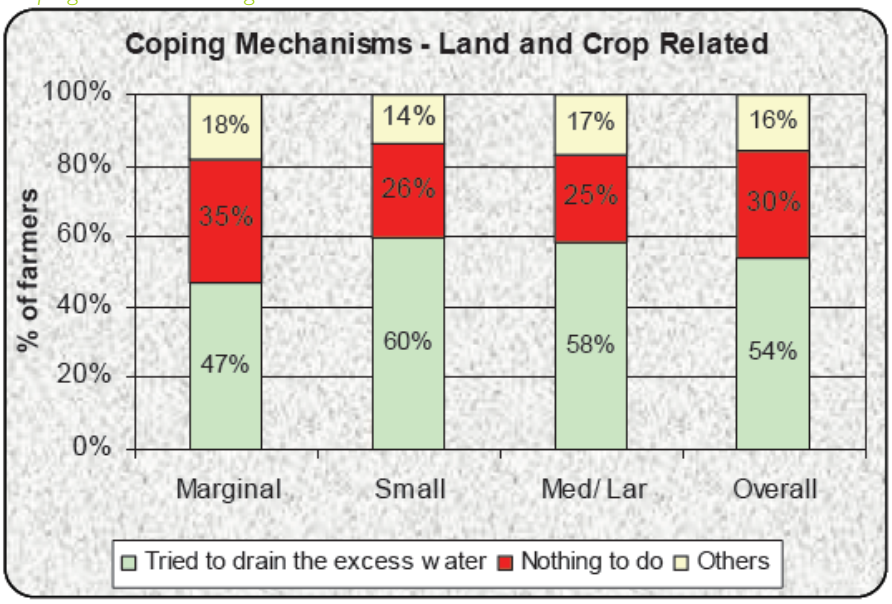


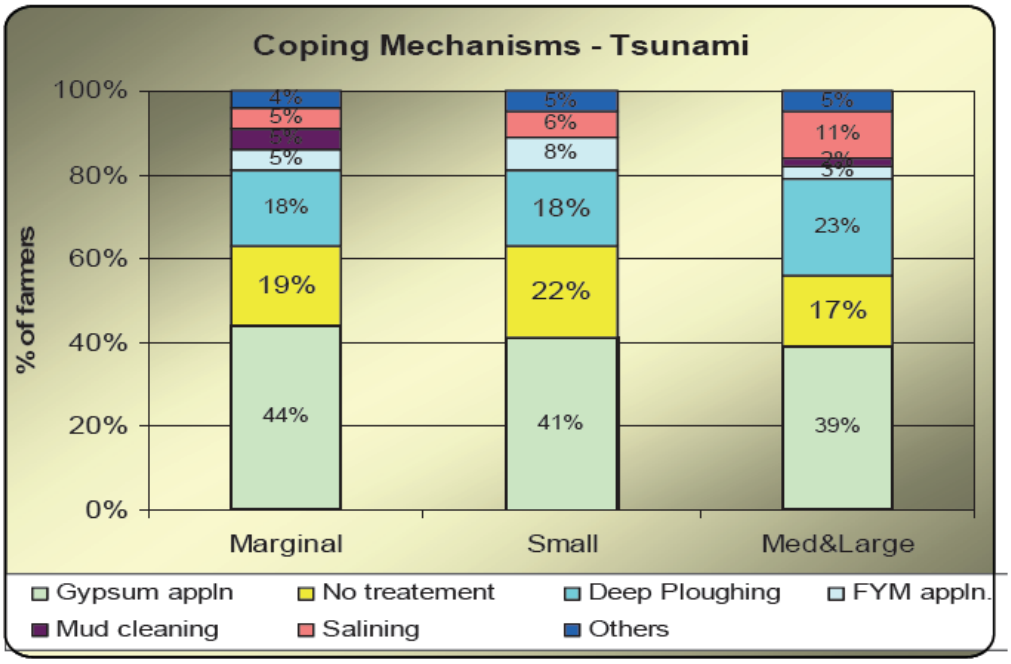
* Source: NGO Co-ordination and Resource Centre (NCRC). 2006d

Coping mechanisms

The coping mechanisms adopted by the farmers were studied in two aspects in Nagapattinam–land and crop. A large proportion of farmers practiced gypsum application, followed by deep ploughing (18 – 23%). In drought years, about 90% of farmers reported that they would not be able to do anything except wait for rain with a few (less than 7%) reporting deepening of farm ponds (NCRC, 2006d). The findings of the study are summarised below:

*Figure 10 & 11: Coping mechanism in agricultural sector **





* Source: NGO Co-ordination and Resource Centre (NCRC). 2006d

Monitoring of crop yield & mapping of water bodies

One of the initiatives taken up by the NGO Co-ordination and Resource Centre (NCRC) is a study to map the water bodies in the coastal areas of Nagapattinam in order to develop safeguard systems against salinity caused by either tsunami or floods by setting a drainage system in place for the water to drain out (NCRC, 2006b). The initiative can be improved upon by use of GIS based mapping along with watershed based management over a larger area. The ground water salinity as well as drinking water sources, both of which have been issues of the past and present can be addressed if taken up. The centre is also involved in the continuous monitoring of crop yield in the Nagapattinam District for the past two monsoons since the tsunami.

Agro-biodiversity

There has been no work on documenting the agro-biodiversity of the affected region. Aspects of wild varieties, land races & cultivars in the entire affected district find no mention the literature post-tsunami.

Impact of the tsunami on groundwater

Groundwater in most coastal areas in India has been facing sea water/salinity intrusion. This has made it very difficult for coastal communities in terms of their daily access and needs of freshwater. So much so, that the prospect of better quality groundwater is one of the reasons given by them for relocating to a new site (Salagrama, 2006). It must be noted that there are a number of factors that are major drivers of changes in water quality and quantity in the coastal zone and there are very few comprehensive studies in this regard.

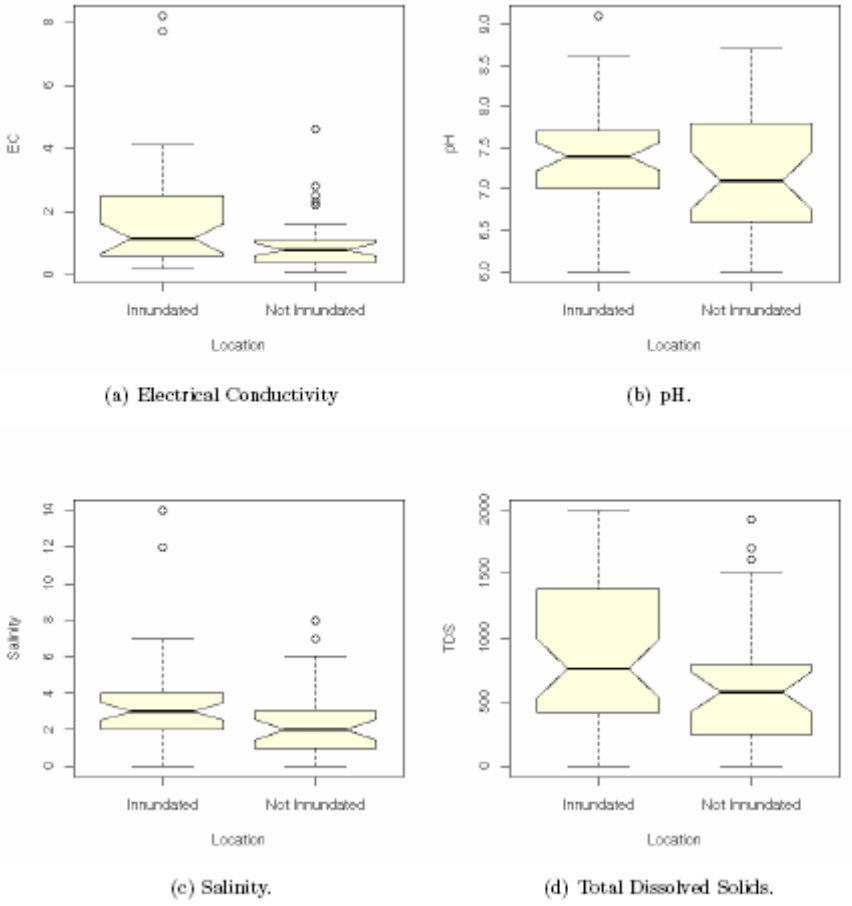
One of the impacts of the tsunami was the increased salinity of groundwater in many areas (Nair 2005). The Central Groundwater Board (CGWB) reports that open wells and tube wells adjoining the sea shore within 300-500 m., turned saline because of inundation and flooding by sea water (in International Groundwater Resources Assessment Centre, 2006b). Many experts d felt that the subsequent rains would improve the groundwater quality. Post-tsunami, in many areas improvement in ground water quality due to natural flushing as well as heavy pumping of these wells to restore water supply was observed (International Groundwater Resources Assessment Centre, 2006b). In some areas, however, contrary to

this, the rainwater dissolved the salt deposited in the soil and thus increased the salinity of groundwater (Srinivasulu, 2006). Studies have also documented and characterised the impacts of the tsunami on geomorphology and water quality (Green Coast, 2006a). Studies have also developed geo-spatial data bases on the damage assessment to ground water village wise showing appreciable damage to aquifer in the form of saltwater mixing and intrusion due to tsunami (Ramasamy *et al*, 2006). The water samples in Andhra Pradesh showed no increase in salinity and in the case of Kerala, the CGWB reported that open wells and tube wells adjoining the sea shore turned saline. Here again there was improvement in ground water quality due to natural flushing and pumping (International Groundwater Resources Assessment Centre, 2006b).

The International Groundwater Resources Assessment Centre (IGRAC) is conducting an overview of the impact of the tsunami on groundwater systems and groundwater based water supply by the collecting, systematising and making available more detailed and/or specialised information. This overview is constantly being updated (International Groundwater Resources Assessment Centre, 2006a).

One study of the impact on water resources shows significant changes in the salinity and Electrical Conductivity (EC) but no major changes in the pH and Total Dissolved Solids (TDS) (Bhalla, 2006). The results of the study are illustrated below:

*Figure 12: Impact of tsunami on water sources**



(a) Electrical Conductivity (b) pH.

(c) Salinity. (d) Total Dissolved Solids.

* Source: Bhalla, 2006

The Central Ground Water Board has developed ground water maps of the coastal areas mapping the groundwater quality including salinity. This is an excellent baseline and shows background trends. It is important to review the background trend of hydrological changes at select sites in the coastal zone and assess the major drivers of changes of these changes in these sites.

Aquaculture

The damages and losses to the brackishwater aquaculture sector, suffered minimal damages and losses due to the tsunami (CIBA, 2005). Being off-season, hatcheries were closed and most farms in the state of Tamil Nadu had not started their stocking operations which normally start around late January or early February (CIBA, 2005). In Kerala, as most of the shrimp farms are creek based rather than sea based and were shut due to the off-season, the damage was minimal (CIBA, 2005).

It should also be noted here that shrimp farms are one of the most common CRZ violations in the more rural stretches of the Coramandel coast (Bhalla, 2006). A study and survey reveals the lack of procedures for selection of sites with a high number of conversions of agricultural land and possible impacts on agricultural areas. It also maps the extent of aquaculture and reveals a huge expanse of this industry along the Coramandel coast (Bhalla, 2006).

Shrimp aquaculture created many social and environmental problems. Some of them include- water pollution, salinisation of ground water & paddy fields, destruction of fry of wild fish & crustacean species and social conflicts related to land conversion. In one case post-tsunami, the housing relocation site is more than 500 m from the HTL, but right next to a prawn farm. The people of this hamlet have asked the Government to ban the prawn farm to prevent further 'salinisation' of groundwater (Praxis, 2005a). Another major impact of this sector has been has been the conversion of mangroves to shrimp farms (Hein, 2000).

The conflicts generated by these problems resulted in public interest litigation in the Supreme Court, the subsequent of this case resulted in the decision banning non-traditional shrimp aquaculture in India's Coastal Regulation Zone in 1996 (All India Reporter, 1997).[81] In this case, the judiciary assumed the pro-active role of a policy-maker (Diwan, 2000). It also used the precautionary approach to curtail commercial shrimp farming in the CRZ (Razzaque, 2002). The Aquaculture Authority was established in order to form a regulatory and institutional framework for the shrimp aquaculture as directed by the Supreme Court. It was established by the introduction of the 1997 Aquaculture Bill.

The Supreme Court ruling and the Authority has had till date very little effect on the sector and the violations continue to exist. The implementation of the current regulatory system is still defective, and in the absence of proper planning and regulation, further expansion of shrimp farms could result in significant additional environmental and social costs (Hein, 2000). The verdict has not been implemented due to the government safe guarding the interest of the industry as well as the lack of willingness by the government administrations towards this. The bill also partly deviated from the Supreme Court decision and allowed existing shrimp farms in the coastal zone to continue operations under certain conditions (Halim, 2004).

There have been very few closures of unlicensed shrimp farms, and hence shrimp farms have very little motivation to apply for a licence resulting in most of them acquiring a licence at all (Halim, 2004). The mandate of the Aquaculture Authority provided a number of directives as per the court order for

[81] The Supreme Court ruling in Jagannath v. Union of India, AIR 1997 SC 811 gave directions prohibiting non- traditional aquaculture along the coast.

shrimp aquaculture in the coastal zone. Some of them included that aquaculture farms were to obtain a licence within six months of the notification of the bill, and no licence was to be granted for aquaculture farming proposed within 200 m from the high tide line or within the CRZ in relation to creeks, rivers and backwaters. However, the restriction on locations did not apply to farms in existence on the day of establishment of the Aquaculture Authority. This provision was a deviation from the initial Supreme Court judgement (Hein, 2002).

Jesu Rethinam of the Coastal Action Network, an NGO which has compiled data on shrimp farms in the CRZ of Tamil Nadu, points out that that successive governments and administrations have not taken any action against the shrimp farms. Just before the tsunami struck, the administration assured various NGOs, that a total of 293 prawn farms in the CRZ would be removed and yet they remained untouched with no action (Raman, 2005).

In Tamil Nadu there are 2086 shrimp farms functioning in all the 12 coastal districts (except Chennai), out of which , only 852 shrimp farms have got approval from the State Aquaculture Authority (Fisheries Dept., 2005). The policy note of the fisheries dept. states "steps are being taken to regulate all shrimp farms functioning without the approval of Aquaculture Authority" (Fisheries Dept., 2005).

It is quite evident from the above that, as of date, there are many farms that are in violation of the CRZ and the Supreme Court directives. The Green Coast study also indicates this, but the exact details/ quantum of these illegal shrimp farms are not known.

Another issue highlighted, specifically in Tamil Nadu was the sector's reliance on mostly tiger prawn indicating a monoculture which has implications in spread of diseases. There is no data, studies and monitoring of the impact these farms are having on economically important fish and wild shrimp species (Bhalla, 2006). Just after the tsunami, documents released by certain multilateral agencies advocated for the conversion of salinised agricultural lands to aquaculture farms (TISS, 2005). Though no formal policy announcement or G.O was issued on this, there are some reports that conversion of salinised agricultural lands to aquaculture farms have occurred, but the exact extent of it is not known (TNTRC, 2006b).

It seems that the allotment of financial resources for rehabilitation in this sector is unproportionally higher than the damage (TRINet, 2005c). These are also lack of details on the policy and rehabilitation for this sector. For e.g., The allotment of Rs 10 Crore to this sector (for 78 aquafarms covering 271.1.07 Hectares and 22 Hatcheries) in Tamil Nadu has no further details and guidelines on how these were identified, the legality of these farms etc. (Govt. of Tamil Nadu, 2005e).[82] The Aquaculture Authority also did not issue any guidelines, order or directives specific to the post-tsunami rehabilitation. The Authority has no powers to grant solatium to shrimp farmers hit by the tsunami and could only make recommendations to the Centre that could form the basis for providing relief to the affected farmers. It was also publicly admitted by the Member-Secretary, Aquaculture Authority that all their "recommendations can cover only licensed farms," and their main concern was "about small farmers, who own land **over an extent of one-fourth of a hectare or half-a-hectare**" (Ramakrishnan, 2005). In fact most of the violations of the CRZ and Supreme Court guidelines are less than half-a-hectare.

The tsunami provided an opportunity to take stock of this sector and put systems in place for better planning, regulation and management in the sector. This unfortunately did not happen. Coastal

[82] G.O.(Ms).No.603- Dated:25.10.2005 , allotted Rs 10 Crore to this sector for 78 aquafarms covering 271.1.07 Hec and 22 Hatcheries in Tamil Nadu

aquaculture has been a controversial issue in the pre-tsunami phase and given the adverse social, ecological and economic impacts which this industry has had on other coastal communities in the past, it has been suggested that measures for its rehabilitation away from the coastal belt should be given serious thought along with provisions for adequate compensation & alternate rehabilitation options (Kurien et al, 2005). Some advocated that the Government use the tsunami as an opportunity to phase out the presence of aquaculture farms (TISS, 2005).

PART II- RECONSTRUCTION & REHABILITATION

Relocation

The Government of Tamil Nadu introduced G.O 172 on 30th March 2005 declaring the stated objective of providing built houses in safe locations to the tsunami-affected families, and that the Government would pledge assistance only to those who agreed to be relocated beyond 200 metres of the HTL (GoTN, 2005b). Those who intended to construct within 200 metres would not be eligible for government assistance. The government also extended assistance to those whose homes were not damaged but who wanted to relocate nonetheless (Sridhar, 2005).

There was strong resentment and opposition towards G.O 172 from various quarters (TISS, 2005). Several fishworker groups and NGOs termed this a discriminatory order (TRRC, 2005c). Many arguments were put forth against this G.O stating that fisher communities have a right to stay close to the shoreline and that their location and visibility of the coastal waters is important for their livelihood. Furthermore, there were other arguments stating that this G.O in effect tried to remove fishing communities from the coast, making it easy for the tourism industry and other real estate interests to make their entries into the coast. Many groups were weary of the G.O citing the Tamil Nadu "Tourism Policy Note 2005-2006" which provided a clear mandate for developing 'eco tourism' in tsunami hit coastal villages, notified just within a week after G.O. 172. (TRINet, 2005b; TISS, 2005; TRRC, 2005b; TRRC 2005b; TRRC, 2005c). Though G.O 172 does provides for the entry of the vacated sites into the Prohibitory Order Book, its effectiveness in keeping the land from being diverted for other purposes has been seen as questionable (TISS, 2005).

The access and visibility of the seas is very crucial for fishermen as part of their daily decision-making, traditional ecological knowledge, and basic livelihood activities such as launch of boats, shore seine, drying of fish, mending of nets, berthing of boats and many other social functions (Bharathi, 1991; Salagrama, 2006; Praxis, 2005l). Furthermore fishermen have odd hours of fishing and also make unplanned trips based on other's landed catches (Kuriakose, 2006). Fishing communities have historically been autonomous and self governing and their interactions with other communities have been minimal. The relocation does increase the problem or tensions related to caste and problems with the non-fishing communities after relocation and there have been some reported cases of this (Mathew, 2005a). In fact, relocating "west wards" is generally looked down upon by fishing communities and mingling with outsiders is seen as a threat to community's inherent nature and customs (Kannam, 2005).

The table below also illustrates this point showing the results of a study revealing that over 98% of the community households are of the view that their location is important to the livelihood (TRRC, 2005b). The study also revealed the disapproval of G.O.172 by a large majority (95%) of the affected communities. It also shows clearly that these communities are not willing to relinquish their existing properties as required by the G.O. in the case of relocation.

*Table 7: Key observations of the sample study on, "People's Perceptions on G.O.172" **

	No. of houses within HTL				No. of families resisting to move beyond 200 m	No. of families willing to move without relinquishing	No. of families willing to move unconditionally	No. of families who opine that their livelihoods will be affected on moving	No. of families who opine that the moving will create new types of caste / religious/cultural issues
	0-200	200-500	above 500	Total					
TOTAL	38314	11446	2814	52574	28523	21262	2789	51340	20189
% TOTAL	73	22	5		54	41	5	98	38

* Source: TRRC. 2005b.

Soon after the tsunami, the government through the district collectorate carried out a survey of houses (damaged and undamaged) in various zones of the CRZ (i.e. 0-200, 200-500 m from the HTL) and whether the community would like to relocate beyond 200 m and 500 m. Most of these surveys are not public documents. For Kanyakumari District, this survey reveals that only 42% of the households that were not damaged in the 0-200 m were willing to relocate by relinquishing their right of the old site (Kanyakumari District Colleatorate, 2005). However, a TRRC study (only totals and percentage from the whole state shown in the above table) for Kanyakumari District shows only a total 10% of the households were willing to move unconditionally. However, the variation of many factors should be taken into account when considering and comparing these two surveys- time of the survey, difference in resolution of data in both surveys (i.e. category of houses, zonations). It is important to systematically document the community views on this periodically and more importantly, analyse the various incentives and disincentives in the community's view for relocation and their orders of priority/ weightage.

There are many factors and reasons as to the way communities may have responded to various relocation surveys, especially to the willingness to relocate, despite an overwhelming majority being of the view that their current location by the sea is critical to their livelihood. The first being, the timing of the survey as the communities were still recovering from the trauma of the tsunami. As these were not normal circumstances, carrying out these surveys for relocation was not appropriate. Moreover, many NGO and experts have felt that these figures would change if surveys were delayed for a year or done later on. The second factor is that most coastal communities esp. fishing communities did not have *pattas* for the land they occupied and hence a plot of 3 cents (1.5 cents in urban areas) with a clear title deed worth Rs 1.5 lakh was clearly a good deal for the vast majority of the poor fishermen households (NCRC, 2005b).

The third is the "Two House Theory" where the communities believed that they could get a new house while still retaining their existing dwelling thus achieving a "two house" formula despite a clear declaration in G.O.172 that this will not be allowed. Communities still believed that they could hold on to their private property on the beach and build their own houses later on. It is on the basis of this belief that they were ready to move to alternate locations (Salagrama, 2006).

Some studies refer to factors such as ground water having turned saline in the existing site and hope of better water supply in the new site as one of the reasons for communities willing to relocate (Gomathy, 2006).

It must be mentioned here a couple of papers have highlighted the fact that communities had not thought out their response while being questioned on the topic of relocation, which was reflected in their frequent shifts of stance, sometimes between extreme positions (George, 2005; Salagrama, 2006).

Box 6: Summary of perceptions on incentives and disincentives to relocate

Incentives

- House with patta/title deed
- Safety (physical and psychological)
- Two house Theory
- Better groundwater in new location
- Lack of paperwork, documents regarding their land

Disincentives

- Access and visual linkage along shore crucial for livelihood, daily decision-making, traditional ecological knowledge such as *mappu* (sighting of fish from shore, thereby deciding to got to fish or not)
- Landing and storage of craft and gear
- Odd hours of fishing
- Unplanned trips based on others' landed catch
- Safety of equipment
- Weary that land may be given to other interests such as real estate, tourism
- Physiological disconnect from sea
- Tension with non-fishing communities
- Sense of belonging, lived there for generations
- Inalienable right to coastal land
- Site next to shrimp farm

Given the problem of availability of suitable land for housing reconstruction and the design of housing guidelines, in most cases additional land or sites were required for housing. This resulted in some ex-situ sites (completely relocated) for reconstruction as well as villages being split into different locations. This, despite the fact that almost all communities feel that relocation will affect their livelihoods. The table below gives a glimpse of re-location in Tamil Nadu:

*Table 8: A glimpse of settlement re-location in Tamil Nadu **

District	Extent of Land Required in hectares							
	Govt / Porom-boke lands identified	Private Lands required	Temple Lands required	In-situ	Total	Total	% of in-situ land	No. of Locations
Cuddalore	4.5	109.51	--	--	114.01	114	0	31
Tirunelveli	16.68.0	41.92.5	--	--	58.60.5	58.6	0	14
Nagapattinam	8.50.0	158.20.5	50.91.0	85.39.0	303.00.5	303	28.182	79

Kanyakumari	10.12.0	27.31.0	--	--	37.43.0	37.43	0	33
Villupuram	4.14.0	39.27.5	0	11.67.5	55.09.0	55.09	21.184	19
Thoothukudi	13.76.5	2.68.5	--	--	16.45.0	16.45	0	10
Kancheepuram	12.37	12.35	--		24.72	24.72	0	
Total	70.07.5	391.26.0	50.91.0	97.06.5	609.31.0	609.29	15.929	186

* Source: NCRC. 2005d

This table reveals that only 16 % of in situ land is being used for the housing reconstruction in Tamil Nadu. In Nagapattinam, closer analysis of data from housing construction reveals that in-situ construction is in only 23 of the 79 affected habitations with a total of approximately 2,500 odd houses which is only around 15% of the total houses being constructed. Thus, an overwhelming 85 % of the houses are being in new locations or ex-situ (analysed from tables of NCRC, 2005d). In Kanyakumari the number houses ex-situ is 78 % (KRRC, 2005a).

An interesting point to note in the case in Nagapattinam district is that the data shows that 15 % of in-situ houses are being built on 28 % of the in-situ land (from the table above) suggesting that the *built up area of settlements exceed the pre-tsunami level*. This is likely to be the case for all other districts as well.

Spatial information on the habitat reconstruction details to get an idea of the extent of re-location (from HTL, CRZ zone, original location) and area of settlement reconstruction is not available.[83] The pre-tsunami information on this is also virtually absent.

Housing Layout & Allotment

One of the other problems in the housing reconstruction is that participation has been very poor especially with respect to site selection, design and plot allotment prior to reconstruction. This has not been done in most of the village sites in Tamil Nadu (less than 35% of the sampled survey) (UNDP and NCRC, 2006). The extent to which traditional *panchayats* are ensuring plot allotment through consultations is not known.

Communities during some surveys/studies have mentioned that besides the location, the layout of their housing was linked to their livelihoods. Groups of households that live close to each other go fishing together or work on each other's boats. Hence they felt allotment of plots was important in terms of consultation and restoring the same layout (Gomathy and Rodriguez, 2007). Women particularly mention that social support systems among neighbours are important to them and hence restoring *status quo* in plot allotment was important to them (Gomathy and Rodriguez, 2007). However, it is unlikely that women would be consulted by traditional *panchayats* when deciding plot allotment internally, given that there is a sharp and marked exclusion of women in the system (Gomathy, 2006).

It has also been pointed that the lack of community engagement in housing and reconstruction may result in many other impacts, one of them being the two houses concept for many families (UNDP and NCRC, 2006; Salagrama 2006).

[83] Except for Nagapattinam where due to the efforts of the NCRC, there has been some systematic collation of data of location of old sites and new sites of villages but do not have spatial attributes.

Environmental planning

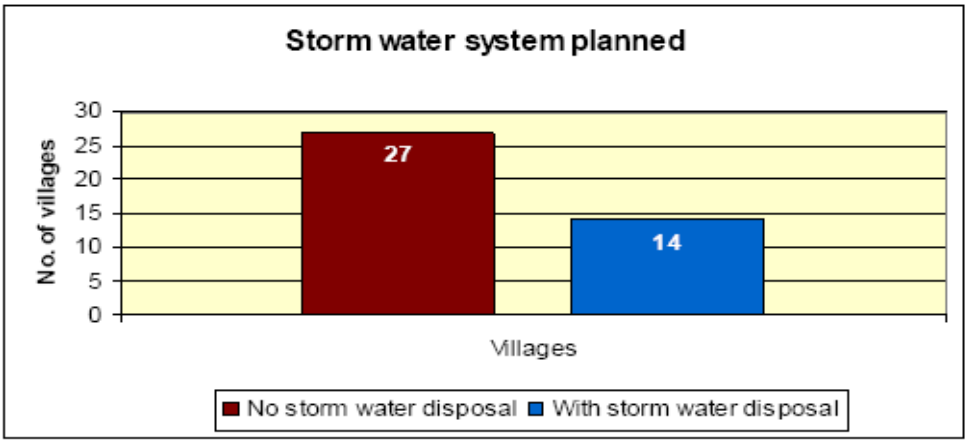
Site selection, elevation and wetland drainage

The housing reconstruction guidelines (applied to both ex-situ and in-situ) have increased the total area of settlements, the built-up area of housing, and in some cases increased the number of hamlets/settlements sites on the coast, when compared to pre-tsunami levels. The actual extent of the above is not known, but it has significant implications for coastal management. The details of settlement reconstruction would need to be collected and mapped for all the sites in different categories & zones of the CRZ (0-200, 200-500 and above 500 m). Preferably the exact location and distance from HTL would need to be spatially mapped and the above incorporated into the CZMP.

Most of the sites of reconstruction are in low lying areas with 42.2% of village sites having a water logging problem (UNDP and NCRC, 2006). The guidelines have not suggested any additional measures for safety in such sites. Thus some of the sites may remain vulnerable, if additional features such as wetland drainage and planning are not incorporated. There have been recommendations that technical guidelines to be evolved further (UNDP and NCRC, 2006). There have also been cases of land filling in many of the reconstruction sites (to meet the elevation requirements in the technical guidelines), which is not permitted as per the CRZ and this will result in a change in the local drainage pattern for surface runoff (Hedao, 2005; Hedao 2006). A lot of these sites will also impact adjoining sites due to spill over effects of their impact on the wetland drainage (Hedao, 2006).

In fact, one study reveals that of the reconstruction sites sampled the storm water drainage has been studied only in one-third of the prior to construction sites (UNDP and NCRC, 2006).

*Figure 12: Extent of storm water system planning in housing reconstruction **



* Source: UNDP and NCRC. 2006.

In some districts, there have been reports of beach sand mining for use in construction (Lal Mohan 2006, pers. comm.; KRRC 2005b; Bhalla, 2007). The extent to which this is happening in all the districts is not known. In addition, the level of awareness of the ban on beach sand mining (and the CRZ for that matter) among most NGOs is very poor.

In some hamlets in Karaikal, communities have traditionally located their hamlets on sand dunes and elevated places, and many of the village names end with the word "*medu*" which, in Tamil, means 'an elevated place' (Praxis 2005c; Praxis 2005d; Praxis 2005g; Praxis 2005h). It is important to document and research the traditional settlement patterns and locations of coastal hamlets over space and time (since the past 30 years or so) given the current relocations. Also, currently there is no data on how the land and site for housing rehabilitation was chosen in each of the affected hamlets.

Environmental clearance

In August 2006, the Government of Tamil Nadu vide their order G.O 531 made Environment Impact Assessments (EIA) mandatory for reconstruction projects accommodating more than 1000 persons or involving discharge of sewerage of 50,000 litres per day or with an investment of Rs.50.00 Crore and thus requiring an environmental clearance from Ministry of Environment and Forests (GoTN, 2006b). However, work on many such projects had started much before any environmental clearances from the Ministry of Environment and Forest (Bhalla, 2006; Bhalla 2007).

Water and reconstruction

The initial government order on housing, G.O 172 mentions that the housing layouts should have water supply and rainwater harvesting structures. It must be recalled here that the housing referred to here, was for areas 200m beyond the HTL. However, the GO No. 25 on "Rehabilitation construction of permanent houses and infrastructure - affected homeless families through public and private partnership" mentions that the government encourages NGOs and other agencies to take housing projects to provide for among other things water supply (Govt. of Tamil Nadu. 2005b). This G.O has no reference to the location of such housing projects and does not explicitly refer to the fact that mechanical extraction within 200 m from HTL (in CRZ –III areas) is not allowed under the CRZ. None of the other documents, G.Os or guidelines refer to this. This clearly shows that the concern for groundwater issues and the provision within the CRZ has been ignored. This aspect has been pointed out earlier by the UNDP in their document "Statement on the CRZ Notification and Post-Tsunami Rehabilitation in Tamil Nadu" (Sridhar, 2005). This was presented to the government in March 2005 and was also available online. This was officially published and disseminated by the UNDP in May 2006. However, an environmental checklist on the government's website mentions that for housing reconstruction projects, that it should be clarified whether the TN Groundwater Authority regulates the abstraction of groundwater in the proposed housing area and that proper clearances / permissions must be obtained, if required (Anon, 2005b).

The lack of guidelines and awareness material for NGOs on groundwater extraction has resulted in mechanical extraction of groundwater, even in 0-200 m of CRZ-III areas. It is not known if NGOs are actually seeking permission from the Tamil Nadu groundwater Authority. Data on the exact extent of this and levels of extraction spatially are not known. Even in areas beyond 200 m the scale of water supply and reconstruction is considerable and hence, even though allowed (only manually), might have negative impacts on the groundwater levels and quality in the long term. The type of water supply and extraction under the reconstruction in all areas of the CRZ is not known. Thus it is important that rainwater harvesting, ground water recharge and watershed management be encouraged in all areas of the coast. This assumes greater importance within the backdrop of the subsequent inundation affected groundwater by the tsunami and the historical salinity intrusion of the groundwater in most of these coastal areas.

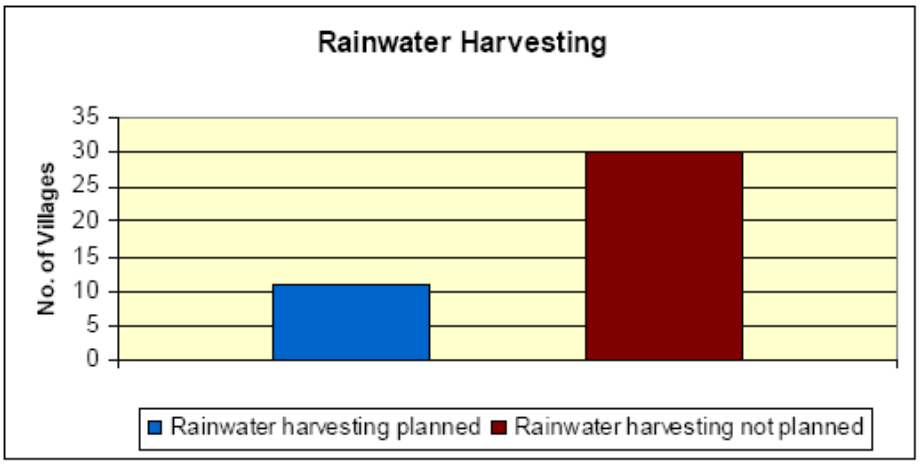
Rainwater harvesting, groundwater recharge & watershed management

The G.O. 172 does mention rainwater harvesting briefly among the other infrastructure facilities in housing reconstruction and the guidelines for reconstruction of house, mentions the provision of rooftop rainwater harvesting under the section on drainage (Disaster Management & Mitigation Department, 2005). The interpretation of this by various agencies is that rainwater harvesting and groundwater recharge are not mandatory and hence has not percolated to the housing programmes (UNDP and NCRC, 2006).

One study reveals that only 25% of the villages sampled for reconstruction had rainwater harvesting (UNDP and NCRC, 2006). It is not clear if this also included groundwater recharge and other

watershed management measure and in most likelihood is probably only roof top rainwater harvesting structures.

*Figure 13: Extent of rainwater harvesting in housing reconstruction**



* Source: UNDP and NCRC. 2006.

Some agencies like Auroville were involved in rainwater harvesting, groundwater recharge and other watershed management measures and had offered their services and assistance on the same (Carel, 2005).

The data and information on measures of rainwater harvesting, groundwater recharge and other watershed management measures in each of the housing sites are not available. There is very little documentation of traditional knowledge and techniques of communities towards rainwater harvesting, groundwater recharge and other watershed management measures. It is most likely that most likelihood many of the coastal agricultural communities would definitely have traditional soil conservation and watershed management techniques. There were in the past, quite a few traditional /indigenous man-made interventions in coastal Tamil Nadu such as *kulams* or *eris* that were appropriate solutions and were well connected with natural drainage pattern of this region. In fact, *kulams* on sand dunes were mainly designed to recharge the groundwater and improve the water quality. Many of these systems of traditional soil conservation and watershed management do not exist today or have declined and the extent of their prevalence in coastal areas is not known/well documented (Sangati CPR Working group).

Sanitation and groundwater

The coastal groundwater table being very shallow in most coastal areas and the inappropriate sanitation facilities provided in the relief phase and intermediate shelters, the ground water table became contaminated. The water contamination from sanitation in the tsunami affected areas of Tamil Nadu (or other states for that matter) has not been well documented (TRRC, 2005a). However, there are few studies to indicate that contamination did occur in almost all temporary and intermediate shelters (Auroville Water Harvest et al, 2005; Bhalla, 2006). A majority of the samples in all three Karaikal, Nagapattinam and Cuddalore had higher than permissible levels of *E. coli.* The average values for *E. coli* were 82.4, 72.3 and 231.5 respectively (Bhalla, 2006). This was due to ground water contamination from the untreated sewage. A large number of the toilets of the relief and intermediates shelters, including those built as part of post-tsunami reconstruction of permanent shelters rely on leach pits, which results in faecal contamination of ground water of most coastal areas, which have sandy soils and shallow water tables. The data suggests that faecal contamination is likely to increase both in terms of higher loads and spatially as more households adopt inappropriate sewage disposal techniques (Bhalla, 2006).

There have been many studies and experts that have called for special designs, guidelines and standards of sanitation and treatment facilities for coastal areas, especially areas with high water tables (TNTRC, 2006a). It has already been identified as a complex issue due to difficult soil and ground water conditions (UNDP and NCRC, 2006). One of the determining factors of design of sanitation and its usage by the community in coastal areas is the quality of water and soil and the availability of water respectively (Green Coast, 2006a; Ahana Lakshmi, 2006, pers. comm.).

Oxfam and RedR-IHE have undertaken a study on 'Ground water - Contamination and Quality Monitoring'. It consists of a coliform study, impact of leach contamination and behaviour in highly permeable soils. The permeability of soil and soil analysis would form as the basis for developing guidelines for toilet systems, disposal strategies (TNTRC, 2005). There are also teams looking at sanitation and treatment facilities for various areas and conditions along the coast. A number of workshops and consultations on the same also have been conducted till date (TRINet, 2006b). Yet, as of date, no special designs, guidelines and standards of sanitation and treatment facilities have been developed by the Government.

The case, as of now is that, the habitation/settlements are being built by one set of actors and another set of actors are dealing with the planning of sanitation after the construction of the settlements. The lack of integration of the aspect sanitation and treatment facilities at the initial stages of design and building of settlements is a problem which poses many limitations on the appropriate options.

Institutional mechanisms in sanitation- maintenance and other issues

The other issue is the lifecycle and financing of maintenance along with the roles, responsibility of community in the sanitation and treatment facilities. Currently there are no institutional structures proposed and one suggestion has been that the *Panchayats* take on some of these responsibilities or evolve mechanisms for the same. Vivekanandan points that the interface and interest of fishing community and fishing community institutions in *Gram Panchayats* is limited which would mean that such measures and ideas might fail in the long run (in TRINet, 2006b). Another issue/question he points out is the situation when the treatment and sanitation facilities have completed their lifespan, how replacement of these systems will be financed (TRINet, 2006b).

Hard options

Immediately after the tsunami, there were reports of sea walls being proposed for a large part of the coast in Tamil Nadu. These were mostly knee-jerk reactions and response to the tsunami, namely, building a 1000 km sea wall along the coastline of Tamil Nadu (Anon, 2005a; Das, 2005) Kerala, already has large part of its coast built up with sea walls. Out of the 560 km coastline of Kerala, the State has so far constructed a 386-km sea wall. The government has sought funding assistance to wall the remaining 92 km and has demanded Rs. 216 Crores from the Centre, pre-tsunami itself (Anon, 2004). The other hard engineering options in the post-tsunami reconstruction were the construction (and reconstruction) of the dykes, groynes, and breakwaters.

Communities have generally not been positive towards building of sea walls in Tamil Nadu, as they feel it is a hindrance to the landing and movement of their boats (Viswanathan, 2005). In Kanyakumari, there are reports that the community was earlier not in favour of Rubble Mount Sea (RMS) walls, but post-tsunami, but are more open to them now (Sunil Paliwal 2006, pers. comm.). In Kerala, due to severe erosion, there has been support for building these sea walls. However, Kerala unlike Tamil Nadu has backwaters where fisherman can dock their boats and hence the impacts and implications on livelihoods are minimal. The landing of craft is not affected drastically by these walls as it would in

Tamil Nadu. In Kerala, the demands for these sea walls have been mainly for the protection of housing. John Kurien feels that sea walls in Tamil Nadu are likely to be the "death knell" of the catamaran, as they need sandy beaches to land in and would otherwise break (Sridhar, 2005).

Agricultural communities are particularly apprehensive about sea walls as they believe it prevents rainwater run off into the sea leading to the flooding of agricultural land and degradation of the soil owing to stagnation of water (Viswanathan, 2005). In Kanyakumari there are many breakwaters that allow beach landing space on the inner side. The local administration has claimed that these are popular and are being demanded by the community. It should be emphasised here that, it is now being widely acknowledged that many of these hard options have serious ecological and environmental impacts (Hedao, 2005). The structures along with their ecological and environmental impacts also affect the livelihoods of fishing communities. There have been almost no studies documenting this, though many fishworker groups have voiced concerns on this aspect. Experts have repeatedly stressed that all hard options should be viewed as a last resort when all other measures are not likely to be effective (Sannasiraj, 2006). They have also pointed that many of the environmental and ecological impacts of these interventions are a result of the lack of or poor scientific and engineering studies in the design and planning of these options (Sannasiraj, 2006).

Sea walls do not prevent erosion they only transfer the problem further north. (Bhalla, 2006; Bhalla 2007). The impacts of these hard options on neighbouring coastlines create a situation where hard options are then required in these new areas creating a vicious spiralling situation. The case of sea walling in Kerala is an illustration of this aspect where the problem has been now shifted to Karnataka coast. In the case of Karnataka, as of 2003, 50% of the coastal zone was subject to moderate erosion and around 6% to severe erosion with varying rates of annual erosion from 5-15 tonnes/hectare in some areas to 15-40 tonnes/hectare in moderate and severe areas (Murthy, 2003; DoEE, 2003). Despite this, Kerala continues to build up the rest of its coastline (Anon, 2005c; Anon, 2006b).

Further, if not designed properly, the engineering structures can cause a negative impact of erosion in adjacent areas. Thus in locations sea walled and areas adjacent to some engineering structures there is a loss of beach space. This lack of beach space makes it unsuitable for basic livelihood activities such as landing boats, drying and repairing nets/motors. In these cases, most of the time the fisher folk are forced to land keep boats and store their gear fairly distant from their houses and sometimes end up anchoring their boats in open water. (Bhalla, 2006).

In many of the tsunami-affected areas there have been reports that the sea walls actually magnifying the damage as a result of the stones from these walls being thrown towards the land by the tsunami waves (Gilbert Rodrigo 2006, pers. comm.). Overall, their effectiveness in preventing tsunami inundation seems to be mixed with the only detailed study being done in Kerala which concludes that they do not seem to have any apparent merit considering the high cost and the aesthetic and environmental considerations (Kurian et al, 2006).

Other initiatives

The Asian Development Bank has undertaken technical assistance, with the objective of formulating a comprehensive program of “hard” and “soft” options for coastal protection (Asian Development Bank, 2006). The Technical Assistance “India: Integrated Coastal Management and Related Investment Development” TA-4692 has two study components, one of which is an assessment of coastal protection measures involving a technical analysis of various options. The analysis will consist of a preliminary feasibility study of alternative strategies considering a range of coastal protection measures suitable for

different scenarios (Asian Development Bank, 2005). However, the consultations for this TA has not been inclusive. For e.g., at a recent workshop held on December 8th 2006 for presenting and finalizing the draft report of the project, very few NGOs (both environment and fishworker) were invited (V. Vivekanandan 2006, pers. com.; Ranawana, 2006).

The World Bank assisted the Govt. of Tamil Nadu in the development of a Environmental and Social Management Framework which states "wherever possible, 'soft' options with fewer adverse environmental impacts should be favoured over 'hard' options that may involve changes to coastal hydrology and other natural processes" (Govt. of Tamil Nadu, 2005a).

Need for guidelines, policy and community space

Currently however, there is no framework for community involvement and consultation in pursuing the various hard options. It seems that large funding and demands of various other stakeholders and lobbies are the driving force behind many of these interventions for coastal protection. There is also no study or data revealing the community perspective and options on these hard options.

A combination of science, environmental and engineering based guidelines and criteria on the use of hard options for various contexts should be developed along with adequate space provided for taking into account the community perspectives and livelihood needs. The above two aspects should be mutually inclusive as they might either conflict or the latter may not always be the appropriate choice scientifically.

Data gaps

Pre-tsunami the spatial information of the details of all hard coastal engineering interventions is absent. In the post-tsunami context the same situation continues for repair work of damaged structures as well as new constructions. However, the presence of hard engineering structures pre-tsunami does provide an excellent opportunity for using tools such as satellite imagery, to study the impacts and role of these structures over time either during extreme events or the changes they cause on the surrounding shoreline.

Bio-shields, shelter belts and the community

Post-tsunami, the majority view of stakeholders has been in favour of natural barriers such as mangroves and vegetation in preference to concrete or stone structures. The Government of Tamil Nadu, under the Emergency Tsunami Reconstruction Project with World Bank assistance of Rs.10.17 Crores have undertaken the task of raising 2000 hectares of shelterbelt plantations and 700 hectares of mangrove plantations in the coastal areas of Tamil Nadu for the year 2005-06 (the same target will be executed the following year) (Govt. of Tamil Nadu, 2006a).

The unwritten policy of the Forest Department that in implementing this programme is that the shelterbelt plantations be a mix of 90% *Casuarina* and 10% other species (Narasimhan, 2005). This is carried our despite repeated suggestions and concerns from many environment-based NGOs to reverse this proportion. In fact, some papers mention that communities preferred other species such as *Thespesia populnea*, coconut, and cashew. These species improve the livelihood of the communities (Narasimhan, 2005).

This section will analyse this programme from a socio-ecological point of view. The model is being followed is part of the Joint Forest Management & Social Forestry programmes of the forest department. The Forest Department in each hamlet needs to take up a PRA based on which a village level micro-plan is developed along with formation of Village Forest Committees (VFC) (Rajeshwary, 2006). This does lay down some partial emphasis on process and participation but the ground reality and quality of process and participation is not known. As part of the programme, a number of entry point activities have been planned and envisaged. This is basically to build the trust of the community and get their

cooperation in return (Rajeshwary, 2006). It must be mentioned here that, the experience of the Forest Department in working with coastal communities have been limited. Unlike other areas, here the communities are also unfamiliar with exercises and programmes such as JFM, social forestry and Village Micro Plans.

As mentioned earlier (in the section on housing) access and visibility of the seashore/sea is highly crucial for fishermen as part of their livelihood and daily decision-making. The presence of bio-shields in front of settlements could impede the same. It is also well known that the communities do not want shelterbelts in front of their hamlet. Hence, understandably one finds that in none of the areas, shelter belts are executed directly in front of a settlement. This defeats the purpose of one of the benefits argued by the forest department namely, protection.

There has been very little focus on the social and legal aspects of the shelterbelts in the coastal areas of the country. However, in the past there have been cases of conflicts between the forest department (who promoted and implemented afforestation projects) and local communities on issues of access, passage and rights (Vivekanandan *et al.,* 1997; Ramasubramanian *et al.,* 2003). The communities are aware of these cases (they have narrated instances in other areas/hamlets where conflict have occurred) and hence their perception has not been positive and they are wary of plantations/restoration projects. In some villages, the communities have admitted to removing saplings being planted (Gomathy and Rodriguez, 2007).

The Forest Department have mostly sub-contracted the PRA exercise to local NGOs. A closer look at the PRA format reveals that it is only a survey exercise (a socio-economic analysis form is translated). Most of the fields of the form are socio-economic in nature and only four fields have direct relevance to the shelterbelts. They are fuel & fuel wood requirements, role of plantations during the tsunami, recommendations for plantations, and plant species needed for plantations. Thus, it seems the processes are not true PRA exercises and lack true participation in the exercise.

A review of the reports and plans from five districts namely, Nagapattinam, Tuticorin, Pudukottai, Thiruvallur, and Thirunelvelli reveal the following:

- Elements of equity in process of choosing the entry point activities and its beneficiaries are not clear (some entry point activities involve individual beneficiaries for e.g. distribution of goats).
- PRA format suggests it is only a socio-economic survey (sign on form) with very little community space for participation. Thus the use of the word PRA is misleading.
- In the Village Micro-plans, aspects on tenure of land, access, rights and benefit are not clear and in most cases are absent.
- The response of the community been lukewarm and their understanding of the ETRP project is poor.
- Surveys were done in too short a time to ascertain the needs and aspirations of the community.
- There is very poor participation of women in VFCs and in the PRA exercises.
- There is no focus and emphasis in watershed management and soil conservation measures as part of the programme.
- 90 % of the species planted are *Casuarina* and 10 % of mixed species is found in almost all the cases.

Data gaps

There are no independent or parallel studies reviewing these aspects in the ETRP project. There is also no uniform level and format of information in each district. At the headquarter level there is very little information available and unlike the Department of Environment (DoE) there is no progress monitoring and reporting on the website of the Forest Department.[84] The information does not have spatial attributes and hence cannot be of use for any spatial analysis. The scope and level of participation has been greatly reduced by not conducting PRAs and instead conducting sign up surveys. Finally, the institutional mechanisms followed for the shelter programme of the Forest Department lacks clarity on aspects of tenure, access, rights and benefit-sharing.

Recommendations

From the above review, it is indeed an ironic finding that reconstruction & rehabilitation can prove as damaging (socially and ecologically) to the coastal ecosystem and coastal communities as the tsunami itself. Based on the review the following suggestions have been made below under different topics.

Fisheries

- There is a need to conduct regular long-term monitoring and assessments of craft composition, use, ranges, fishing grounds, engine capacities, trips per month along with net use, targeted species, catch and income in all affected areas. This can then be used to arrive at the Catch per Unit Effort (CPUE) and other analyses in the fisheries. Some innovative aspects such as community-based monitoring of fish catch and income can also be initiated as part of this. For e.g. the SIFFS societies which already keep records can be further trained to keep records and collect data for scientific monitoring of income and catch. This will be able to arrive at the long-term trends and their implications for the fisheries sector.
- A study documenting and mapping the conflicts pre- and post-tsunami on aspects related to fisheries. A further analysis of these conflicts especially their underlying causes will give a better understanding of the present problems linked (categorised into those related to rehabilitation and those which are not related to rehabilitation).
- Document the region specific TEK and community perceptions of changes and trends pre- and post-tsunami, and the community adaptations to these perceived trends.
- Assess the roles, capacities, spaces and mechanisms for community and traditional community institutions for various fisheries management approaches. Based on these pilot studies, fisheries management approaches could be explored.
- Detailed understanding of the factors that influenced resumption of fishing post-tsunami in each village in all the affected districts.
- Survey of the extent of use of destructive fishing gear such as drag nets and mini seine nets "surukuvalai".
- Study of ownership, crew dynamics especially group ownership in each region pre- and post-tsunami.
- Detailed study of land tenure and rights in the coast with special emphasis and focus on fishing communities.

[84] The DoE, GoTN has posted the progress of its component of the World Bank ETRP project online at http://www.environment.tn.nic.in/DOCU/ETRP.pdf

- A study to understand the history, origins and reasons for group ownership pre-tsunami as well as the context of how and why they have failed in some areas, while succeeding in other areas to obtain a better understanding of socio-ecological resilience of these communities.

Agriculture

- Documentation of the agro-biodiversity of all the districts along with seed conservation measures (wild varieties, land races & cultivars). As some of the areas are prone to disasters such as storm surges and floods, seed conservation and storage strategies of the locally used varieties need to be developed.
- There is a need to document the knowledge and support the revitalisation of traditional water, irrigation and watershed management practices along with evolving/reviving mechanisms (such as traditional community institutions &, gram *panchayats*) that can support and sustain them. Government and civil society support is essential for this.
- Steps to address many of the above-mentioned long-term issues and background trends in agriculture such as disasters, management of water bodies, soil quality, poor crop yield etc. using both traditional and modern tools should be taken as part of the rehabilitation.
- The current initiative by NCRC, Nagapattinam of the mapping of coastal water bodies should be done with spatial tools, satellite imagery and data in order to enhance its execution and should be extended to all the affected coastal districts.
- Continuous monitoring of crop yield, soil and water quality in all the affected districts should be taken up for the next few years.

Groundwater

- Analyse the impact of land use and hydrological changes at select sites in the coastal zone of the affected states.
- Document the current status of the quantity and quality of ground and surface water resources in the coastal zone with the predicted trend in the short and long-term and assess the major drivers of changes in water quality and quantity in the coastal zone including emerging land-use/water-use such as aquaculture and reconstruction.

Aquaculture

- A spatially mapping and stock-taking of aquafarms and hatcheries of all categories and sizes should be undertaken in the CRZ.
- The stock-taking should be followed by the enforcement of the Supreme Court's verdict and all guidelines on aquaculture.

Reconstruction & rehabilitation

- Spatial mapping of the new shelters as part of rehabilitation (both in and ex-situ reconstruction) in all affected states. The above will give an idea of changes of built up area in the coastal zone and exact details on the levels of re-location spatially. It is also important to spatially map the pre-tsunami settlement baseline.
- The details of settlement reconstruction would need collected and mapped for all the sites in different categories & zones of the CRZ (0-200, 200-500 and above 500 m). Preferably the exact location and distance from HTL would be needed to be spatially mapped and the above incorporated into the CZMP.
- It is important to study and analyse the trends of settlement patterns and locations traditional of fishing hamlets over space and time (pre-tsunami over 2-3 decades). This will also cover the

linkages of housing layout and its importance in socio-ecological and socio-economic aspects of communities.

- Ensure participation especially of women in housing layout allotment in the reconstruction process.
- It is important to document and analyse the various incentives and disincentives in the community's view for relocation and their orders of priority/ weightage for settlements .
- Study and document through case studies and micro level studies, the socio-economic & socio-ecological implications of relocation on ecosystem-derived livelihoods.
- The technical guidelines for shelter reconstruction need to be further developed incorporating aspects of environmental planning such as sanitation, wetland drainage, water and watershed management.
- In other cases of environmental planning, post-facto measures, surveys and studies in the sites retrospectively should be carried out to at least minimise by the impacts and perhaps reduce vulnerability of the settlement. Specifically, mapping of wetland drainage and watershed in all the reconstruction sites should be undertaken along with retrospective drainage planning and management measures.
- Due process should be followed for environmental clearance procedures for all rehabilitation projects esp. those in G.O 531.
- The type of water supply and extraction under the reconstruction in all areas of the CRZ is should be documented and mapped. All details of groundwater extraction as part of the reconstruction should be furnished to the State Coastal Zone Management Authority with a request for permission along with a No Objection Certificate from the State Ground Water Authority.
- Water harvesting, ground water and watershed management measures should be made mandatory as part of the rehabilitation.
- Develop standards and guidelines for sanitation - toilet systems and disposal strategies in coastal areas.
- Develop mechanisms for roles, responsibility maintenance and replacement of sanitation systems.
- Build stronger environmental advocacy and awareness among NGOs involved in shelter reconstruction.

Hard engineering options

- Develop guidelines and policy on the use of hard engineering options for coastal management and other purposes along with space for community participation and consent.
- A comprehensive assessment of role of hard engineering options in the impact of the tsunami and other natural disasters.
- Detailed quantitative study of the impacts of sea walls and other engineering structures on livelihoods.
- EIA and environmental clearance should be made mandatory for all hard engineering projects are undertaken on the coast.

Shelterbelts & bio-shields

- The Forest Department should develop policy and guidelines for their shelter belt programme through a participatory and consultative process with clarity on aspects of consent, tenure, access, rights and benefit-sharing.
- Awareness & capacity building of communities on various community policies and programmes of the forest department such as JFM, social forestry etc.
- Spatial mapping of all natural and shelter belt vegetation in all the tsunami affected districts.

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