

Beyond the Tsunami

Coastal Sand Dunes of Tamil Nadu, India - An Overview

2008



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Back cover photo: *Ipomea pes-caprae* on sand dunes along the east coast, India (Photo credit: A. Sridhar, 2008.)

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1. Background

There has been considerable pressure from ill-planned developmental activities on the coastal areas of the east coast of India, especially Tamil Nadu, which have already lead to repercussions on the coastline and its ecology. Though ecosystems like mangroves, coral reefs and seagrass beds are getting recognition as important coastal ecosystems and shoreline stabilizers, sandy beaches and sand dunes do not get adequate attention as important coastal ecosystems in their own right, and their role in stabilizing the coastline is mostly overlooked.

After the December 2004 tsunami that hit the south-east coast of India, there has been recognition among coastal communities living adjacent to coastal sand dunes about the value of these habitats in protecting the hinterland and coastal hamlets, and their role in preventing salt water intrusion as a result of inundation by large waves. Their value and profile have risen after the tsunami and resulted in better recognition of their cultural, social and ecological significance. Post tsunami community initiated attempts to conserve and revive sand dune ecosystems in some parts of Tamil Nadu is in itself a good indicator of the fact that communities have recognized the value of sand dunes. In spite of all this, sand dunes have not enjoyed the kind of attention or popularity that is given to other coastal ecosystems like mangroves and coral reefs. In fact, both funds and attention have been focused on bioshields for coastal protection, which are in fact controversial from both ecological and community perspectives.

As part of the first phase of the UNDP/UNTRIS Post Tsunami Environment Initiative project, a rapid preliminary field survey was conducted on the east coast of India, covering Tamil Nadu and southern Andhra Pradesh in order to document the current status of sandy beaches and sand dunes of the region (Gokul & Shanker 2007). The study aimed to characterise the physical and biological features of beaches and dunes and to understand the extent of human impacts on them. The study revealed that a majority of the sandy beaches and sand dunes of many stations were already severely affected by anthropogenic impacts of various sorts and the others were under threat.

Further, a rapid literature review was carried out to compile existing baseline information and document gaps in the study of sandy beaches and sand dunes along with other major coastal and marine ecosystems (Mukherjee *et al.*, 2007; Muthuraman *et al.*, 2007). The gap analysis from India revealed a dearth of information on coastal ecosystems, especially sand dunes. It was observed that prior to late 1990s, there were virtually no studies on coastal sand dunes along the Tamil Nadu coast. The little information available on coastal sand dunes in India is scattered in various reports and inaccessible sources. The need for a simple, easily accessible and comprehensible source of information on coastal sand dunes for the community, academic institutions, and managers and decision makers becomes imperative.

The report has the following objectives:

- To compile general information on sand dunes (formation and dynamics, local flora and fauna, socio-ecological and cultural significance, threats, management and rehabilitation)
- To prepare a bibliography on all relevant information on sand dunes from India and Tamil Nadu which would help in directing and focusing future research
- To compile information on restoration of dunes and effective management practices
- To analyse and present information on legislation and policy with regard to sand dunes

2. Gap Analysis

In order to achieve the above objectives, we reviewed existing baseline information on sand dunes ecosystems from Tamil Nadu, India, to determine the current status of research, analyse gaps and focus future research in the subject. Information on sand dunes was compiled from literature, including peer reviewed publications, reports, popular articles, newspaper reports and anecdotal reports. As part of the sociology, ecology and fisheries components of the PTEI project, we conducted extensive interactions with local communities in order to understand their perceptions and understanding of the coastal environment including sand dunes.

Various methods were used to collect literature, including internet searches, searches through online databases, visits to institutions, and information from the networking components of the project. The available information was found to be scattered over various articles, reports and publications with only a handful of peer reviewed publications. We therefore compiled a bibliography of available information on coastal sand dunes along the Tamil Nadu and Puducherry coasts and other regions in India (See Appendix 3 & 4). The conclusions of the gap analysis may be summarised as follows:

- Only two major studies have been conducted on coastal sand dunes and there was no other mention of sand dunes of Tamil Nadu in reports prior to the December 2004 tsunami. There were seven major studies on sand dunes within the next three years (2005-2007) and more than ten reports mentioning the importance of sand dunes and their importance in shielding and stabilizing the coastline. This clearly indicates the general neglect and overlooking of coastal sand dunes prior to the tsunami and a sudden recognition of sand dunes as important coastal features after the event.
- Information on the types, distribution and floral and faunal diversity of coastal sand dunes are very poorly documented or understood in India (and even more so in Tamil Nadu).
- There is little information on the present status, social and ecological value of coastal sand dunes and the threats they face.
- Though there are reports of sand dune destructive practices prevalent in coastal regions, no attempt has been made to scientifically document the ecological and social repercussions of these practices.
- Coastal sand dunes have received much less attention than they deserve as natural shields protecting the hinterland from storm surges, rare events such as tsunamis, in maintaining water table levels in coastal areas and shielding coastal agriculture from salt laden winds.
- Though sand dunes receive some legal protection under the CRZ (Coastal Regulation Zone) Notification, 1991, issued under the Environment (Protection) Act, 1986, lack of awareness among resource managers and communities of their legal status leads to poor implementation of these regulations.

3. Context

India has a coastline of about 7,500 km (Chandramohan *et al.* 2001) and nearly 250 million people live within a distance of 50 km from the coast (Areti 2007). The coastal area acts as a buffer-zone between the marine and the terrestrial realms, soaking up a major portion of the impact and energy of waves and storms (Mascarenhas 2004). The coastal zone is endowed with a wide range of ecosystems such as mangroves, coral reefs, sea grasses, salt marshes, sand dunes, and estuaries and each of these ecosystems are in turn characterised by distinct biotic and abiotic processes. In addition to their ecological value, these ecosystems play a vital role in the nation's economy by providing livelihoods for a majority of the coastal population. Despite their diversity of terrestrial and aquatic habitats, ecological landscapes along the coast remain rather poorly understood, but nevertheless under intense human pressures (Daniels *et al.* 2006).

With increasing recognition of the economic value and the ecosystem deliverables that are derived from coastal areas and owing to increasing human population, urbanization and accelerated developmental activities, coastal areas are receiving more attention and importance in recent years. Further, coastal areas are also prone to cyclones and natural disasters. The entire east and west coasts of India, and the islands of Lakshadweep and Andaman and Nicobar face frequent cyclonic storms which sometimes cause large-scale destruction of life and property. Meteorological information shows that more than 1000 cyclonic disturbances occurred in the Bay of Bengal during the last century (Shrestha 1998), among which over 500 were either depressions or deep depressions, and over 400 were either cyclonic storms or severe storms, making the east coast of India one of the most vulnerable coastlines of the world.

The tsunami, which occurred on 26th December 2004, was one of the most destructive natural catastrophes to occur along the Indian coast in recent times. Major destruction was caused by the tsunami to life and property and natural resources along the coast of Andaman and Nicobar, Tamil Nadu, Puducherry and Kerala. It will take several years to restore the damage caused by this event. While it may not be possible to devise man made interventions to fully control the impact of such an event, the value of natural protecting systems such as coastal plantations (bioshields), mangroves, coral reefs, and sand dune in mitigating impacts is now being examined (Shanker *et al.* 2008).

4. Formation of coastal sand dunes

In physical geography, a dune can be defined as a hill of sand built by aeolian processes (wind action) (Bagnold 1954). Dunes form in different sizes based on their interaction with the wind (Tinley 1985; McGwynne & McLachlan 1992). Dunes are formed by sand particles carried by the wind from the beach. The wind transports the sand particles by suspension, saltation or by surface creep (McGwynne & McLachlan 1992). 'Suspension' is the lifting of the lighter sand particles by the wind, which carries them for a comparatively long distance while 'saltation' is the lifting of heavier particles by the wind in a series of hops and jumps. 'Surface creep' is the rolling of the particle on the surface and its transportation to another area. Most sand particles are moved by saltation (Bagnold 1954). Obstacles such as vegetation, fences, rocks and other geographic features trap the moving sand grains. As the sand grains get trapped they start to accumulate, and this is the start of dune formation (Fig.1).



(Source: McLachlan, A. & A. C. Brown. 2006. *The Ecology of Sandy Shores*, Academic Press. pp. 373)

Figure 1: Sand particles carried by wind from the adjacent beach are trapped by obstacles, gradually forming a small mound (embryo dune) and later with more accumulation of sand into large dunes.

The wind then starts to affect the mound of sand by eroding sand particles from the windward side and depositing them on the leeward side (Fig.2). Over time, they develop into a series of dunes, which are usually named primary, secondary and tertiary, starting from the seaward line (Fig.3). Most kinds of dunes are longer on the windward side where the sand is pushed up the dune, and have a shorter "slip face" in the lee of the wind.



Figure 2: Sand on the windward side (facing the sea) is carried and deposited on the leeward side (facing land), forming a gradual slope on the windward side a slip face on the leeward side (Courtesy: Deepthi Radhakrishnan, Handesigns, 2008).

Coastal sand dunes are generally formed in close proximity to beaches where waves encourage the accumulation of sand on the beach, and prevailing onshore winds blow this sand inland (McLachlan & Brown 2006). The sand blown inland gets trapped by the vegetation and this action causes the dune to “migrate” inland. As it does, the dune accumulates more and more sand and some coastal areas have one or more sets of dunes running parallel to the shoreline directly inland from the beach (McLachlan & Brown 2006). In most such cases, dunes are important in protecting the land against potential ravages of the sea. The valley or trough between dunes is called a ‘slack’.

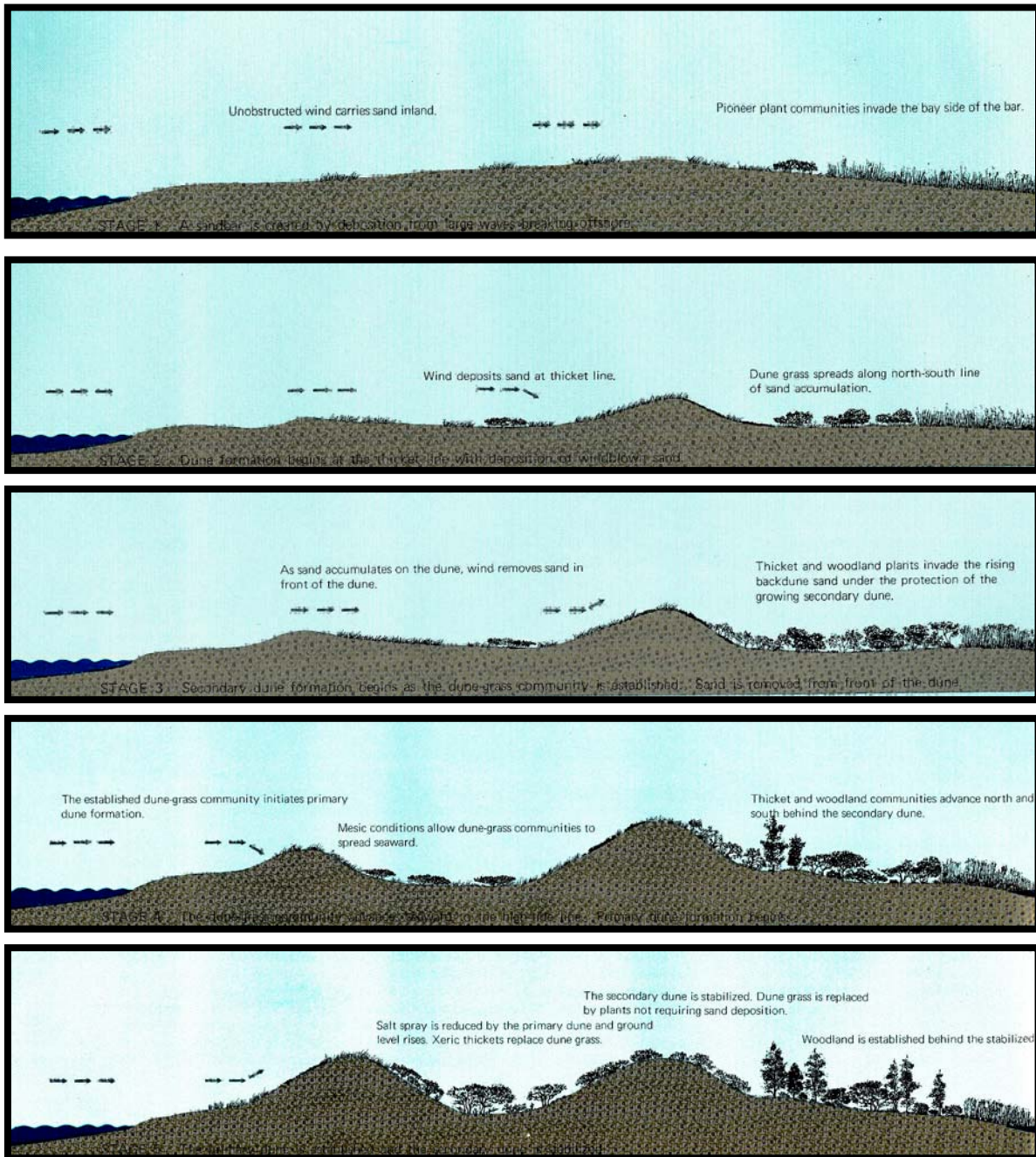


Figure 3: Various stages of sand dune formation (Source: McHarg, I. L. 1995. Design with Nature)

5. Types and classification of dunes

Coastal sand dunes are shaped and sculpted by the prevailing conditions of wind, sand supply, climate, vegetation and human disturbance. Various shapes, sizes and morphology of dunes have been described (e.g. Tinley 1985, McGwynne & McLachlan 1992, Silverside 2001), and this has led to considerable confusion in describing and naming different dunes types. Consequently, some studies have reduced dune classification to three major categories (Hesp 1991; Izak & Illenberger 1996; McLachlan & Brown 2006): (a) Foredunes (b) Parabolic Dunes, and (c) Transgressive dunes.

Foredunes are the most common dune type of the coasts and are accretionary in nature. They are the most vegetated of the dunes types; the presence of vegetation is the critical factor that causes the distinctive accretionary character of retentive systems, where aggressive pioneer plants dominate the windward side and thicker, dense xeric vegetation dominates the landward (precipitation) side. They are formed on sheltered or low-wind energy beaches where the pioneer plants are able to trap more sand and stabilize dunes. Foredunes grow mostly by accretion, and are comparatively static. The foredunes may exist in the form of:

- incipient foredunes - which are in the process of accretion with pioneering plants dominating
- established foredunes – where woody vegetation has reached reasonable height and the dunes are quite stable
- relict foredunes – remnants of earlier foredunes left behind by a prograding shoreline (where the shoreline shifts seaward due to fresh sand accretion or changes in sand dynamic on the beach).

Foredune systems are efficient in buffering the shoreline as they store sand in the littoral active zone that may be released to the beach during storms. This sand is stored over a short time or over decades to millennia depending on the wave activity of the shoreline.

Parabolic dunes occur in regions of higher wind speeds, forming typical strong concave shaped cavities called blowouts. A large amount of sand gets transported to the landward side of the dunes. Vegetation on the seaward side is sparse and dominated by prolific and sturdy species of primary colonizers. When harsh conditions and excessive sand transport lead to a reduction of vegetative cover on the seaward side, blowouts form.

Transgressive dunes occur in regions dominated by strong winds regimes, where huge volumes of sand are transported. Such dunes are generally devoid of vegetation and highly mobile generally moving several meters per year. While these dunes grow by accumulation of sand, a conspicuous feature is the dynamic down-wind movement of the individual dunes as well as the dunefield (Rust & Illenberger 1996). The axis of these dunes run at an angle perpendicular to the prevailing winds. Most transgressive dunes move sand inland, away from the beach and the littoral active zone.

6. Coastal sand dunes along the Tamil Nadu and Puducherry

A review of available literature on distribution of coastal dune systems in Tamil Nadu indicates that information on the distribution of coastal sand dunes along the Tamil Nadu coast is scarce and patchy. Praxis (2005 b-i) and EQUATIONS (2006) have conducted some studies on the distribution of sand dunes and their shielding effects in the wake of the tsunami along the Tamil Nadu coast.

Coastal sand dunes are present in almost all the maritime states of India. Along the Tamil Nadu coast, almost all coastal districts including Thiruvallur, Chennai, Kancheepuram, Vilupuram, Cuddalore, Nagapattinam, Ramanathapuram, Thoothukudi, Thirunelveli and Kanyakumari have sandy beaches and dunes in their coastal areas (EQUATIONS 2006).

The maximum length of dunes was observed at Nagapattinam (594m) and minimum at Marakkanam (42m) beaches. The dune height ranges from 0.5 to 10 metres. Groyne have been built along the Nagapattinam coast for dune formation and sand accumulation has been observed near the groyne. Common flora on the beach include *Ipomoea pes-caprae*, *Spinifex* and *Casuarina*. Palm and coconut trees dominate the background. *Prosopis* is also found extensively along the coast mixed with ground vegetation and background trees.

One of the major studies on coastal sand dunes of the Tamil Nadu coast is by Sanjeevi (1996); the section below largely summarizes his findings, unless otherwise specified.

6.1 Chennai Region

Coastal dunes are seen most prominently south of Chennai city, but the beaches in Chennai are primarily recreational areas and have, more recently, become residential areas. Areas adjacent to sand dunes have potable groundwater available at shallow depths, which is being over exploited resulting in extensive salt-water intrusion in coastal aquifers of these areas, disrupting the dynamics of groundwater. The Tiruvanmiyur aquifer located on a huge stretch of dune is a major source of water for the city.

Coastal sand dunes are well developed north of Chennai and south of Pulicat Lake, even reaching heights of 3m in places. They are covered by vast *Casuarina* plantations and are quite stable.

A long stretch of well developed coastal sand dunes lies between Mahabalipuram and Marakkanam and the dunes are used for coconut and *Casuarina* plantation. A notable feature of these dunes is the availability of high-grade silica sand (Fig. 4 and 5).

6.2 Puducherry and Portonovo regions

While coastal dunes of the Chennai region are wide, dunes of the Puducherry and Porto Novo regions are narrower, but high, reaching heights of about 10m. Pitchavaram has ancient and stabilized dunes and they are peculiarly shaped due to the water occupying inter-dunal depressions or swales. The swales have a high clay-content giving the soil an impermeable character that has helped the formation of fresh water lakes. These dunes are well stabilized and the locals claim that they are quite ancient. Though most of the dunes here have *Casuarina* or coconut plantations, some areas also have mixed vegetation supporting species like *Prosopis*, *Eucalyptus* and other shrub species.

Many of these dunes have been reported to have been flattened for agriculture, as the swales have a high mineral and clay content, making it a very fertile soil to grow paddy.

6.3 Cauvery delta and Point Calimere region

Some coastal areas like Karaikkal and the region from Nagapattinam to Point Calimere in the Coromandel coast have remarkable and extensive belts of coastal sand dunes. Poigainallur and South Poigainallur in Nagapattinam district have extensive dunes reaching up to 15 metres which extend all the way up to Velankanni in the south. Satellite images of these coastal dunes have shown them to be linear and hyperbolic strandlines. It is theorised that the presence of so many dunes in this area is due to the constant supply of sand from the Cauvery River. Many of these dunes have been reported to have been flattened and converted into agricultural land and recently to build aquaculture ponds. Mixed vegetation of *Casuarina*, *Prosopis* and mangrove species are seen.

Ancient coastal dunes observed about 35 km from Point Calimere coast have been dated as paleodunes, roughly identified as those from the Holocene period. However, these dunes have been reported to prevent the draining of rain water to the sea, causing floods during the monsoons. (Ramasamy *et al.* 1989).

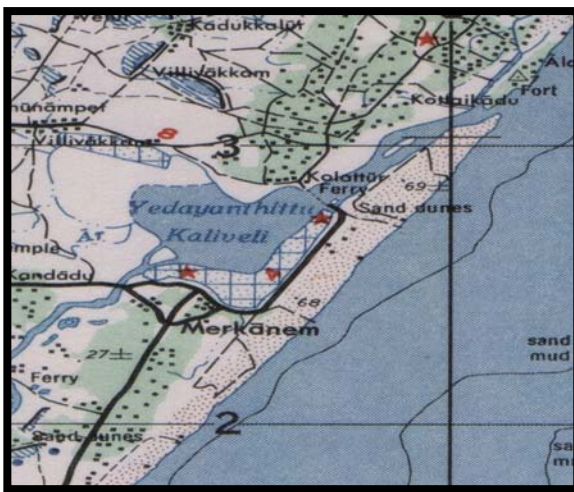


Figure 4: Coastal sand dune formation near Markanam



Figure 5: Coastal sand dune formation near Mahabalipuram

(Source – USAMS & Survey of India, 1954; areas marked with red dots indicate the presence of sand dunes)

6.4 Rameswaram region

Rameswaram has areas of wide and gently undulating interspersed dunes with areas of black soil. Between Puddupattinam and Tondi, wide dune systems are found running parallel to the coast. On the Rameshwaram Island, the dunes are of great height and have sparse vegetation, and are subject to frequent surges during the monsoons. *Palmyrah*, *Prosopis*, *Casuarina* and coconut are commonly observed on these dunes.

6.5 Tuticorin and Cape Comorin

This region is not reported to have extensive dunes. Few dunes occur near Circular Fort (“*Vattakotta*” in the vernacular) and the beaches are quite broad and are known to have deposits of heavy minerals like magnetite, limonite, rutile and garnet. This is heavily exploited, leading to considerable impacts to the coastal ecosystems (Fig. 36). A small dune is also observed in the spit at Tuticorin port. There is a sudden change in morphology of the coast towards the west of Kanyakumari, with dunes up to a height of 10 m. A distinct feature of these dunes is a pair of oval shaped basins of sand.

7. Unique adaptations and ecological succession on sand dunes

Conditions on a newly evolved dune are harsh. The dune system has several physio-chemical parameters, which are typical and limit the distribution of flora and fauna. Such parameters include poor nutrient levels, higher temperature, exposure/desiccation, low moisture retention, soil erosion, sand accretion, soil salinity, salt spray, changes in organic matter and pH (Hesp 1991). Under such environments, plants have certain coping mechanisms to enable successful establishment (Kumler 1969). Some of the major adaptations of these plants are fast vertical growth in order to escape burial by sand, thick xeric leaves and a protected stoma that minimize transpiration. Dune sand also has a high content of calcium carbonate from seashells. Poor nutrient levels limit plant growth and rotting seaweed and other beach wrack (dead and decaying organic matter of plant and animal origin) add nutrients which allow pioneer species to colonize the dune (Skiba & Wainwright 1984).

Pioneer plant species are well adapted to the harsh conditions that prevail by having deep roots which reach for the water table, root nodules that produce nitrogen compounds and a protected stoma and thick leathery leaves that reduce water loss by transpiration. The deep roots help in anchorage and in holding the sand in place, and the dune grows into a foredune as more sand is blown over. Most of the pioneer species are prostrate with runners or creepers that help them to overcome burial by the continuously shifting sand particles. *Spinifex sericeus* and *Ipomoea pes-caprae* are the major pioneer species of the Tamil Nadu coast. Later, smaller shrubs *Lumnitzaria racemosa* and *Desmodium triflorum* take over, giving way to larger shrubs like *Prosopis julifera* and other xeric species (cacti). In certain areas, grasses nitrify the soil, therefore allowing less hardy plants to colonize the dunes. These flora are adapted to low soil water content and have small, prickly leaves which reduce transpiration. During rains, leaching occurs on the dunes, washing all the nutrients and humus into the slacks and the slacks in turn may support a wider array of flora and fauna than the exposed tops of dunes. It is usually in the slacks that more rare species are developed and sometimes the soil of the dune slacks gets waterlogged and only marsh plants can survive (McLachlan 1991) (Fig. 6-9).

Dunes are highly dynamic topographic features, and may undergo rapid changes when not anchored by vegetation. They may move inland as a result of onshore winds and may be eroded by wave action and high water levels associated with severe storms. Depending on the wind direction, vegetation cover, disturbance etc., the size and shape of the dune system can change or even be completely destroyed in a short period of time, despite the relatively longer period taken in the formation and stabilization of a dune system. Structural changes such as blowouts and parabolic dunes could be created due to any change in wind direction and loss of vegetation cover due to animal grazing (Caribbean Environment Programme 1998).

Stages in the succession of flora on sand dunes:



Figure 6. Creepers like *Spinifex* spp, are initial colonizers, on foredunes (Photo credit: A. Murugan)



Figure 7: Secondary stage where shrubs colonise the leeward side, consolidating the dune further. (Photo credit: Aarthi Sridhar)



Figure 8: Tertiary or final stage, where larger shrubs and trees take over on the leeward side (Photo credit: Sudarshan Rodriguez)



Figure 9: All three stages evident with creepers like *spinifex* and *Ipomoea* in the foreground, smaller shrubs (*Prosopis julifera*) behind and large palmyra trees in the background (Photo credit: A. Murugan)

8. Flora

The flora of coastal sand dunes have received comparatively more attention than the faunal elements. Various forms strand vegetation are found on the coastal sand dunes of the Indian subcontinent (e.g. mat-forming creepers, prostrate/erect herbs and sedges, climbers, plants with perennating organs, scrubs, trees) (Rao & Meher-Homji 1985). Strand and associated flora of Indian sand dunes consist of 154 species belonging to 108 genera and 41 families (Arun *et al.* 1999; Rao & Sherieff 2002). Fabaceae has the highest number of species (24 species), followed by Poaceae (22 species), Asteraceae (15 species) and Cyperaceae (13 species).

During the year 2007, a rapid survey was conducted along thirteen beaches of the Palk Bay and Coromandel coasts along Tamil Nadu as part of Phase1 of the UNDP/PTEI project (Gokul & Shanker 2007). In the study, the coastal vegetation, extent of dunes, and the type and extent of anthropogenic disturbance were recorded (see Appendix 1). It was observed that areas with extensive dunes also had a higher diversity of plants and trees. The Palk Bay region did not record any sand dunes, and the mangrove species *Avicennia marina* was recorded in nearly all the three stations. Some of the most common and widely distributed of the shrubs were *Prosopis juliflora* and *Ipomoea pes-caprae*.

Listed below are common plant species observed in the dune system of Tamil Nadu.

Creepers- *Ipomoea pes-caprae* (Tamil-Vernacular-*Attukal*) (Figures 10 & 13), *Spinifex sp.* (Tamil-vernacular- *Ravanan meesai*) (Figures 11 & 14).

Shrubs like *Lumnitzaria racemosa* (Fig. 12), *Desmodium* were also encountered on the foredunes of Tamil Nadu coast.

Trees- Palmyrah (*Borassus flabellifer*), *Casuarina* (planted) (Fig. 16), Cashew (*Anacardium oxydentrum*) *Pandanus sp.*, *Calophyllum inophyllum* etc. Local tree species like *Tamarindus indica*, *Erythrina indica*, *Hibiscus tiliaceus* have the ability to survive in dune systems but are mostly restricted to landward slopes of rear dunes. *Casuarina* and *Prosopis* are some of the invasive/introduced species that out-compete native sand dunes species (Fig. 15, 39 & 40).

Derris triflorum, *Pandanus sp.* and *Sesuvium portulacastrum*, and some common mangrove associates can also survive on sand dunes.



Figure 10: *Ipomoea pes-caprae* (Photo credit: A. Gokul)



Figure 11: *Spinifex sericeus* beds in Narippur, Southeast Tamil Nadu (Photo credit: A. Murugan)



Figure 12: *Lumnitzaria racemosa* from Adirampattinam coast (Courtesy: A. Gokul, ATREE, 2007)

Ipomoea pes-caprae
 Common name - Goat's foot convolulus/railroad vine
 Vernacular name Attukkaal
 Description:
 The goat's foot convolulus is a prostrate, perennial herbaceous plant with leaves shaped like the footprints of a goat's foot. The succulent runners produce a milky sap. Leaves are alternating in venation and have a notch at the end. Tap roots reach deep into the sand. They produce purplish-pink bell-shaped flower and the globular seed capsule is about 10-12 cm long, containing up to 4 seeds. They are salt tolerant and the initial colonisers of the seaward slopes of dunes and the berm of beaches. They are quite common along the beaches of Tamil Nadu and help in stabilizing the substrate. They can be established on a dune by sowing their seeds directly into the sand. The seeds can also be raised in the nursery. A more common method of planting is by the direct planting of the runners during spring. Runners of 30 cm length can be planted at 1-3 metre gaps.








Figure 13: Description of *Ipomoea pes-caprae*

Spinifex littoreus
 Common name - Sand spinifex grass
 Vernacular name - Ravana meesai
 Description:
Spinifex is a prostrate, perennial grass capable of growing up to 40 cm tall. They have strong creeping runners, with nodes and internodes. The nodes produce roots and numerous upright leafy branches. They are very common on the seaward sides of the berm and foredunes along the Tamil Nadu coast and along with *Ipomoea* are the most important initial colonizers of dunes. The nodes and vertically erect leafy branches help them withstand burial and the roots provide strong anchorage in the shifting sand. They are a salt tolerant species, and vital in trapping and stabilizing sand. They grow on all parts of the dunes and is usually the dominant species colonizing the seaward slope and is an important plant used in recovering and replanting dunes.





Figure 14: Description of *Spinifex littoreus*

Casuarina equisetifolia
 Common name - Horsetail she-oak
 Vernacular name - Savukku maram
 Description:
 Casuarina are fast growing, pine like trees reaching up to 10 m height. They produce needles which are long, jointed green branches with minute scale-leaves. The inconspicuous male and female flowers grow in the same tree. The trees are highly adapted to growth in a variety of ecosystems, especially in dry and arid regions. The slender green branches that replace leaves are specialized adaptations that permit them to minimize moisture loss. Its aggressive root system enables it to survive in usually dry and impoverished substrate. It is a native of Australia and was introduced to different parts of the world as a wind-break and as a source for wood. It is now considered an invasive species as it out-competes native species, acting as a serious threat to local biodiversity.






Figure 15: Description of *Casuarina equisetifolia*

Borassus flabellifer
 Common name - Toddy palm, Sugar palm
 Vernacular name - Pana maram
 Description:
 The toddy palm is a strong robust palm reaching heights of 30 metres and can live up to a 100 years. The trunk is stout and brownish-black in colour with leaf scars. It produces a canopy of leaves on several dozen fronds. Fruits are borne in clusters, large and black and 4-7 inches in diameter, with a black husk inside. It is the most common native tree species found on the coastal sand dunes of Tamil Nadu. The tree used to be cultivated in large areas in order to extract jaggery. The seeds are planted about 2 ft apart on the back dunes. The leaves, fronds, fruit, sap, trunk and the sprouts are all used by the local coastal communities for various purposes. The tree grows slowly in its initial stages, but speeds up later. They successfully colonize dry, sandy areas and are capable of withstanding considerable wind speed.






Figure 16: Description of *Borassus flabellifer*

9. Fauna

Coastal sand dune fauna of India are very poorly studied and understood. There is virtually no information on their diversity, status and distribution. We are therefore providing some general information pertaining to coastal sand dune fauna from other regions of the world. Generally, the dominant tropical sandy beach micofauna includes nematodes, turbellarians, and gastrotrichs (Urban-Malinga & Opaliński 2001). Other meiofaunal groups such as copepods, ostracods, amphipods and polychaetes are also commonly observed in the wet/moist regions of sand dunes (Van der Merwe & McLachlan 1991). In wet dune slacks, the biomass of the interstitial communities may exceed the biomass of macrofauna (McLachlan *et al.* 1996).

Coastal sand dune fauna are limited, but may contain unique elements, and is a generally neglected group of fauna, especially in the Indian context. Arthropods and vertebrates usually predominate in coastal dune fauna. Insects particularly hymenoptera, coleoptera, and diptera predominate (Van Heerdt & Morzer Bruyns 1960; Hoeseler 1988). Molluscs may be well represented on lime rich soils, and frogs and other groups have also been recorded (Roberts 1984). Vertebrates include reptiles like the fan-throated lizard (*Sitana ponticeriana*) (Fig. 20), sand boa (*Eryx conicus*) (Fig. 18), birds like terns and gulls, and a few small raptors (Ranwell 1972); and mammals, especially rodents like common rats and mice, small carnivores like jackal (*Canis aureus*) (Fig. 17), fox (*Vulpes bengalensis*) (McLachlan 1991), mongoose (*Herpestes edwardsi*) and common palm civet (*Paradoxurus hermaphroditus*).

Olive ridley (*Lepidochelys olivacea*), leatherback (*Dermochelys coriacea*), hawksbill (*Eretmochelys imbricata*) and green turtles (*Chelonia mydas*) nest on the beaches of India and its offshore islands. Olive Ridley turtles are commonly reported to nest along the Tamil Nadu coast (Bhupathy & Saravanan 2006). Olive ridleys also nest in significant numbers along the Andhra Pradesh coast (Tripathy *et al.* 2006) and in large numbers in Orissa (Shanker *et al.* 2003) (Fig. 19).



Figure 17: Jackals are the major predators of coastal dunes. (Photo credit: Abi Tamim)



Figure 18: The sand boa (*Eryx conicus*) a reptile of arid regions also occurs on sand dunes (Photo credit: Kartik Shanker)



Figure 19: Olive ridley (*Lepidochelys olivacea*) turtles nest on sandy beaches along the east coast of India. (Photo credit: Aarthi Sridhar)



Figure 20: The fan throated lizard (*Sitana ponticeriana*) is commonly encountered on coastal sand dunes (Photo credit: Kartik Shanker)

10. Ecological and social importance of the dune system

10.1 Importance of dune flora

Coastal sand dune plant species have value-added nutritional, medicinal and agricultural uses. Many coastal sand dune flora are used as food, fodder and green manure. Sridhar & Bhagya (2007) report that coastal sand dune plants are also a source of bioactive compounds of pharmaceutical and veterinary value.

In an ecosystem with a highly impoverished supply of nutrients, sand dune legumes quite vital in fixing nitrogen and phosphorous into the dune sand with the help of symbiotic mycorrhizas and rhizobia (Sridhar & Bhagya 2007). They are used as cover crops in coconut basins and other plantations as they not only are efficient nitrogen fixers, they also provide green manure and mulch. Most dune plant species have ethnobotanical importance and our knowledge of these aspects of coastal sand dune vegetation is inadequate.. A few dune plant species are used for the purpose of fish aggregation in traditional fishing. They also serve as nutritious fodder for the livestock (Arun *et al.* 1999). Latex from *Launaea sarmentosa* is commonly used by fishermen to heal skin injury caused by fish spines while fishing.

10.2 Swales and groundwater

Very often, extensive sand dune systems may have inter-dunal swales, which are low elevation areas located between dunes. Swales are otherwise known as dune slacks (Ranwell *et al.* 1959) and some times as inter-dunal wetlands (McAvoy & Clancy 1994). These dune slacks are formed in areas where the water table is high (Grootjans *et al.* 2002). Swales also act as sinks for rain water and help in recharging the aquifers and support densely populated wetland plant communities that form a striking contrast to the surrounding xeric vegetation (Shumway and Banks 2001). Depletion of vegetation, razing of sand dunes, and extraction of sand that accompanies development can result in land erosion, affect water circulation and recharging of ground water reservoirs, It can result in bad impacts on tourism as the aesthetic value of the local coastline is reduced (Noronha *et al.*, 2002). Coastal aquifers are also vulnerable because the proximity to the sea inclines a heightened vulnerability to salt-water intrusion. Since water is moving underground continuously, bores that are too deep or extract too much, can result in salt-water intrusion leading to destruction of the basin.

Coastal dunes have been reported to assist in groundwater recharge (Bhalla 2007). There were, in the past, quite a few natural water bodies or traditional /indigenous man-made interventions in coastal Tamil Nadu such as *kulams* on sand dunes were mainly designed to recharge the groundwater and improve the water quality (Rodriguez, 2007). These traditional water management systems also supported agriculture in coastal areas, sometime right next to beaches. The dunes not only recharged ground water aquifers, they also prevented seawater intrusion and shielded the crops from salt and sand laden winds (Fig. 23). 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 well documented (Sangati CPR Working group). From field visits to south Poigainallur as part of Phase II of the UNDP/PTEI project and interactions with local communities, we learned that they have been practicing agriculture right next to the leeward side of the dunes for centuries. Local communities felt that coastal sand dunes and natural swales in the area were vital to maintaining the water table in the areas to sustain their livelihoods (Fig. 21-22).



Figure 21.



Figure 22.

Figure 21: Very shallow man made pits of one to two metre depth on the leeward side of dunes of south Poigainallur are source of fresh water for irrigation and domestic use.

Figure 22: Natural swales like these behind sand dunes serve as sinks for rainwater, recharging the groundwater aquifers and maintaining ground water levels.
(Photo credit: Naveen Namboothri)



Figure 23: Paddy cultivation being carried out right behind the frontal dunes at Karwar, Karnataka. (Photo credit: Aarthi Sridhar)

10.3 Protection against erosion

Coastal sand dunes are important coastal protective formations serving as a buffer and barrier against sea erosion, preventing storm waves and tides from entering into the land area behind the beach. Dunes are considered as the first line of defense against erosion. Coastal sand dunes further serve as stock-piles of sand to feed the beach in times of extensive beach erosion (during storms and rough seas) and can provide protection more effectively and more economically than building a seawall (U.S. Army Corps of Engineers 1984). The beach and foredunes may retreat under wave attack, losing considerable amount of sand, which form offshore bars. During calm weather, the beaches and dunes may recuperate as sand that is returned by wave action from the offshore bars to the beach gets trapped by the coastal vegetation (EI Banna 2004).

10.4 Protection from tsunami

Evidence of sand dunes as a defense against tsunami inundation is persuasive [Figure 24(a) and 24(b)]. Dunes act as windbreaks, protect against storm surges and tsunami inundation. Many coastal settlements built behind or on coastal dune formations were protected from the tsunami. Unfortunately, dunes are not considered a worthy ecosystem, sometimes condemned even by ecological restoration projects. However, they are integral to the livelihood of artisanal fishing communities. The Praxis reports (2005a) observed that during the December 2004 Indian Ocean tsunami, many coastal villages along Tamil Nadu were protected by the presence of sand dunes. Some of these cases are outlined below:

Case Study 1: Chinnurpettai (Praxis 2005f)

Chinnurpettai is on elevated land and there are high sand banks by the shore. Locals attribute the comparatively lower loss of property and life in the tsunami to the sandbanks and the elevated location of the village. All houses that were on higher ground were relatively undamaged in the tsunami as water moved into the low-lying areas around the village. Many villagers who did not realise this advantage, ran in fear and panic onto the low-lying land near their homes and lost their lives.

Case Study 2: Nambiyarnagar (Praxis 2005i)

The center of the village is located on upland and hence was less affected by the tsunami. After the giant waves passed, water congregated to form a small pond on the southern side of the village. Karuvai (*Prosopis julifera*) bushes, on the southern side were also washed away by the tsunami.

Case Study 3: Nayakarkuppam (Praxis 2005j)

The village is roughly 1 sq km in area. The nearest seafront house stood as 500 metres from the sea. A concave shaped sand dune 5 feet in height was the natural defense for the village against the sea. The dune was like a crest sloping down to the sea and spread from the north to the south of the village and beyond. There are three different sand dunes between the shoreline and the village. About 50 metres east of the village is a canal that runs parallel to the shoreline. The community sees these as natural barriers.

Case Study 4: Kottucherrymedu (Praxis 2005b)

Sea-front houses escaped the impact of the tsunami as they were built on a raised sand dune. When the tsunami hit Kottucherrymedu, it engulfed the village from both sides leaving the houses on top of the sand dunes unaffected. The sand dunes were about 15 feet high, but the tsunami has eroded the dunes and now they only stand at 6-7 feet high. According to the villagers, the water level in the sea has risen since the tsunami and now the waves reach very close to the houses. It is mostly thatched houses that were severely damaged. Tiled and terraced houses only suffered partial damage. Those houses that were closer to the shore, and not in elevated positions, were totally washed away by the tsunami.



Figure 24: The Bommayapalayam Dune. a: Satellite shot of inundation along vegetation (yellow) and the dune (blue). b: Looking North, near the blue transect shown in (a). Imagery not to scale. (Courtesy: FERAL, Puducherry)

The coastal village Pudukuppam got seriously affected due to its location in a low-lying area and the absence of a dune system before it (Praxis 2005h). The report also mentions the Nagapattinam port playing a protective role at the time of the tsunami, and it is said that the local people realize the importance of sand dunes against natural disasters like a tsunami (Narayan *et al.* 2005).

In Karaikal District, it has been observed that the effects of the tsunami were reduced in places with sand dunes and *Pandanus* plants, in comparison to places where these natural protective features were absent (EQUATIONS 2006).

10.5. Socio-economic and cultural significance

Sand dunes are closely integrated to the socio-economic life of the coastal population living adjacent to them. A very good example of this is the palm “palmyra” or “toddy palm” (*Borassus flabellifer*), which is quite common on sand dunes of south India. Before sugar was brought into markets in south India, palm was a major plantation in southern Tamil Nadu from which jaggery was extracted. Jaggery was not only a major replacement for sugar; it was also a major source of livelihood for the Nadar community of south India. Their economy centered on the palmyra palm, the only commercially viable crop in the region then. The men climbed the palmyra to tap its sap, some of which was fermented to make an alcoholic beverage called toddy. The palmyra also yielded other useful products: mats and baskets were woven from its fronds, and the tree trunks were used as poles and roof beams for houses” (<http://www.nadarsangam.com/whattheydo.html>).

Jaggery extraction is still a source of livelihoods for coastal communities in some parts of southern Tamil Nadu (Fig. 25 a & b). Further, the leaf fronds are used for thatching roofs and the thick tubular sheath are used for making fences and as firewood (Fig. 26 & 27).



Figure 25 a.



Figure 25 b.

Figure 25. a. & b: A woman in south coastal village of Tamil Nadu pouring liquid jaggery into coconut shells to cool it. Palm jaggery extraction still remains a livelihood source for some of the coastal people of south Tamil Nadu (Photo credit: Murugan)



Figure 26.



Figure 27.

Figure 26: An old man carrying palmmyra leaf sheaths for fence constructions (Photo credit: Peeyush Seksharia)

Figure 27: *Palmmyra* leaves used to thatch roofs and to make fences (South Poigainallur, Nagapattinam) (Photo credit: Shashwati)

The beach space which includes the beach and the nearby sand dunes are also an important part of the social and day-to-day activities of fisherfolk. Foredunes and beaches are used for various purposes such as landing of boats (Fig. 30), mending nets, auctioning of fish, sorting of catch (Fig. 29), drying fish (Fig. 28) and even for settlement. Further, fisherfolk prefer elevated regions of the coast (mainly on dunes) to build their houses, as this not only offers security from storms and waves, it also affords them a direct view of the sea, which is vital for them to determine the direction of winds and the weather conditions prior to a fishing trip. Whole colonies and villages are situated on dunes in many parts of coastal Tamil Nadu (see section on Land Use Changes for more details).



Figure 28: A dune adjacent to the fishing village of Chandrapadi, Tamil Nadu, being used for drying a large haul of sardines (Photo credit: Sudarshan Rodriguez).



Figure 29.



Figure 30.

Fore dunes and beach space play a vital part in day-to-day activities of fisherfolk.

Figure 29: Fish caught in nets being disentangled and in the background fish catch being auctioned (Photo credit: Gokul A).

Figure 30: Boats are landed on beaches above the high tide line in a fishing village in Cuddalore (Photo credit: Naveen Namboodiri)

11. Coastal Sand dunes as bioshields

Coastal sand dunes as geomorphic features act as physical barriers offering natural protection to the hinterland from the forces of the ocean, including wave run-up due to storm surges, a beneficial function that needs acknowledgment. Wide beaches and high dunes act as efficient dissipaters of wave energy offering protection to inland property (McLachlan & Brown 2006). They also protect coastal cash crops, acting as a barrier, warding off salt laden wind from the sea (Fig. 23 & 32).

In many coastal villages of Tamil Nadu, cultivation of paddy and other crops are common on the hinterland of dunes towards the landward side. The dunes shield the crops from direct wind action and also from the high salt content of these winds (Fig. 28). Retentive dune systems act as local sand sinks, and tend to store sand in the littoral active zone that may be released to the beach during storms. Sand deposited on the beaches are transported and stored within dunes and in the wake of storms or other major impacts of the sea, dunes release sand back into the sea, helping them replenish the sand (Fig. 28).

But when human development gets in the way, coastal physical and storm processes turn into natural hazards that often culminate in disasters. Impacts of hazards are thus consistently amplified by human alterations of the coastal environment. The protective role of coastal sand dune fields in the wake of extreme events is well documented globally (Clark 1996; Nordstrom 2000; Mascarenhas 1999) and is also demonstrated for the Digha coast of West Bengal (Paul 2001) where human interference on dunes leads to inundations and destruction of habitations, dwellings and resorts.



Figure 31.



Figure 32.

Figure 31: In undisturbed conditions, foredunes begin right beyond the high tide line, and during storms, when a large amount of sand is lost from the beach, the foredunes help to stabilize the beach once again. (Photo credit: Naveen Namboothri)

Figure 32: This picture shows vegetables being cultivated just behind dunes in South Poigainallur, Nagapattinam (crops in the foreground and dunes at the back). The survival of these crops depends on the existence of the dunes which shield them from the salt laden winds from the sea-ward side. (Photo credit: Naveen Namboothri)

12. Threats to coastal sand dunes

Pollution, mining, disruption of sand transport and tourism development are the main threats to coastal dune systems, and these systems may be subject to increased erosion in future, yet there have been few attempts to review them. Given below is an extract from Foundation for Environmental Conservation, UK, (Brown & McLachlan 2002) which reviews of the state of coastal dune systems and predicts the possible states of the system by 2025:

The data presently available and the uncertainty of a number of predictions do not permit quantitative assessment or modeling of the state of the world's sandy shores by the year 2025, but some tentative, qualitative predictions are offered.

Storms and associated erosion present the most substantial universal hazard to the fauna of dune systems. Human-related perturbations vary from beach to beach; however, structures or activities that impede natural sand transport or alter the sand budget commonly lead to severe erosion, often of a permanent nature. Many beaches also suffer intermittent or chronic pollution, and direct human interference includes mining, trampling, bait collecting, grazing cattle on dune vegetation and ecotourism. These interferences typically have a negative impact on the system.

Identified long-term trends include chronic beach erosion, often largely due to natural causes, and changes related to global warming. It is not expected that predicted temperature changes will have dramatic effects on the world's beaches by 2025, but the expected rise in sea level, if coupled with an increase in the frequency and/or intensity of storms, as predicted for some regions, is likely to lead to escalating erosion and consequent loss of habitat. Increases in coastal human populations and tourism, thus increasing pressure on the shore, while serious, may largely be offset in developed and developing countries by better management resulting from greater understanding of the factors governing sandy-shore systems and better communication between stakeholders and developers. Beach nourishment is likely to become more widely practiced. However, the continuing hardening of surfaces in and above the dunes due to improper nourishment practices is bound to be damaging. Human pressures in many underdeveloped countries show no signs of being mitigated by conservation measures; it is likely that their sandy shores will continue to deteriorate during the first quarter of this century. A long-term trend that cannot be ignored is the excessive amount of nitrogen entering the sea, particularly affecting beaches in estuaries and sheltered lagoons.

Extreme events result in severe shoreline changes and hence affect coastline configuration: beach and dune erosion, modifications of dune complexes, sandbank breaching, over wash, bay formation and, at places, complete elimination of sand-dune complexes is documented (Paul 2001; Dolan & Davies 1992).

In spite of their value as natural 'bioshields' coastal dunes are subject to various increasing forms of anthropogenic disturbance like human settlements, developmental activities (ports, recreational/tourism, industrial etc), sand mining, large-scale plantations of exotic species, trampling of dune vegetation etc (see Fig 30-33). In these conditions, these features are unable to act as protective landforms against various natural calamities. As such, an adequate cushion between the sea and artificial structures is crucial for the functioning of coastal dune systems (Mascarenhas 2004).

Urbanization of sandy coasts demands leveling and hence large-scale removal of sand dunes. Razing of dunes and a consequent sediment deficit over time results in man-induced erosion, shoreline recession, submergence of beaches and loss of wave-absorption capacity of coastal dunes (see Fig. 32).



Figure 33.

Figure 33: Fisher folk settlement on coastal dunes in Karaikkal. (Photo credit: A. Murugan)



Figure 34.

Figure 34: Sand dunes along the coast are being replaced by construction work along the Kanyakumari coast. (Photo credit: A. Murugan)



Figure 35.

Figure 35: Coastal sand dunes help in maintaining the water table and paddy cultivation is done on the leeward sides in many places on the north east coast of Tamil Nadu. Razing these dunes for building roads and for other development activities, will not only make the coast more susceptible to natural hazards like storms and hurricanes, but will also affect coastal cultivation. (Photo credit: Naveen Namboothri).



Figure 36.

Figure 36: Sand mining on beaches and dunes of Vattakottai, (Kanyakumari) south Tamil Nadu, by mining companies has led to drastic erosion in beach structures. (Photo credit: Anjana Mohan).

During the rapid survey of the Phase 1 of the UNDP/PTEI project (Gokul & Shanker 2007), threats to dunes by way of human constructions and human activities were characterized (Refer Appendix 1) along thirteen stations of the Palk Bay and Coromandel coast. The nearest domestic settlement to the shore 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, Puducherry, 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 stations sampled, but this form of impact was least at Pulicat, Marakkanam, Cuddalore and Manora beaches.

Anthropogenic threats to sand dunes can be classified under the following broad heads:

12.1. Sand mining

Extraction of sand for construction and mineral extraction is a major threat to the coastal ecosystems. Despite the fact that sand from coastal areas like beaches and dunes due to their high salt content should not be used for construction purposes, rigorous coastal development has led to extraction of sand from the coast. Sand mining for construction is more profound on the dunes, while sand extraction for minerals is higher on the beaches. While sand extraction from dunes flattens them out, sand from beaches leads to an impoverished supply of sand to the dunes.

Beaches along south India have some vast deposits of minerals. Some of the major mineral resources found on the beaches of Tamil Nadu of radioactive and economic importance are monazite, ilmenite, zircon and rutile. Major placer deposits in the state are distributed in the coastal districts of Kanyakumari, Tirunelveli, Thoothukkudi, Ramanathapuram and Nagapattinam¹. The minerals have wide use in pigment, refractory, ceramic industries and the nuclear industry. Sand mining for the purpose of mineral extraction is rampant on the beaches of Vattakottai in the Kanyakumari District of south Tamil Nadu. Similar sand mining on beaches for extracting radioactive minerals has had considerable impact on the ecosystem in Aleppey district of Kerala, on the southwest coast of India (Sekhar & Jayadev 2003).

12.2. Artificial sea defense and stabilization mechanisms

Impacts of tropical cyclones and sea-level rise have been and continue to be the most disruptive recurring events for coastal inhabitants of eastern India. Nowhere are the losses more severe as in the coastal states surrounding the Bay of Bengal. Every cyclone creates a considerable impact on the economy and slows down the economic activity of the region. Hard protective structures like seawalls (Fig. 37 & 38) provide a false sense of security often turning into hazards themselves, as they block or slow down return run-off of flood waters, as evidenced by persistent flooding. The failure of artificial hard structures indicates the unsustainability of expensive coastal protection works (Dolan & Davies 1992, 1994; Clark 1996; Ali & Chowdhury 1997; Paul 2001). Worldwide, there has been change in the erosion control measures with many of the developed countries changing to soft measures instead of hard ones. For example, Netherlands, a country that heavily

¹ <http://www.tnmine.tn.nic.in/TN-Mining.htm>

depended on hard coastal protections and dykes in the past is now exploring soft options.. Dr. Ronald Waterman, an expert on integrated coastal development and coastal protection is of the view that hard options can no longer be regarded as protection against the sea. He emphasizes “implementing Integrated Coastal Policy by adhering to the principle of *Building with Nature*, using the soft solution of dunes & beaches with a minimum of “hard” elements such as rocks and jetties, or dykes & dams”². His approach sees dunes and beaches working in harmony with the sea as the coastal defences of the future, as they are lower in costs, require a minimal effort to maintain but also promote multiple-use system of the coastline.

Waterman views “*Integrated Coastal Zone Development via Building with Nature*” as the only realistic option for Third World countries who only have to protect and restore these ecosystems and habitat. (Waterman *et al.* 1998; Waterman 2007).

It was observed in Upparu, near Kancheepuram, that sea walls were constructed where earlier sand dunes served as natural protection. The construction of seawalls resulted in fragmentation of the coastal ecosystem and aggravated the force of the sea (EQUATIONS 2006). Many dune systems are affected by sea defense works or artificial stabilization measures such as sand fencing and planting of *Casuarina*. In many developing countries, drifting sand is perceived as a threat to urban or tourism development projects. While carefully applied dune management measures can help to counteract severe erosion which may threaten the existence of a dune, engineered defense systems usually reduce the biodiversity inherent in the natural state of the dune systems, and may cause sediment starvation down-drift.



Figure 37.



Figure 38.

Figures 37 & 38: Extensive sea wall constructions along the Puducherry coast.

² See <http://www.ronaldwaterman.com/>

12.3. Land use changes

Increase in the population density along the coast has resulted in the buying of land along the coast by companies and private owners. Subsequent development projects and constructions have had a huge impact on coastal dune systems. Construction of resorts and buildings, roads in sand strips and sand mining are major anthropogenic threats to dune systems that severely degrade it (Mascarenhas *et al.* 1998; Mascarenhas 2000).

It is also important to note that in coastal villages in Tamil Nadu such as like Chinnakotaimedu (Praxis 2005f), Chinnurpettai (Praxis 2005g), Kottaimedu (Praxis 2005h), and Kottucherimedu (Praxis 2005b) fishing communities have resided on the dune for decades to facilitate easy access to the seashore and ease of fishing activities. This has resulted in flattening and degradation of the original dune system.

In some hamlets in Karaikal, communities have traditionally located their hamlets on sand dunes and elevated places (see. Fig. 30) (A. Murugan & S. Rodriguez *pers. obs.*), and many of the village names end with the word “*medu*” which, in Tamil, means ‘an elevated place’ (Praxis 2005b; Praxis 2005e; Praxis 2005g). It is important to document and research the traditional settlement patterns and locations of coastal hamlets on dunes over space and time, the impacts they have on dunes (over the past 30 years or so) and assess changes that have resulted after the major tsunami relocation programmes. A review of the post tsunami land-use policies have indicated ecologically damaging relocations/rehabilitation programmes that have caused small-scale to extensive damages to sand dunes along the Tamil Nadu coast (Sridhar 2007).

12.4. Plantations

Afforestation of dunes with *Casuarina* and other exotic species of plants has been taking place on a large scale along the entire east and west coasts of India and this has had a major effect on large areas of dune landscape (Fig. 39-40). Some sites hold large *Casuarina* plantations which have the effect of suppressing the dune vegetation communities, affect sand transport to and from the dunes affecting their structure, and lowering the water table. They also outcompete most of the local varieties of plants, severely disrupting the existing natural ecological balance. *Casuarina* has been reported to be very efficient in controlling other plants which it has to compete against for light and nutrients. When established it alters the temperature, light, and chemistry of soils, which drastically affects the native plants and animals beneath it. *Casuarina* is also reported to possess allelopathic properties (Jadhav & Gaynar 1995). Allelopathy is the ability to exude chemicals that inhibit growth of other species beneath it. The chemicals called tannins that are leached from its “needles” are carcinogenic and can kill cattle that forage on them (Elfers 1988). It has also been proved that *Casuarina* is capable of decreasing soil pH, which has a dramatic effect on the capacity of the soil to retain nutrients (Ussiri *et al.* 2006). A recent study on *Casuarina equisetifolia* plantations along the Chennai and Puducherry coasts has shown that the plantations have not only suppressed local biodiversity, they also are lowering the nesting frequency of the endangered olive ridley turtle (*Lepidochelys olivacea*).



Figure 39: Casuarina plantations on the Karaikkal coast (Photo credit: A. Murugan)



Figure 40: Casuarina planted quite close to the high tide line (south Poigainallur: Nagapattinam) could affect sand transport, sand budget and in turn change profiles of beaches. (Photo credit: Peeyush Seksharia).

12.5. Recreation and tourism

Altering coastal sand dunes for recreational activities is a major land use pattern in popular tourist places. Moderate pressure by pedestrians may cause little damage. However, excessive pedestrian use, such as routes between fishing villages and beaches, has caused considerable erosion on many dune sites. Building of hotels and beach resorts on flattened dunes or existing dunes have caused serious damage to these sensitive systems (UK Biodiversity Steering Group 1999). Further, construction of new roads and permitting vehicles on to beaches could lead to serious damage to sand dune fauna unless controlled from the offset (Stephenson 1999).

Flattening of sand dunes, removal of coastal forests, reclamation of wetlands, inappropriate layout of buildings and roads reduce the inherent functional potential of these ecosystems as natural barriers against damages due to storms, erosion and in some cases such as South Poigainallur, even tsunamis (Mascarenhas 2004).

12.6. Erosion

Unless the dune system is stabilised or artificially constrained, the seaward edges of sand dunes can be highly mobile and insufficient sand supply is frequently the underlying cause. Both erosion and accretion are found to be present along any stretch of coast. Changes may be cyclical, both seasonally and over longer periods of time. In a few cases dune systems may move inland when they are not artificially constrained and this landward movement of sand may be impeded by development of agricultural land and *Casuarina* plantations along windward side of dunes. Blowouts are areas in dunes, where vegetation is damaged and rapid sand erosion by wind takes place resulting in the formation of a large depression in the dune area.

12.7. Falling water tables

Dune slacks often have high faunal and floral diversity and support characteristic communities dependent on a seasonally high water table, including the formation of temporary or even permanent ponds. Variations in the behavior of the water table from year to year results in a stressed ecosystem where only specialized species can survive. However in some dune systems a long term fall in the water table has led to loss of the specialist slack flora and fauna caused by local extraction of water and/or drainage of adjacent land used for agriculture or housing.

12.8. Grazing

In the absence of human interference, most stable dunes would develop into scrub and woodland. Grazing by livestock causes the dunes to loose vegetation cover and hence affects floral diversity of dunes. Loss in vegetation cover exacerbates erosion of the dune and the movement of sand landwards.

12.9. Other anthropogenic influences

Apart from housing developments, industrial development, and sand extraction, indirect effects on dunes include atmospheric nutrient deposition, and coastal squeeze due to rising sea levels and a resultant increase in the intensity and frequency of storm surges. The potential for dredging and

marine aggregate extraction, through the disruption of coastal processes, to have cumulative and long-term effects on sand dunes is an area for further investigation.

Offshore oil spills that ultimately reach the beach as tar-like balls of varying sizes also could affect the beach and dune ecosystem. This could seriously affect the flora and fauna of the beach and dune system as oil components are toxic to most organisms. This kind of oil pollution has been observed in the sandy beach regions of Gujarat coast (Sunderraj *et al.* 2006).

13. Prevention, recovery and restoration

13.1. States of sand dunes

In general, based on the degree of stability, coastal dunes can be classified into the following types:

- Highly degraded: Dunes with a large portion of the vegetation degraded due to natural/human disturbances and the proportion of bare sand is comparatively much higher. Here, high levels of sand movement leads to eventual flattening out of the dunes and can be a considerable threat to the infrastructure and crops inland. Dunes in this state need active restoration programmes to bring them back to health.
- Partially degraded: Dunes that have undergone degradation due to human disturbances to a certain extent but capable of returning back to their near original state when the disturbance is stopped. Such dunes have some amount of vegetation but are under serious threat of further degrading and require preventive and protective measures.
- Undisturbed: Certain dunes in remote regions along the coast are still free of disturbance. Such dunes can not only be used as reference dunes, for restoration projects, but also as a resource for the endemic sand dune flora and fauna.

13.2. Prevention of degradation and facilitating recovery of sand dunes

In most instances simple prevention of stress factors would stop degradation of dune system. Areas with potential stress factors like cattle grazing, human trampling, and sand mining should be identified and those activities should be prevented to facilitate recovery (English Nature, Environment Agency, DEFRA, LIFE & NERC 2003). In areas with tourism, where the prevention of human access to the dune and beach system is not possible, sign boards, awareness boards should be established, and areas for walking and crossing the dune system should be designated. Coastal urbanization interferes with the natural sand budget of beaches and dunes and also upsets the dune's natural cycle of erosion and accretion, leading to their destruction (El-Banna 2004).

Many coastal communities are aware of the importance of the coastal sand dunes and have their traditional methods of dune conservation and restoration, as in the case of South Poigainallur, Nagapattinam District, Tamil Nadu. It is necessary to revive these traditional practices as they are locally tested and successful strategies. These need to be supplemented with advanced scientific research and ecological studies to suggest suitable species as vegetation cover, plantation techniques and method of site selection, which would effectively serve restore dunes.

13.3. Restoration

In cases where destruction of the dune system has passed a stage where simple methods such as removal of stress factors and protection may not reverse the damage, restoration efforts may be necessary. Dune restoration efforts not only help in dune formation, but also help in bringing back floral and faunal diversity, which previously existed in the healthy system. For instance, Aarde *et al.* (2004) studied a coastal dune system (after 27 years of rehabilitation efforts), and found that trends in both bird and rodent communities indicated that rehabilitation is a management tool that could potentially reverse the ubiquitous trends of loss of habitat and species diversity.

13.4. Factors to be considered prior to restoration of dunes

Site selection:

- Prior to planting, the current state, structure, size and area of the sand dune should be determined.
- The interest of the community and their continued participation are important factors to be considered while selecting sites for sand dune restoration.
- The ownership of land designated for restoration is another major issue that needs to be addressed prior to beginning restoration programmes. Ownership of land along the coast by private people and developmental activities along the coast (in the form of buildings, industrial activities and tourism) seriously constrain land available for sand dune restoration. The requirements of fishermen in terms of space for fishing related activities also need to be taken into consideration.
- This information can help indicate the likely consequences of selecting a particular site, define a course of action and its cost. Also, the information need must be met locally and is site specific (English Nature, Environment Agency, DEFRA, LIFE & NERC 2003).

Restoration targets:

The goals for the restoration activities should be focused towards the recovery of the dunes, dune stabilization, species enrichment, planting in back dunes, providing protection from cattle grazing and fuel wood collection through fencing, creating awareness among local village people, and ensuring community participation in restoration activities by assigning tasks to local groups for planting, watering and watching.

13.5. Routes to restoration

Sand dunes stabilization and restoration is being carried out in many parts of the world, but Faroda's (Faroda 1998) long-term study in the semi arid regions of northwest India is the best suited approach to sand dune restoration in India. According to Faroda (*ibid*), most sand dune stabilization programmes include:

- protection of the area from human and livestock encroachment
- creation of micro-wind breaks on the dune slopes, using locally available shrubs or materials either in a checkerboard pattern or in parallel strips
- direct seeding or transplantation of indigenous and exotic species
- plantation of grass slips or direct sowing of grass seeds on leeward side of micro-wind breaks
- management of re-vegetated sites

Karukkalacherry - Restoration Project: (Source: FERAL, 2007)

Karukkalacherry has vast areas of natural sand dune ecosystems, where many areas were considerably degraded (Fig. 39 & 40). Puducherry based NGO- FERAL carried out dune restoration in an area of 8.88 ha. The presence of a dune structure and continued community participation were also factors that favored selection of this site. The area available for restoration also includes area under *Casuarina* plantation in the southern part of the beach. The deposition of sand around the fence erected for protecting *Casuarina* from cattle, has resulted in the formation of a dune structure, with a slope rising up to 1.3 m, both seaward and landward. Landward structures are presently found between the front dune and back dune zones. Remnants of the natural dunes, with an area of 0.54 ha, can be found just south of the settlement. However, according to local people, except for a small portion, dune structures were largely damaged during the tsunami, as it acted as a barrier and sand was carried inland by the water. It has been reported that run up heights for the tsunami waters along Karaikkal region had been 2.63 m.



Figure 41.



Figure 42.

Figure 41 and 42: Dunes in Karukkalacherry, Tamil Nadu (Photo credit: Devi Subramanian)

Planting in the dune slopes:

It is important to use locally available runners and shrubs for the stabilization of the sand dune slope. It has been reported that small shrubs and grasses are better sand binders than trees (Faroda 1998), and hence should be used for the binding of sand on the slopes.

The different zones of the frontal dune could be divided into:

1. high tide line to the slope,
2. slope to berm, berm to front dune, and
3. the back dune.

Berm and front dune planting:

The berm and the front dune would be stabilised by shrubs and runners, mainly hardy, salt tolerant local species. Faroda (1998) advises planting in a checker board pattern with 1m spacing between each sapling.

Back dune planting:

Local palm species such as *Borassus flabellifer* could be planted in the back dunes, in parallel strips, each strip running along the entire length of the area available for planting with intervals of 2 feet and the remaining seeds could be broadcast over a certain area to allow for natural growth.

The planting would be carried out during the rainy season to ensure reduced heat stress, meeting water requirements and to ensure soil moisture. Care should be taken to plant the right species in the right places. For example, floral species like the *Pandanus sp.*, *Tamarindus indica* and some reed species that require more water than the other species should be planted closer to the swales.

Species of plants chosen:

It is best to choose indigenous variety of runners and shrubs for planting. The runners, *Spinifex littoreus* and *Ipomoea pes caprae* - are prevalent through out the Coromandel Coast, have a pan-tropical distribution. They are considered important in the initial stabilization of the sand, as they are one of the earliest species to colonize newly deposited dunes (Bach 1998). The saplings of *Calophyllum inophyllum*, *Pongamia pinnata*, *Terminalia catappa* and *Thespesia populnea* are found through out the coastal region as is the palm *Borassus flabellifer*.



Figure 43: Fencing of a dune in Karaikal
(Photo credit: Devi Subramanian)

Soil enrichment:

Dune soil is loose and sandy in nature, with very little water and nutrient retention capacity. The soil may require addition of farm yard manure, mats of coconut fiber and coconut coir powder, which can be placed at the bottom of the pit for water retention. Waste from kitchens can also be added for increasing the fertility of soil.

Watering:

The runners, saplings and palm seeds may need to be watered at least once a week. Pits could be dug at regular intervals to access this water already below the ground.

Fencing:

Sand trapping fences can be erected to facilitate dune growth. Fence-built dunes must be stabilized with vegetation or the fence might release the sand once it deteriorates. In some instances, severe destruction such as after a cyclone has mandated mechanical dune building efforts in certain countries (Caribbean Environment Programme 1998).

An artificial fence may be needed for the saplings. The available fencing could be strengthened with bamboo or *vellikathan* fences purchased locally. However, the dunes closer to the settlement are a priority for fencing to prevent grazing and trampling of saplings (Fig. 43).

13.6. Monitoring

Bimonthly assessment of survival and growth of the saplings is recommended to assess the success of the planting program. It also is important to employ corrective measures if the survival rates are not sufficiently high. Each individual sapling could be tagged and given an identification number to enable monitoring of survival and growth rates.

The S. Poigainallur Example:

Observations of the Praxis report, 2005, summarized as follows:

South Poigainallur is very well known for its sand dunes along the seashore. The dunes which range in height from 30-40 feet start at a distance of 15 metres from the sea. 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 km.

According to the local residents, these sand dunes were formed about 500 years ago, when sand was dug to construct a port at Nagapattinam. The sand that was dug out was kept along the shore. The sand accumulated and formed into dunes in due course. Even now, sand piles up on the dunes through the day adding to the height.



In order to protect crops from the waves and check soil erosion, the people erected fences using palm leaves along the seashore and planted palm trees along the fence. The high tides brought sand to the shore carried on the waves, which was then cast along the fencing lines along the seashore. The farmers then planted palm trees, created casuarina plantations, bamboo and *Alexandria laurei* (Pumai) on the sand dunes to check soil erosion and prevent sand casting onto the agriculture fields.

Since sand is carried easily by the wind, the accumulation has been easy and the height of the dunes has grown over time. 500 years ago, the height of the sand dunes was believed to be only 5-10 feet, whilst now it is 30-40 feet.

The height of the dunes has been increasing year after year. In the year 2001, some outsiders started digging sand from the sand dunes for construction purposes. The landowners resisted the outsiders and prevented the digging of sand from the sand dunes by presenting a united front.

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. After the tsunami, the Panchayat passed a resolution to protect the sand dunes and banned outsiders digging sand from the sand dunes.

Figure 44: Sand dune protection in S. Poigainallur. [Sources: Praxis (2005d) and Balakrishnan (2006)]

13.7. Participation of stakeholders

Complete support and participation of the local community is indispensable for any habitat restoration projects. The success of the restoration project is dependent on the support received, involvement and commitment of local community towards it.

Various measures can be employed to ensure the same:

- regular discussions with local people
- creation of awareness
- the involvement of local women and self-help group members for planting and after care.

This becomes a source of income for the local community making the protection of the planted saplings a matter of personal interest for the local communities.

14. Legal protection for sand dunes and sandy beaches

Explicit legal protection is afforded to the Indian coastline by the Coastal Regulation Zone (CRZ) Notification, 1991, issued under the Environment (Protection) Act, 1986. It does this by firstly zoning the entire coast on the basis of the demographic and ecological characteristics into CRZ-I, II and III areas. CRZ-I are ecologically sensitive areas where activities are largely prohibited, CRZ-II comprise developed areas and CRZ-III comprise all rural areas as well as undeveloped areas in urban limits. The notification declares all coastal stretches of seas, bays, estuaries, creeks, rivers and backwaters which are influenced by tidal action (in the landward side) up to 500 m from the High Tide Line (HTL) and the land between the Low Tide Line (LTL) and the HTL as the Coastal Regulation Zone. In this CRZ, it then overlays regulations on development, namely a set of prohibited and permitted activities pertaining to each zone. The CRZ Notification explicitly mandates the protection of sand dunes. According to the notification, sand mining is a prohibited activity on the mainland coast. Section 2(ix) of the notification prohibits the 'mining of sands, rocks and other substrate materials' within the CRZ areas. However, various amendments to this notification have allowed for sand mining and other destructive activities. The notification also prohibited the 'dressing or alteration' of sand dunes, hills and natural features for either beautification or recreation or landscape changes.

As per the notification, all state governments were required to prepare Coastal Zone Management Plans (CZMPS) 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 (MoEF 1996). 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 recognized 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).

Protective features within law have been changed considerably with targeted amendments made to the CRZ framework. Sand mining for construction purposes is one of the significant threats to sandy beaches and dunes. Within its implementation history, committees have been set up to examine the issue of local needs and limits to sand extraction have been prescribed (for the Andaman and Nicobar Islands) but the activity is unregulated and carries on unabated. There has been an overall lack of awareness of the legislation and this has not really resulted in either a change in the resource use pattern or its demand.

In India, though the dune systems are protected by CRZ regulations they are still facing many anthropogenic stresses (Mascarhenas 1998; Mascarhenas 2002a, b). There has been considerable amount of citizen action over the protection of sand dunes, particularly well documented in the states of Kerala (Sahasranaman 2000) and Goa (Goa Foundation 2005).

There are several criticisms leveled 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.

Implications of the proposed CMZ Notification

Despite all the criticism that the CRZ can be charged with, as a legal measure, it was the only law that explicitly recognized the need to protect some of these ecosystems. There are changes that are being proposed to the CRZ Notification and to the whole coastal regulation regime. The MoEF constituted the M.S. Swaminathan Committee to review the functioning of the CRZ Notification and to suggest an alternative legal regime. The Swaminathan Report highlights the importance of beaches and sand dunes. However, the report is equivocal about the ‘uses’ of dunes for sand mining and mineral extraction. A review of the Swaminathan Committee report highlights these limitations and states that there are ambiguities in the report on sand mining, where ‘restricted sand mining’ is advocated in one section, but discussion on banning the same activity appears in another section (Sridhar *et al.* 2006).

Based on the recommendations of the Swaminathan Committee, the MoEF has introduced a new draft notification termed as the Coastal Management Zone (CMZ) Notification. Similar to the CRZ Notification, the CMZ Notification also proposes to declare sand dunes as Coastal Management Zone – I areas. However, there are serious concerns with the entire notification, which nullify its seemingly positive aspects. The new notification is viewed by many as toeing the industry line, and is in line with environmental governance ‘reform’ measures the MoEF has been pursuing (Sridhar 2006; Menon *et al.* 2007). The most serious concern identified by several groups is that there is no clarity on the issue of violations that are yet to be dealt with under the 1991 Notification. The recommendations of the Swaminathan Committee do not anywhere state that violations committed under the 1991 notification must be dealt with before any new notification is considered.

The main concern with the newly proposed coastal regime is that there was absolutely no implementation of the earlier notification (CAGI 2006). The present draft CMZ Notification does not have a convincing implementation mechanism to ensure coastal protection, and opens up the possibility of unregulated development as a result of this law (Sridhar *et al.* 2008).

15. Gaps and recommendations

Ecological research

Research on the dynamics of this system at a particular site and documentation of flora and fauna, their ecology and available threats are very limited. Effective research needs to be conducted to protect this ecologically sensitive and socially important ecosystem. Apart from dune vegetation, some dunes with swales/slacks have unique and interesting associated flora and fauna. It is imperative to study their ecology as well.

During the field visit to Andhra Pradesh coast it was observed that sand dunes in many places of the coast have been affected by extensive *Prosopis* sp. invasion. This may eradicate the typical dune vegetation that covers the dune surface. The possible effects of extensive planting of exotic species like *Casuarina* are still quite poorly understood. A lot of research needs to be undertaken so as to understand the ecological and physical changes in the shoreline and coastal areas as a result of such large scale plantation of exotic species.

Monitoring

Status surveys, ecological studies, and monitoring have been carried out in the last century elsewhere in the world, but in India barring few dune surveys and dune vegetation studies (Masharenhas 2002 & Arun *et al.* 1999) no studies have been carried out on aspects of the ecology of floral and faunal communities, their interactions, and dune health.

16. Management recommendations and action plans

The following are some of the salient recommendations and suggested action:

- Develop and promote planning policies and procedures which will aim to prevent or minimize further losses of sand dune habitat because of development.
- Protect the existing sand dunes from further losses to anthropogenic factors, whether caused directly or indirectly. Offset the expected net losses due to natural causes by encouraging new dunes to accrete and where possible by allowing mobile dune systems to move inland.
- Seek opportunities for restoration of sand dune habitat lost to plantations, agriculture or other human uses.
- Encourage natural movement and development of dune systems, and control natural succession to scrub and woodland where necessary. Maintain dune grassland communities on the majority of dune systems.
- Develop and promote agri-environment schemes which will encourage restoration and sustainable management of dune habitats.
- Develop and promote incentives to encourage the management and restoration of landward transitional dune habitats and where appropriate allow landward movement of dunes, especially where there are seaward losses due to sea level rise
- Develop and promote coastal zone management policies which allow the maximum possible free movement of coastal sediment and pay full regard to the conservation of sand dunes. Include in Shoreline Management Plans where they have a role to play in flood defence.
- Raise public awareness about the importance of sand dunes, and the essential mobility of coasts and the value of maintaining unrestricted coastal processes. Promote awareness of the implications of the policies outlined in this plan among decision-makers.

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18. Appendices

Appendix 1: Distribution and dimensions of dunes, types of coastal vegetation, coastal constructions and human disturbances along thirteen stations of the Palk Bay and Coromandel coast.

Modified from Gokul & Shanker 2007.

Site	Dune		Ground Vegetation	Constructions on the shore	Human Disturbance
	L (m)	H (m)	Species		
Thondi	-	-	<i>Prosopis</i> pp.(++), <i>Borassus flabellifer</i> (++)	Concrete houses	++
Adiramapattinam	-	-	<i>Prosopis</i> spp. (++) <i>Avicennia.marina</i> (+) <i>Pandanus</i> spp (+) <i>Spinifex</i> spp. (+) <i>Cyprius</i> spp.(+), <i>Borassus flabellifer</i> .(++)	-	++
Manora	-	-	<i>Prosopis</i> spp. (++) <i>Avicennia</i> spp. (+) <i>Sueda</i> spp. (+), <i>Borassus flabellifer</i> .(++) <i>Cocos nucifera</i> (+)	-	++
Nagapattinam	594	1.3	<i>Casuarina</i> spp. (++) <i>Ipomoea pes-caprae</i> (+) <i>Prosopis</i> spp.(++) <i>Cocos nucifera</i> (+) <i>Thespesia</i> spp. (+) <i>Pongamia</i> spp. (+) <i>Acacia</i> spp.(+) <i>Borassus flabellifer</i> spp. (+) <i>Casuarina</i> spp.(+) <i>Neem tree</i> (+)	Govt. Offices, Concrete houses and huts	++
Tharangambadi	793	2	<i>Casuarina</i> spp. (++) <i>Prosopis</i> spp.(+), <i>Borassus flabellifer</i> .(++) <i>C.nucifera</i> (+) <i>Thespesia</i> spp (+)	Concrete houses and Huts	++
Velankanni	-	-	<i>C. nucifera</i> (++) <i>Thespesia</i> spp (+)	Concrete houses and shops	++
Cuddalore	68	1	<i>Casuarina</i> sp. (++) <i>Prosopis</i> spp (+) <i>C. nucifera</i> (+) <i>T. populenea</i> (+), <i>Ipomoea pes-caprae</i> (++)	-	-
Marakkanam	42	1	<i>I.pes-caprae</i> (++) <i>Spinifex</i> spp(+), <i>C. nucifera</i> (++) <i>Thespesia</i> spp (+) <i>Casuarina</i> spp.(+) <i>Borassus flabellifer</i> (+)	Huts	++
Pondy	-	-	<i>T.populeneo</i> (+) <i>C. nucifera</i> (+)	Govt.Buildings	++
Kovalam	-	-	<i>Prosopis</i> spp.(+)	-	++
Neelangarai	80	0.5	<i>I.pes-caprae</i> (++) <i>Spinifex</i> spp(+), <i>T.populenea</i> (++) <i>Calotropis</i> spp(+) <i>C. nucifera</i> (+)	Resorts, Houses and Huts	++
Marina	-	-	-	Govt.Buildings	++
Pulicat	60	1	<i>I.pes-caprae</i> (+), <i>Casuarina</i> sp. (++) <i>Borassus flabellifer</i> (+) <i>Cocos nucifera</i> (+) <i>T. populenea</i> (+)	-	-

Appendix 2: A detailed bibliography of peer-publications, reports and studies on sand dunes from the Tamil Nadu coast.

Author	Title and author	Year	Source	Contents
Ramasamy, S.M., R. Pavanivelu, & S. Sanjeevi.	Remote sensing and ecosystem modeling of Coromandel coast, South India.	1989	In: Coastal Zone '89. Proceedings of the 6 th Symposium on Coastal Zone Management, Charleston, South Carolina, American Society of Civil Engineers, New York.	Observed ancient coastal dunes about 35 km from Point Calimere coast dated as Paleodunes, roughly identified as those from Holocene period. Some discussions on significance of dunes and people's perceptions.
Sanjeevi, S.	Morphology of dunes of the Coromandel coast of Tamil Nadu: A satellite data based approach for coastal landuse planning,	1996	Landscape and Urban Planning 34 (3): 189-195.	Studies on the distribution and morphology coastal sand dunes of Tamil Nadu coast
Narayan, J. P., M. L. Sharma & B. K. Maheshwari.	Effects of Medu and coastal topography on the damage pattern during the recent Indian Ocean tsunami along the coast of Tamil Nadu.	2005	Science of Tsunami Hazards 23 (2): 9-18.	The report studies the shielding effects provided by the recent Indian Ocean tsunami on the Tamil Nadu coast and the increasing awareness among local people on the importance of sand dunes against natural disasters like a tsunami
Praxis	Accountability overdue: Learning from participatory engagement with the tsunami affected,	2005	(ed. T. Mathew). Praxis-Institute for Participatory Practices, Delhi. pp. 50	The Praxis reports observed that during the Dec 2004 Indian Ocean tsunami many coastal villages along Tamil Nadu were protected by the presence of sand dunes.
Praxis	Chinnakottaimedu: Chinnurpettai: Madathukuppam: Nambiyarnagar: Nayakarkuppam: Kottucherryedu: Southpoigainallur: Kotaimedu: Pudukuppam: Village level people's plans: Realities, Aspirations, Challenges,	2005	Praxis-Institute for Participatory Practices, Delhi. pp. 21, 41, 111, 27, 33, 47, 28, 28	The Praxis reports observed that during the Dec 2004 Indian Ocean tsunami, the coastal village of Kottucherryedu along Tamil Nadu was protected by the presence of sand dunes.

Prashanth hedao	Protecting the Coast - Restoration of Coastal Ecosystems	2005	Auroville Tsunami Relief & Rehabilitation Project Auroville, Tamil Nadu	Detailed descriptions of formation of sandunes along the coast of Tamil Nadu also mentions sea walls. Also discusses the negative impacts of man-made shore protection structures on the ecology and natural resilience of the coasts and the value of the traditional sand dune rehabilitation techniques.
EQUATIONS	Tamil Nadu & Pondicherry coastal area assessment post tsunami study on coastal conservation and regulation.	2006	Published in India, by EQUATIONS	Studies on the distribution of sand dunes and their shielding effects in the wake of the tsunami in some villages along the Tamil Nadu coast
Mascarenhas, A.	Extreme events, intrinsic landforms and humankind: Post-tsunami scenario along Nagore?Velankanni coast, Tamil Nadu, India.	2006	Curr. Sci.: 90(9); 1195-1201.	Discusses the socio-ecological importance and impacts of regular storm surges and the 2004 tsunami. Also enumerates the shielding effect of sand dunes and bioshields
Sridhar, A.	Environmental Governance Reforms, Rephrasing the Reform Process,	2006	Draft Submitted to International Institute for Environment and Development, New Delhi. pp 15.	
S. Srinivasalu.	Important geomorphological features of the Tamil Nadu coast with special reference to the effects of the tsunami	2006	Department of Geology, Anna University, Chennai - 600 025	Says that well developed dune systems protected the coast in the northern sector of Tamil Nadu
Bhalla, R. S.	Do bio-shields affect tsunami inundation.	2007	Current Science. 93 (6): 831-832	Looks at the effectiveness of various bio-shields in minimising tsunami inundation and also identifies sand-dunes as an effective shield.
Gokul A. & K. Shanker.	A brief assessment of sandy beaches on the southeast coast of India. In: Report on ecological and social impact assessments post-tsunami in mainland India;	2007	In: Report on ecological and social impact assessments post-tsunami in mainland India; Submitted by ATREE to UNDP. Post-Tsunami Environment Initiative. 83-93 p.	A rapid assessment of the beach profiles, ecology and anthropogenic disturbances along the South East coast, including many parts of Tamil Nadu

Rodriguez, S.	A preliminary socio-ecological review of post-tsunami ecosystem-derived Livelihoods & Rehabilitation efforts.	2007	In: Report on ecological and social impact assessments post-tsunami in mainland India; Submitted by ATREE to UNDP. Post-Tsunami Environment Initiative. 151-191 p.	
A. Sridhar	Pre and post-tsunami coastal planning and land-use policies and issues in India.,	2007	In Proceedings of the workshop on coastal area planning and management in Asian tsunami-affected countries, 27–29 September 2006, Bangkok, Thailand., RAP Publication 2007/06: pp. 81-110, FAO.	Highlights the natural buffer capacity of littoral sand dunes and coastal forests, as proved during the December 2004 tsunami. Some coastal management imperatives are explained and the lack of appropriate coastal hazard policies as a cause of human loss is emphasized.
Mascarenhas, A.; Jayakumar, S	Protective role of coastal ecosystems in the context of the tsunami in Tamil Nadu coast, India: Implications for hazard preparedness	2007	The Indian Ocean tsunami. eds. by: Murthy, T.S.; Aswathanarayana, U.; Nirupama, N. Taylor and Francis; London; UK; ; 423-435.	

Appendix 3: A detailed bibliography of peer-publications, reports and studies on sand dunes along the Indian coast

Author	Year	Title	Source	Contents
Rao, T. A. & Meher-Homji, V. M.	1985	Strand plant communities of the Indian sub-continent.	Proceedings of the Indian Academy of Science (Plant Science) 94: 505–523.	About the variety of strand vegetation exists on the coastal sand dunes of the Indian subcontinent (e.g. mat-forming creepers, prostrate/erect herbs and sedges, climbers, plants with perennating organs, scrubs etc.
Mascarenhas, A.	1996	The fate of sand dunes of Goa.	A report to the independent world commission on the oceans. ed. by: Rajagopalan, R. International Ocean Institute; Madras; India; p. 111.	A report on the distribution, importance and threats faced by sand dunes along the coast of Goa, with management strategies for their conservation.
Faroda, A.S.	1998	Arid zone research: An overview. In, Fifty Years of Arid Zone Research in India,	(eds. A.S. Faroda & Manjit Singh), CAZRI, Jodhpur. pp. 1-16.	An annotated bibliography of all the Arid-zone research conducted in India (including sand dunes).
Mascarenhas, A., K. Sawkar, A. G. Untawale, & P. V. Sathé.	1998	The distribution of and impacts on sand dune systems of Rajebhag (Nagorcem), Canacona, Goa.	National Institute of Oceanography, Goa.	Deals with the impacts of development projects and constructions on the sand dunes along the coastal area of Goa.
Arun, A. B., K. R. Beena, N. S. Raviraja, & K. R. Sridhar.	1999	Coastal sand dunes – A neglected ecosystem.	Current Science 77: 19–21.	A study on the floral diversity and composition of the dune ecosystems of the Karnataka coast - Mangalore to Karwar, and the threats they face.
Mascarenhas, A.	1999	The Coastal Regulation Zone of Goa: oceanographic, environmental and societal perspectives.	Current Science 77: 1598–1605.	A critical evaluation of current developmental practices and their impacts on the aesthetic and ecological value of the coastal ecosystems. Also discusses the protective value of coastal sand dunes and its legal protection and CRZ status..
Sahasranaman, P.B.	2000	Coastal Regulation Zone - India, An enactment for the protection of Coastal Areas of	http://www.geocities.com/sahasram_2000/crz/crzjt.html (Accessed November 25, 2007)	Gives links to some of the major policy and legal-protection websites for the CRZ's in India, with ongoing cases and issues.

		the country.		
Mascarenhas, A.	2000	Human interreference along the coast of Goa	Environmental problems of coastal areas in India. ed. by: Sharma, V.K.(Semin. on Coastal Cities in India: Responding to Environmental and Socio-Economic Issues of Concern; Indira Gandhi Inst. of Development Res. (IGIDR), Mumbai (India); [nd]). Bookwell; New Delhi; India; 145-171.	Discusses the various alterations and degradations of the dune ecosystems along the coast of Goa in the last two decades. Also tries and addresses some of the major reasons for these changes and impacts with some recommendations and suggestions.
P., B. K. Jena and V. S. Kumar.	2001	Littoral drift sources and sinks along the Indian coast. Chandramohan,	Current Science 81 (3): 292-297.	This study identifies the sources for the littoral sediment transport, which feed to the nearshore transport mechanism on sinks and the annual discharge of sediments to sea in some sites along the Indian coast. It evaluates the long-term sediment deposition in Gulf of Kachchh, Gulf of Khambhat, Gulf of Mannar, Palk Bay and Sandheads.
Paul, A. K	2001	Cyclonic storms and their impacts on West Bengal coast. Proceedings of the International Seminar on Quaternary Sea Level Variation, Shoreline Displacement and Coastal Environment.	(eds. G. V. Rajamanickam & M. J. Tooley), New Academic Publishers, Delhi. pp. 8–31.	Gives some information on the protective role of sand dunes in the wake of natural catastrophes like the tsunami.
Mascarenhas, A.	2002	Sand dunes: an introduction.	In: Fish, curry and rice: A source book on Goa, its ecology and life-style. The Goa Foundation, Mapusa, Goa, India.	A general paper on sand dunes, higlighting their ecological and social significance, recent degradation, threats they face, as well as the legal protection they enjoy

Mascarenhas, A.	2002	Restoration of sand dunes along human-altered coasts: a scheme for Miramar Beach, Goa.	In: Proceedings of the International Conference on Eco Balance and Life Cycle Assessment in India, February 13-15, 2002, Indira-Gandhi Institute of Development Research. Mumbai, India. pp 27-31.	This paper examines the state of sand dunes of a developed coast by taking the tourist beach of Miramar (Goa), India as an example. It looks at the human actions responsible for the degradation and elimination of these geomorphic features and the associated impacts of wind-blown loss of beach sand. Also gives management practices and restoration measures for dunes and the need to involve them in the coastal manafement programs
Rao, T.A. & A. N. Sherieff.	2002	Coastal Ecosystem of the Karnataka State, India II - Beaches.	Karnataka Association for the Advancement of Science, Bangalore, India.	The book is a preliminary effort to collect base line data from the field and the desk as an initial step at certain vulnerable and non-vulnerable places for planning the action plan and management of the beaches and their environs. This book includes the scientific study covered out by the authors throughout the length, width and overlaps of the coastline under the influence of the sea, during the years 1984-1998, providing few broad spectrum proposals for prescriptive measures are suggested to enable the concerned departments of the Karnataka State to take action at appropriate stages of development.
Sekhar, L.K & S.K. Jayadev.	2003	Karimanal (Mineral Beach-Sand) Mining in the Alappuzha coast of Kerala.	A people's perspective. Proceedings of the Third International Conference on Environment and Health, Chennai, India (eds. J. Martin Bunch, V. Madha Suresh & T. Vasantha Kumaran) Chennai: Department of Geography, University of Madras and Faculty of Environmental Studies, York University. pp. 470 – 488.	The study tries to comprehend the ecological and socio-economic impacts of sand mining in the Aleppey district of Kerala. The study tries to assess the seriousness of the social, environmental and health hazards that might result from the indiscriminate mining activity by a profit oriented company. The paper also attempts to compile the history of similar mining projects, their

				environmental consequences, social implications and mass movements that were successful in checking the negative implications of such hazards.
Arun, A. B. & K. R. Sridhar.	2004	Symbiotic performance of fast-growing rhizobia isolated from the coastal sand dune legumes of west coast of India.	Biol Fertil Soils 40: 435-439.	The study looks at the symbiotic efficiency of coastal sand dune rhizobial isolates on cultivated legumes. Inoculation of the isolate P2 induced higher shoot biomass against uninoculated controls and revealed significant difference in the shoot biomass between uninoculated and inoculated plants.
Mascarenhas A.	2004	Oceanographic validity of buffer zones for the east coast of India: A hydrometeorological perspective.	Current Science 86 (3): 399-406.	A review of the various hydrometeorological events that have turned into major natural hazards and afflicted the inhabitants of the east coast of India, highlighting flattening of sand dunes, removal of coastal forests, reclamation of wetlands, inappropriate layout of buildings and roads reduce the inherent functional potential of ecosystems etc. as some of the major man-made interventions that make the coast more susceptible. Also provides some alternatives for long-term hazard management.
Mascarenhas, A.	2004	Oceanographic validity of buffer zones for the east coast of India: A hydrometeorological perspective.	Curr. Sci.: 86(3); 399-406	Discusses how the CRZ (Coastal Regulation Zone) does not protect low-lands prone to inundations due to storm surges; hence adaptation rather than mitigation should be the key of hazard management. Also stresses on the need for a public policy that identifies coastal geological processes, recognizes the protective value of coastal landforms, acknowledges

				mandatory buffer zones and considers options for adaptation, is the sustainable alternative to attenuate the ravages of hydrometeorological events.
Goa Foundation.	2005	Goa Foundation Research Library-Coastal Works. Goa Foundation.	Available from http://www.goacom.com/goafoundation/ (Accessed November 25, 2007)	A website with links and access to publications on CRZ, coastal ecology and other coastal works of Goa.
Areti, K.K.	2007	Evolution of Environmental Legislation.	Available at SSRN: http://ssrn.com/abstract=956228 (Accessed on 31st March, 2008)	This article is a general review of the evolution of environmental legislations in India
Menon, M., S. Rodriguez and A. Sridhar. .	2007	Coastal Zone Management Notification '07 – Better or bitter fare?	Produced for the Post-Tsunami Environment Initiative Project, ATREE, Bangalore. pp. 31	A critical review of the CRZ, wherein a review of the legal protection offered to sand dunes has been done.
Mukherjee, N., B. Muthuraman, A. Gokul, V. Kapoor, R. Arthur and K. Shanker.	2007	A gap analysis of ecological impact assessments done in the tsunami affected states. In: Report on ecological and social impact assessments post-tsunami in mainland India.	Submitted to UNDP. Post-Tsunami Environment Initiative. 31-42 p.	A gap analysis of available literature in various coastal ecosystems to understand the shortage if any in the availability of baseline information and the current status of research on coastal ecosystems (including sand dunes)
Sridhar, K R and B. Bhagya.	2007	Coastal sand dune vegetation: a potential source of food, fodder and pharmaceuticals.	<i>Livestock Research for Rural Development. Volume 19, Article #84.</i> Retrieved September 16, 2008, from http://www.cipav.org.co/lrrd/lrrd19/6/srid19084.htm	A study on the nutritional, medicinal, traditional and economic value of coastal sand dune vegetation. Also identifies threats to their diversity and to the dune ecosystems in general.

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- Current Status of Mangroves in Kerala and Tamil Nadu, India, with regard to Vegetation, Community Perceptions and Policy
- Coastal Sand Dunes of Tamil Nadu, India - An Overview
- A Protocol for Ecological Monitoring of Sandy Beaches and Intertidal Fauna on the Indian Coast
- Sand in my Hands! An Activity Book on Sandy Beaches and Sand Dunes for Children
- Policy Brief: Bioshields
- Policy Brief: Sand Dunes
- Policy Brief: Sea Walls



The Coastal and Marine Programme at ATREE is interdisciplinary in its approach and applies skills in the natural and social sciences to its research and conservation interventions.