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Techniques and Methods to Assess and Monitor Coastal Habitats in India

S. Prakash, C. Ramesh and K. Sivakumar*

Wildlife Institute of India,
P.O. Box 18,
Chandrabani, Dehradun

***Email:** ksivakumar@wii.gov.in

Summary

India has a 7500 km long coastline, including the mainland and offshore islands, which has been blessed with a vast network of backwaters, estuaries, creeks, lagoons and specialized ecosystems such as mangroves and coral reefs. These harbour some of the world's most significant coastal and marine biodiversity. There is an urge to preserve, conserve and protect the coastal habitats and marine environment from all anthropogenic activities. Assessment and monitoring of marine biodiversity is critical for effective management of these resources. In this context, in this paper we describe certain basic technique to assess and monitor the coastal and marine biodiversity of India.

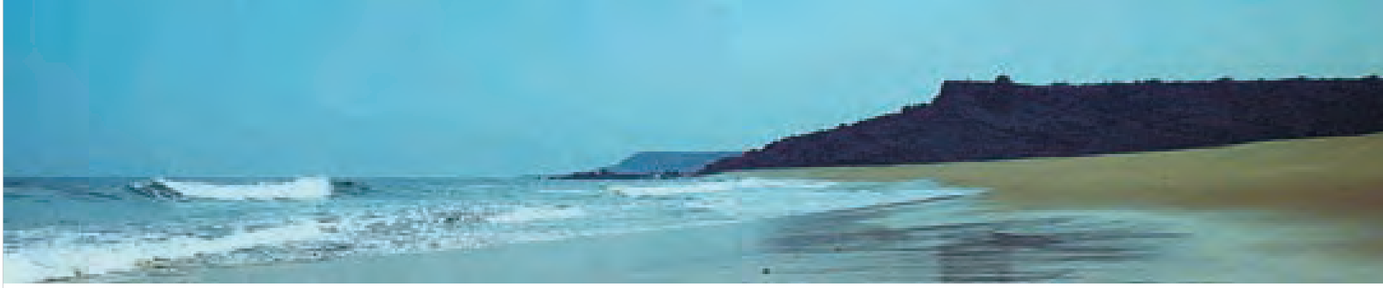
Keywords: *Coastal habitats; coral reefs; mangroves; estuaries; sea grass; beaches.*

Introduction

Coastal and marine ecosystems and resources provide considerable benefits to the countries of the region through fisheries and tourism, which are very important economic sectors in most of the countries, particularly India. Millions of people rely heavily on coastal and marine ecosystems and resources for employment, income and protein. For example, in the Lakshadweep Islands, as much as 90% of the protein intake for poor households comes from reef fishing (Tamelander & Jayasuriya 2008). Healthy ecosystems provide humans with a range of ecosystem services. Therefore, maintaining the health of coastal ecosystems is vital for human well-being in the region.

India has an extensive coastline, of length 7517 km, of which 5423 km is in peninsular India and 2094 km is in the Andaman and Nicobar and Lakshadweep islands. The extent of the exclusive economic zone (EEZ) is 2.02 million km2. This coastline also supports a huge human population, which is dependent on the rich coastal and marine resources. It is estimated that nearly 250 million people live within a 50 km swathe along the coastline of India. Therefore, the ecological services of the marine and coastal ecosystems of India play a vital role in India's economic growth (UNISDR/UNDP 2012).

Climate change is the main regional threat faced by the coastal and marine habitats, such as coral reefs, mangroves, sea grass meadows, estuaries and beaches of tropical developing countries such as India. These systems are also facing severe direct human stresses due to overfishing and destructive fishing, coastal development, runoff from the land and increased sedimentation. Poor management of coastal areas, including many marine protected areas (MPAs), as well as intensive reef resource use, remains a concern in all countries. However, there are also no significant regional changes in the number and magnitude of threats faced by coral reefs, mangroves and sea grass beds (Tamelander & Jayasuriya 2008). In many areas, localized stress is becoming increasingly severe, especially around urban centres and highly populated areas, from overfishing and pollution from the land. Hence, the present contribution provides details about methods of assessing selected coastal and marine habitats such as coral reefs, mangroves, sea grass beds, estuaries and beaches. It also recommends methods for continuous monitoring and long-term conservation.



Coral Reefs

Coral reefs are the most spectacular and diverse marine ecosystems on the planet today. Complex and productive, coral reefs can boast of hundreds of thousands of species-many are still undescribed by science. Coral reefs are spectacular, renowned for their extraordinary natural beauty, biological diversity and high productivity, nurtured by the tropical coastal environments between the latitudes 25oS and 25oN, with the water temperatures between 18°C and 30°C (Veron 1986). Coral reefs, however, also have a crucial role in shaping the ecosystems that have have been present in our tropical oceans for the last 200 million years (Hoegh-Guldberg 1999). The reef substrate is mainly composed of calcium carbonate from living and dead scleractinian corals. Many other invertebrates, vertebrates, and plants live in close association with the corals, with tight resource coupling and recycling, allowing coral reefs to have extremely high productivity and biodiversity (Hoegh-Guldberg 1999). The protection offered by coral reefs from storm damage also enables the formation of associated ecosystems such as sea grass beds and mangroves, which allows the formation of essential and unique habitats.

Coral reefs in India have been under stress for quite some time. The major reef formations in India are restricted to the Gulf of Mannar, Gulf of Kachchh, Andaman and Nicobar Islands and Lakshadweep Islands (Figure 1). Scattered coral growth has also been reported along certain intertidal belts and submerged banks on both the east and west coasts of the country (Venkataraman et al 2004). At present the reefs are important to the local community only to the extent of sustenance fishing. Tourism is being developed at some places, but local communities do not benefit much from the revenue generated.

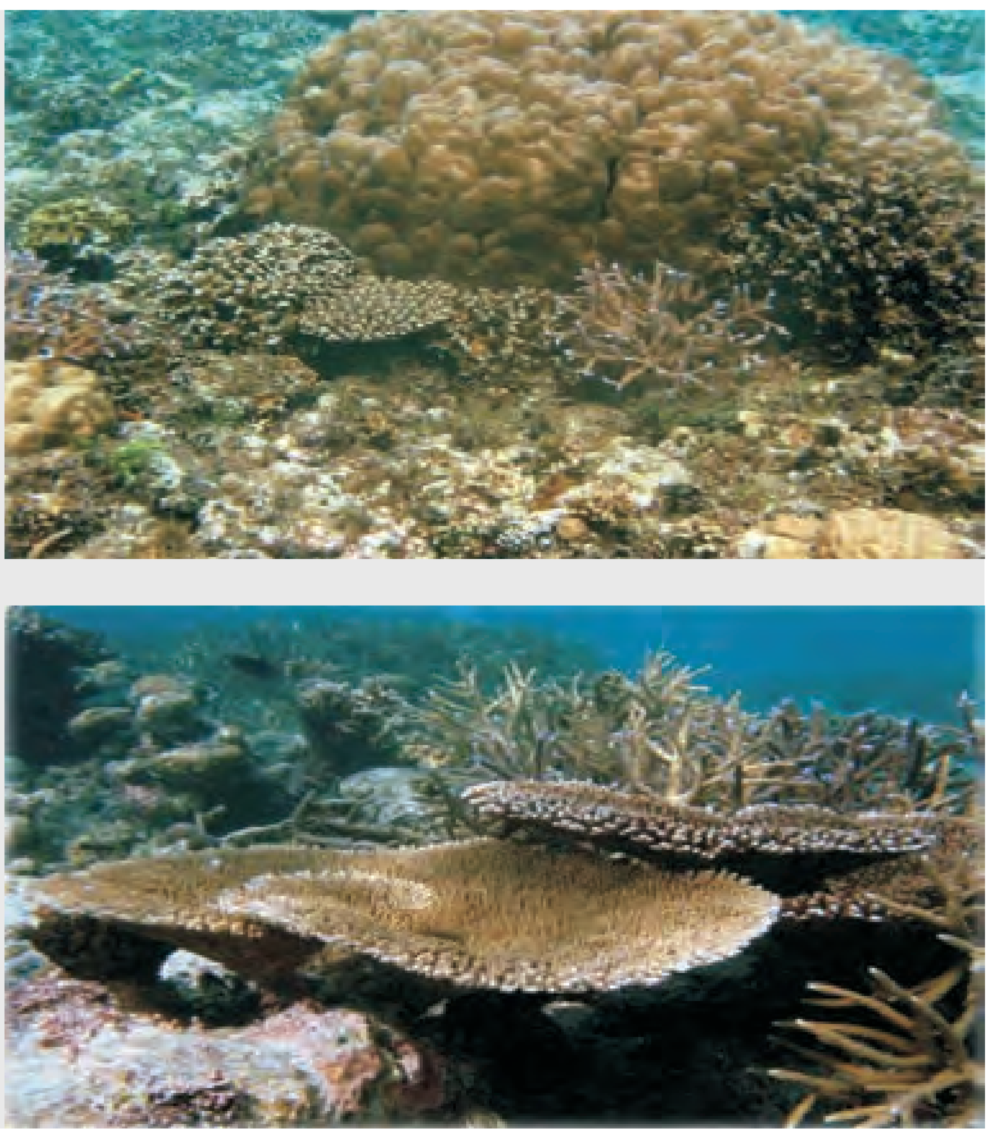
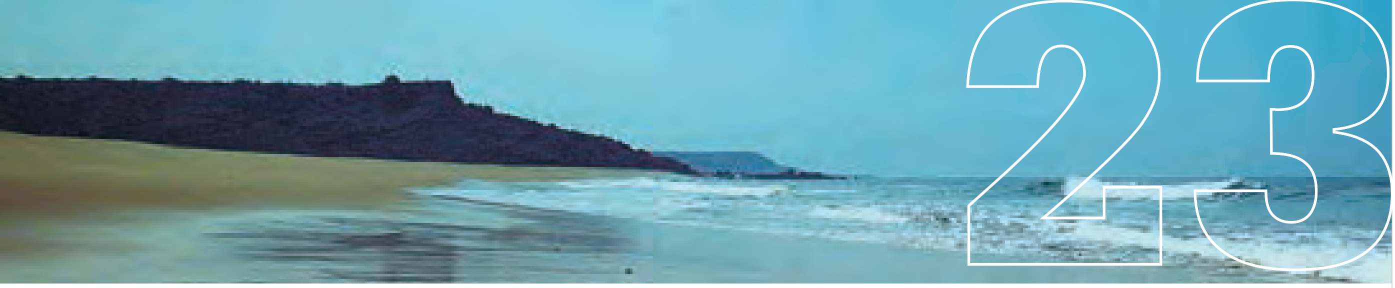


Fig 1 : Underwater views of live corals at Lakshadweep Islands (Photo courtesy: Dr. T.T. Ajith Kumar)



The condition of the reefs is generally poor and declining in near-shore waters and areas of high population densities. Sedimentation, dredging and coral mining are damaging near-shore reefs, while the use of explosives and bottom nets in fishing are damaging offshore reefs at specific sites. The bleaching event of 1998 is reported to have increased dead coral cover to about 70% in the Gulf of Kachchh, 40-60% in the Gulf of Mannar, 60-80% in Lakshadweep and about 80% (subsequent studies do not confirm this report) in the Andaman and Nicobar Islands. Quantitative data are lacking, and few studies have been carried out to monitor the health of coral reefs.

Coral Reef Habitat Assessment

Examination of coral reef health and resilience, in an attempt to identify strategies that could be incorporated into management to enhance the ecological resilience of these ecosystems, is a recent focus of applied coral reef research (Hughes et al 2005). Measurements of coral demographics, mortality and recruitment are combined with assessments of benthic cover types, biomass of algal functional groups, population structure of commercially valuable and ecologically relevant reef fishes, and environmental resilience indicators determined using a standardized, rapid quantitative survey protocol. Concurrent ground truthing is used to define the bathymetry, identify habitat classes and their spatial distribution and extent, characterize dominant species assemblages, substrate types and underlying geomorphology and create high-resolution habitat maps.

The assessments provide information on

(1) The status of coral reefs and species that create and help maintain the health of the reefs and associated habitats;

(2) Local and regional threats, causes, impacts, and potential mitigation strategies.

(3) Patterns of recovery from past disturbances. Coral reef data are compiled into a geographic information system (GIS) database with satellite imagery, habitat maps and other physical and oceanographic GIS data layers, producing a landscape-scale tool useful for marine spatial planning (Bruckner & Renaud 2012).

The rapid assessment protocol can be adopted from Global coral reef expedition protocol (Lang et al 2003) and the IUCN Resilience Assessment of Coral Reefs protocol (Obura & Grimsditch 2009), with additional parameters. Quantitative data can be obtained on the

(1) Coral community structure (diversity, size structure, partial mortality and condition), using 10 m × 1 m belt transects, and coral recruitment (five 0.25 m quadrates per 10 m transect).

(2) Diversity, size and abundance of over 100 commercially valuable reef fishes (food and ornamental fishes) and ecologically relevant functional groups of reef fishes (e.g. herbivores, invertebrate feeders and piscivores) using 30 m × 1 m belt transects.

(3) Cover and abundance of major functional groups of algae (turf algae, macroalgae, crustose coralline algae and erect coralline algae), corals and other benthic invertebrates using a point intercept method (100 points per 10 m transect).

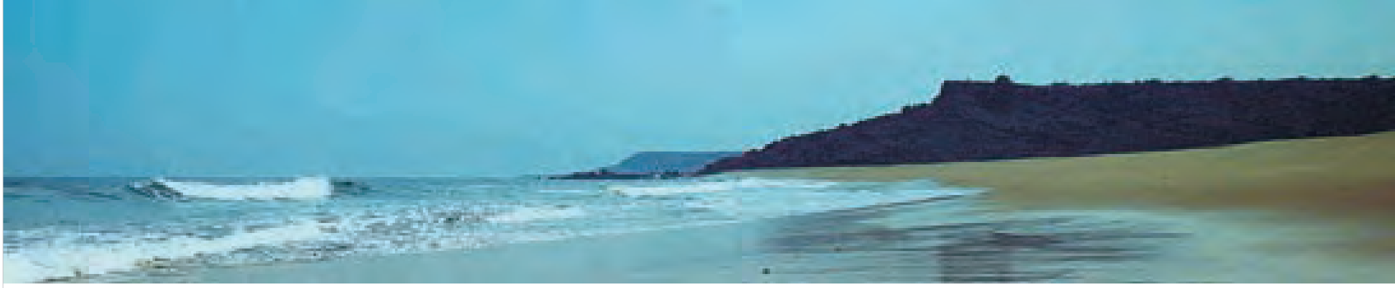
(4) Approximately 50 other ecological and environmental resilience indicators.

These could be quantified (e.g. abundance of corallivores, disease prevalence), ranked on a scale of 1 to 5 (e.g. rugosity, slope), measured off satellite imagery (e.g. reef direction and size, distance from land, to nearest reef and associated habitat and to deep water), or obtained from external sources (e.g. sea surface temperature). Coral reef assessment data are incorporated into a GIS database with satellite imagery forming a base layer, high resolution bathymetric and habitat maps developed through this program, and other available data layers (Bruckner & Renaud 2012).

The manta tow technique is a tool for rapid visual assessment of coral reefs at the scale of a reef or a section of a reef. It involves towing a snorkel diver at a constant speed, behind a small boat, using a rope and a manta board (a hydrodynamic plane angled by the diver's arms to control depth). One tow is carried out over 2 minutes, after which the boat stops and the observer records the cover of live coral, dead coral and sand and rubble, selecting one out of 11 possible categories (Figure 2). These categories follow the international standard for the Global Coral Reef Monitoring Network (UNESCO 1991). Surveys carried out by the AIMS Long-term Monitoring Program (LTMP) involve three tasks: manta-tow surveys for Crown of Thorn Starfish (COTS), broad-scale surveys (reef cover) and surveys for benthic sessile organisms (Sweatman et al 1998). The AIMS LTMP also includes independent detailed surveys of reef benthos (video transects) and fish (visual census using belt transects) on permanently marked sites in contiguous habitats. Historically, this technique has been used to characterize reefs at several sites throughout the Indo-Pacific (Chesher 1969; Roads 1971; Devaney & Randall 1973; Endean 1974).

Mangroves

India has only 2.66% of the world's mangroves, covering an estimated area of 4827 km2. About 57% of this extent is found on the east coast, 23% on the west coast and the remaining 20% on the Bay Islands (Andaman and Nicobar). The insular



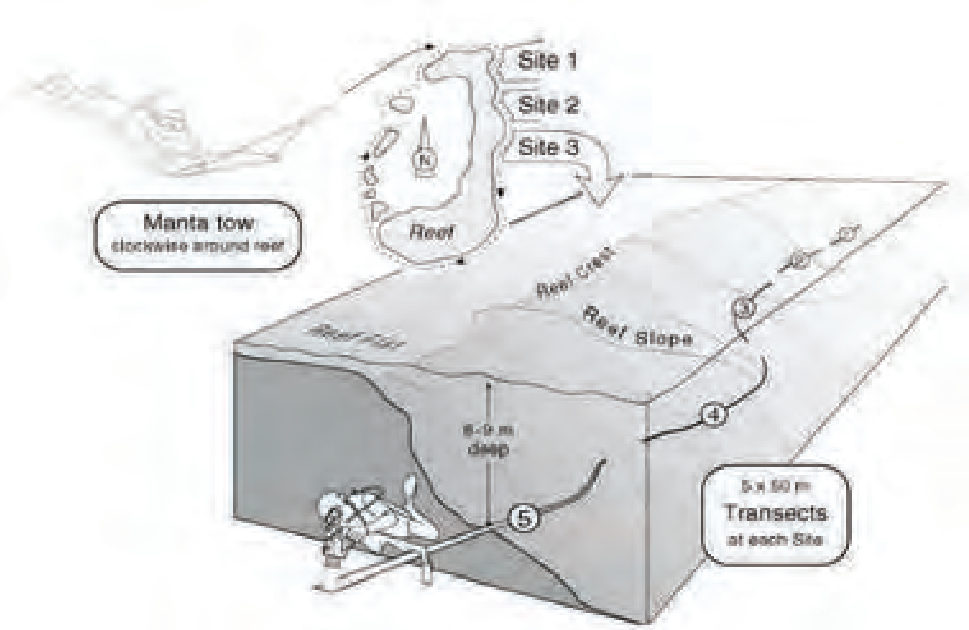


Fig 2 : Schematic showing sampling on a typical survey reef (Adopted from: Sweatman et al (1998))

mangroves are present in the Andaman and Nicobar Islands, where many tidal estuaries, small rivers, neritic islets and lagoons support a rich mangrove flora. The coastal zone, in general, and the mangroves in particular, are used for multiple purposes such as recreation, tourism, forestry, agriculture, aquaculture, housing and commercial fishing. Our knowledge about the occurrence and distribution of mangrove species is inadequate. The mangroves of India comprise 69 species excluding species found in salt marshes and other associated species, under 42 genera and 27 families. The mangroves serve as a wildlife sanctuary, especially in the Sunderbans, Orissa and Andaman and Nicobar Islands. Mangroves are also important nursery areas for the juveniles of many commercial fish and crustacean species (Robertson & Duke 1987) and play important roles in coastal protection and water quality (Saenger et al 1983). Mangrove forests are one of the most productive and biodiverse wetlands on Earth. It is very important that to develop standard methods for monitoring changes in mangrove habitats.

Assessment of Mangrove Habitats

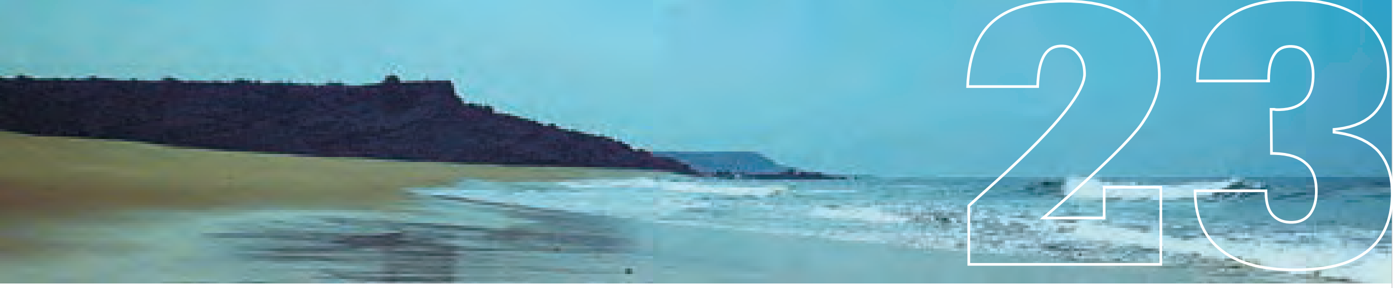
Schwarz et al (2004) developed the method described in the following. It can be used to understand the distribution, habitat and character of mangroves and their changes over time.

Choosing sites. Study sites should be selected so as to be representative of the type of habitat so that the results will also be relevant to other parts of the mangrove habitat. A predetermined number of sites should be delineated within the area of interest. Monitoring multiple sites (replicates) will help account for natural variability. Monitoring transects over time is the recommended approach. This means that one or more sites need to be chosen where transects can be established that can be easily located at a later date. For a statistically rigorous monitoring programme, it is essential to have more than one transect at each site. The choice of the number of replicate transects will depend on the size of a given estuary or the size of the area of interest in an estuary, as well as the specific question of interest regarding a particular community group. It is suggested that carrying out the following method be used on at least two transects across similar boundaries of interest at each site (Figure 3).

Frequency of sampling. The methods outlined in the following should be used on an annual basis and all the parameters should be sampled at the same time of the year, as much as possible. The reason for this is that the production, survival and growth of mangrove seedlings have a seasonal component. With sampling at the same time of the year, differences in seedling numbers between annual monitoring events will reflect year-to-year changes rather than seasonal fluctuations. Additional sampling using the same methods outlined below can be carried out at 6-month intervals to obtain a seasonal component if that is of interest.

Physical characteristics may be sampled more frequently, at least initially, to build an understanding of how quickly things change at the study site.

Methods for recommended minimum level. Each transects needs to be permanently marked so that it can be returned to on different occasions and in successive years. Wooden stakes (approximately 100 cm × 5 cm × 5 cm)



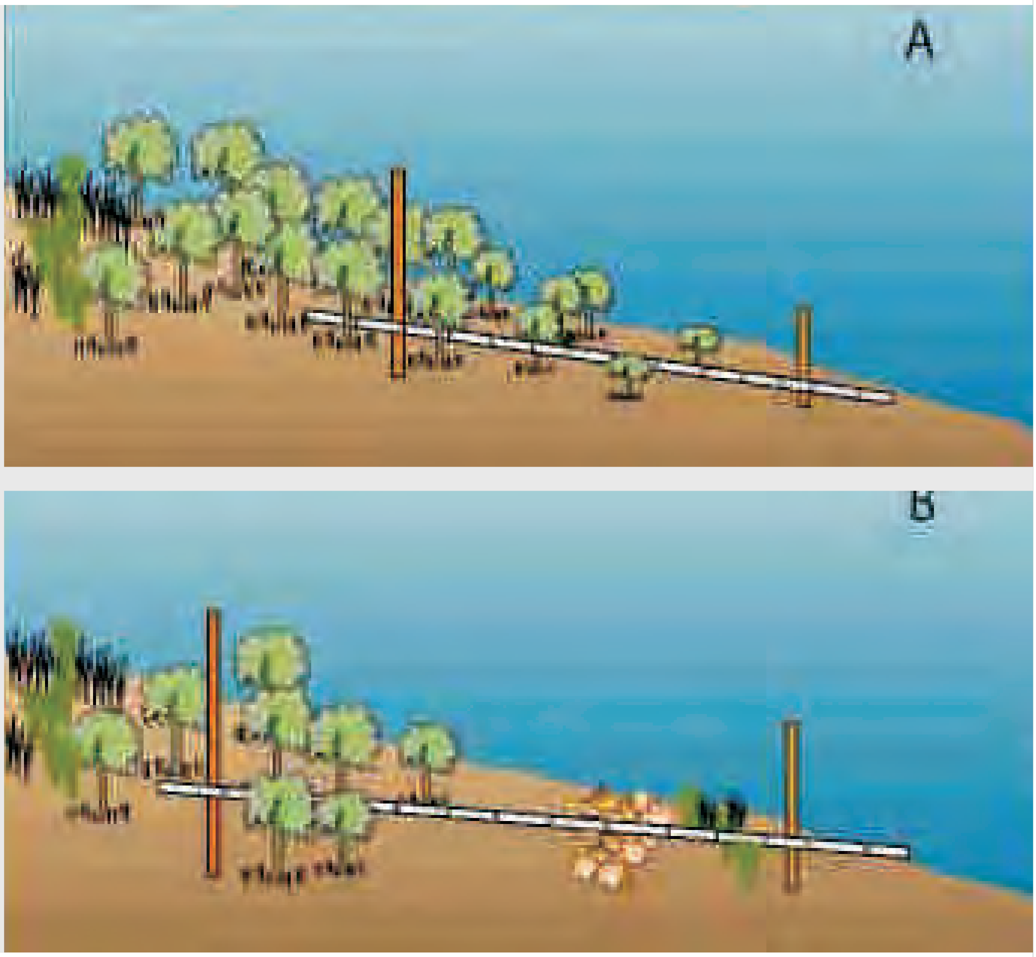


Fig 3 : Permanent markers with a temporary measuring tape laid between them across
(A) A mangrove mudflat/sand flat boundary.
(B) Mangrove/shell bank/salt marsh/mudflat boundaries (Adopted from: Schwarz et al (2004))

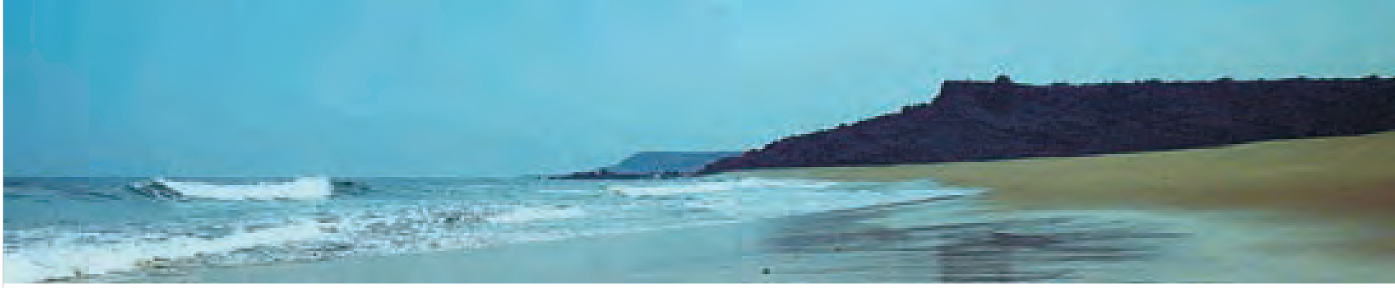
hammered into the ground will fulfil this purpose. Ideally these stakes will also be located with a GPS position and a simple sketch map made of the relevant features so that transects can be relocated if the markers are lost. Making measurements on transects running perpendicular to channels and/or the shoreline is recommended; however, the exact location will depend on the selected location or interest.

Placing transect. The selected site needs to be marked at each end of the two replicate transects by hammering a tantalized wooden stake (approximately 100 cm × 5 cm × 5 cm) into the ground. The length of transect, and the location relative to the mangrove boundary, will depend on the characteristics of the selected site. The important thing is to ensure that the transect is long enough to cover the habitats of interest (e.g., edge of mangrove forest and mudflat or edge of mangrove forest and salt marsh-as an indication, it is likely to be 20-50 m long). It is important to place permanent markers so that transects can be relocated. The GPS location also needs to be noted where the stakes are placed in case they are removed or lost at any time.

Habitat boundaries on mangrove transects. Transect is delimited using marked rope or measuring tape laid between the stakes. Record which stake is equivalent to zero, and this should be the same on subsequent visits. Walk along one side of the transect line only (to avoid trampling) and note the distance on the transect line where there are changes in plant communities (e.g., sea grasses, mangrove seedlings, saplings, pneumatophores and mangrove trees) or surface features, including different types of sediment.

Mangrove community characteristics across boundaries. This method enables you to follow changes in relative numbers of seedlings, saplings and trees between years and so better understand how a forest develops with time. The seaward boundary between the mangroves and tidal flats is likely to be selected as the main boundary of the area. However, the same methods can be used across other boundaries if doing this is relevant to the selected site.

A plot that crosses a mangrove forest boundary should be marked. See Figure 4 for an example. The plot size will depend on the characteristics of the selected site (e.g. 5 m × 10 m was appropriate for sparse shrub and seedling cover on a sand flat, while 5 m × 1 m or 2 m × 1 m was appropriate for dense areas of seedlings in very muddy habitats). It is important



that one edge of the plot run along the transect and that an accurate record of the location of the plot relative to the transect be maintained for future reference. A sketch can help. Ensure that the plot overlaps the existing boundary of mangrove trees and a mostly clear area where mangroves might be expected to expand into overtime. Within the plot, measurements should be taken of the following variables, related to the characteristics of mangroves:

(a) Total number of trees.

(b) Total number of saplings.

(c) Total number of seedlings.

If the number of seedlings in the plot is too large to count, counting can be done of all individuals in smaller subplots and the number multiplied up to the area of interest. It is important to keep a record of exactly which methods were used. On subsequent visits, carry out mangroves counts in exactly the same plots using the same methods.

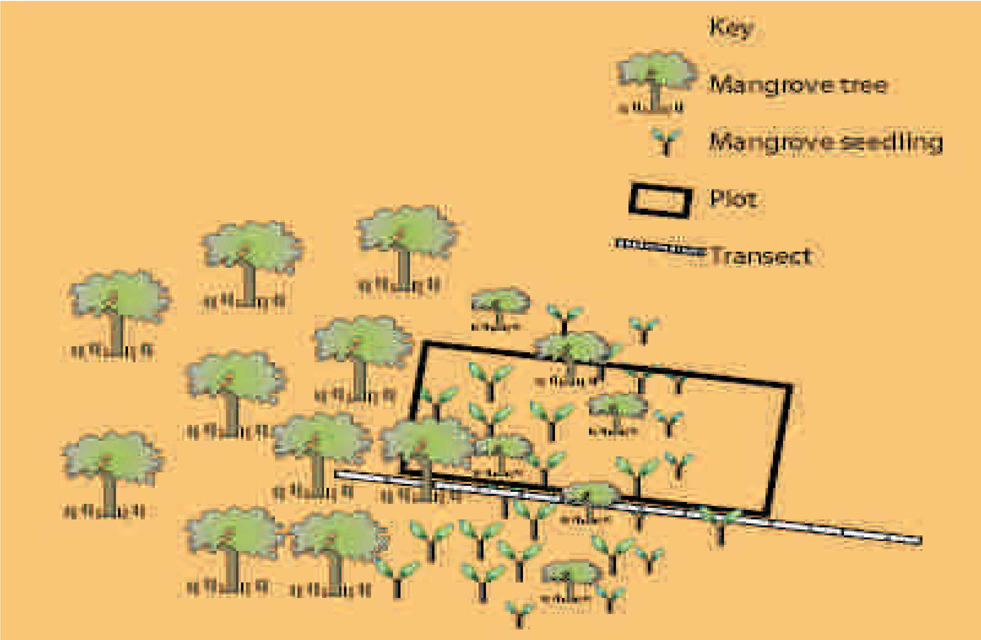


Fig 4 : Plan view of the boundary of a mangrove forest showing a transect line crossing a boundary of trees into seedlings and the positioning of a 5 m × 1 m plot (black rectangle). If the number of seedlings in the plot is too large to count, three 1 m × 1 m subplots could be laid and the numbers of seedlings in each of these counted. (Adopted from Schwarz et al (2004))

Table 1 : Mangrove monitoring data sheet (5 m × 1 m plot), 5 plots in a line at 100 m intervals (modified from Schwarz et al. 2004)

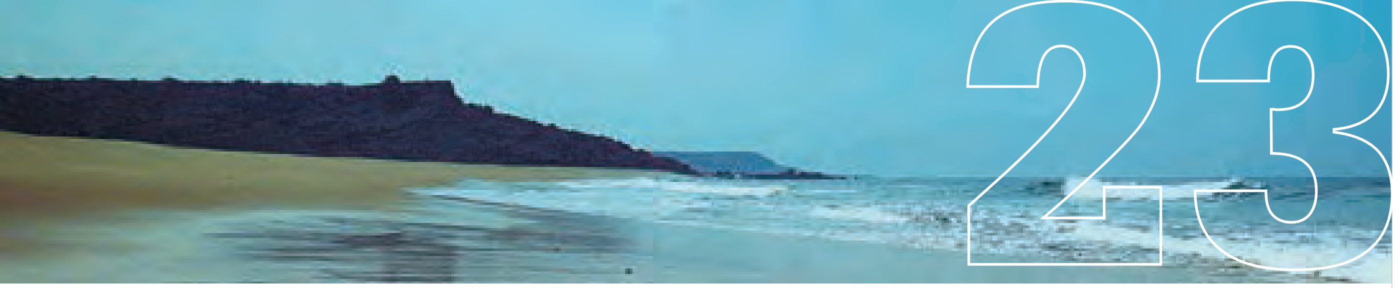
Name of Observer: ………………Date: …………… Time: Tide: Low/high Type:
Natural/plantation Weather: GPS location:
Grid no.: ……………………………… Plot no.: …………………

Sl. No.	Species	Tree/ shrub	GBH (cm) of tree	Alive/ dead	Phenology status	Height	No. of seedlings	% Canopy cover	Compaction of ground (cm)	Salinity (‰)
1.										
2.										
3.										

Phenology status: Inflorescence/flowering/development of fruit/ripened fruit. Total number of saplings/seedlings in the plot. Compaction: Check availability of sediments using a penetrometer (50 m long, 0.5 cm diameter iron rod-drop from 1 m height; take 5 readings in each plot. Height: tree height. Salinity: salinity of water found in a pit in or close to the plot..

Satellite Remote Sensing

Satellite remote sensing in coastal environments is one of the effective methods of obtaining information on mangroves (Bira et al 1980; Eong et al 1992; Chaudhury 1990; Selvam et al 2003). It has been frequently used for assessment of



mangrove areas (Dutrieux et al 1990; Gang & Agatsiva, 1992; Aschbacher et al 1995; Green et al 1996). Remote sensing can be used to map coastal habitats, and it is often an easier and cheaper alternative to ground-survey methods of mapping, particularly in remote or inaccessible regions (e.g. Aschbacher et al1995; Laba et al 1997; Mumby et al 1999). A variety of remote sensors and image processing methods can be used-their advantages and disadvantages are site-specific and vary with the requirements of the project. Green et al (1998) described the assessment of mangrove areas using high resolution multispectral airborne imagery, including the leaf area index and canopy structure. Recently Space Application Centre, Ahmedabad (SAC) (2012) compiled studies related to coastal land use mapping, inventory of vital costal habitats, impacts of a rise in the sea level and development of a coastal zone information system (SAC 2012). Generally the linear extent and area of mangroves are estimated using commercially available topographic data, aerial photographs and Landsat Thematic Mapper imagery (Manson et al 2001).

It is well known that mangrove wetlands are marshy in nature and are intersected by a number of tidal creeks, channels and large canals. This makes regular and direct monitoring of mangrove conservation and restoration activities difficult. Further, getting a synoptic view of the status of resorted areas and making a comparative study of the past condition of a mangrove wetland with the status after restoration are primary requirements for convincing managers, decision makers and planners that restoration activities need to be extended further. Remote sensing data can be used as a monitoring tool to assess the effectiveness of restoration and conservation programmes (Selvam et al 2003).

Mangrove Mapping at Community Level

Remote sensing is a practical alternative to field-based surveys and is being successfully used over a number of years for mangrove mapping at the primary level, especially in differentiating mangroves from other vegetative cover (FSI 2001, 2003). In recent years, there have been new initiatives to understand the spatial relationship between mangroves and their immediate environment, viz., 'community zones' (Tomlinson 1994; Hogarth 1999), using advanced digital image processing techniques (Bahuguna & Nayak 1996; Blasco et al 1998). These mangrove zones exhibit unique spectral signatures, and studies carried out at selected sites by Nayak and Bahuguna (2001) revealed the potential use of remote sensing data in discerning and mapping these communities effectively. Indian Remote Sensing Satellite (IRS) data have been extensively used to map mangroves and other coastal vegetation along the entire Indian coastline. Large databases on the spatial extent of mangroves has been created on 1:25,000, 1:50,000 and 1:250,000 scales using IRS data from 1990-1993 (Nayak & Bahuguna 2001).

The SAC study (2012) envisages mapping mangroves at the community level (1:25,000 scale) for all maritime states/union territories with mangroves. These are Andhra Pradesh, Goa, Maharashtra, Orissa, Karnataka, Kerala, Puducherry, Tamil Nadu, Gujarat, West Bengal and the Andaman and Nicobar Islands. IRS P6 LISS-III and LISS-IV data of 2005-2007 (for October-March) have been utilized for discerning mangrove communities of the coasts of Andhra Pradesh, Goa, Maharashtra, Orissa, Karnataka, Kerala and Puducherry (Figure 5). As mangrove forests are tide inundated, care was taken to utilize data sets of coastal regions relating to low tides. For delineating fringe mangroves along narrow creeks and new plantation areas, QuickBird data available from Google Earth services were also utilized.

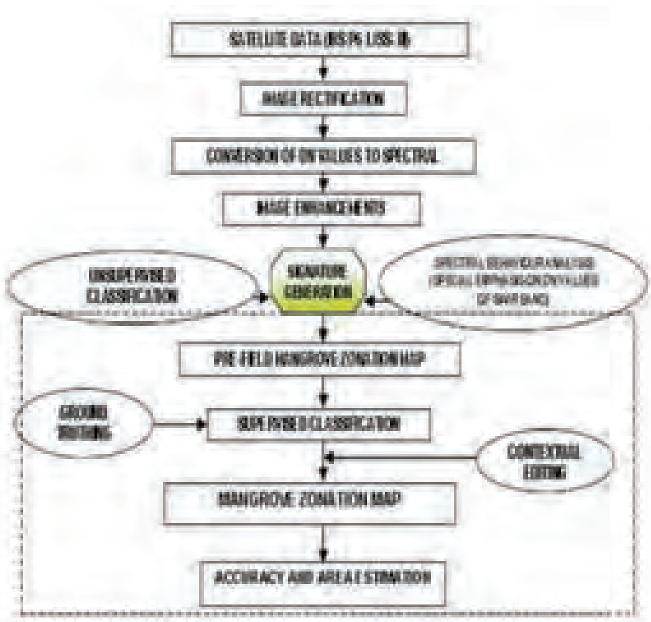
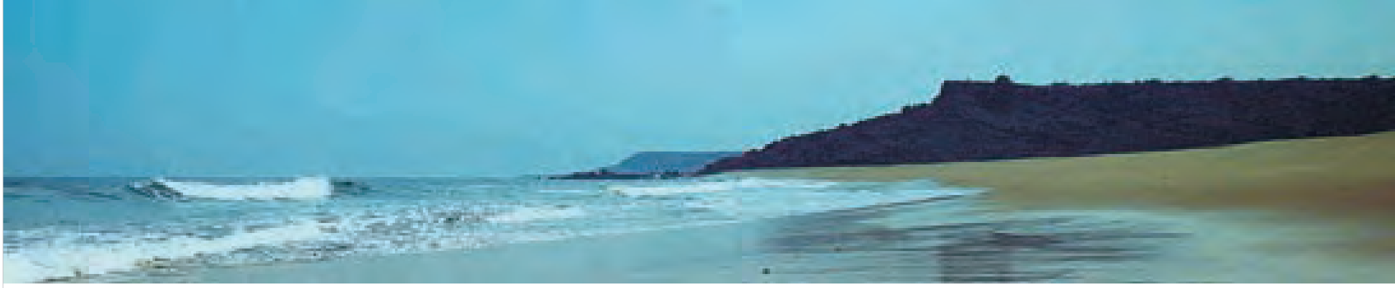


Fig 5 : Methodology for mapping mangrove communities (Source: SAC (2012))



IRS P6 LISS-III data are considered to be the primary data source for digital data analysis. Digital values are converted to spectral radiance values using equations and calibration coefficients obtained from the sensor calibration details available in the metadata.

$$Lrad = \{[DN / max\ grey] \times [Lmax - Lmin]\} + Lmin$$

where DN = digital number of each pixel and max grey = 255 for LISS-III.

As the information available regarding community zonation was scanty, geo-referenced spectral radiance images were subjected to unsupervised classification using the commonly used Iterative Self-Organizing Data Analysis (ISODATA) classifier to start the work. The ISODATA method uses the minimum spectral distance to assign a cluster for each candidate pixel. Depending upon the scene characteristics, arbitrary clusters are specified with a convergence threshold of 0.99. The clusters thus obtained were colour coded for better visual discrimination, and pre-field classification maps were prepared. From the field observations, the elevation of land, level of salinity and duration of tidal inundation were found to be the predominant factors influencing the species composition. The false colour composite developed from the digital data is able to discern the major communities to a considerable extent. To identify the subtle differences in species composition, classified outputs developed from the ISODATA classifier are used in ground truthing. Ground truth points are selected in such a way to sufficiently represent all the digitally discernible communities. Geographical coordinate information, species composition and dominance, influence of tidal inundation and digital view of each selected reference point are also collected. Based on the ground truth information, supervised classification is performed using a sufficient number of training sets for each community. The mangrove community classes thus obtained is evaluated critically against the ground information and expert knowledge. The shortwave infrared band of IRS LISS-III, with a spatial resolution of 23.5 m, has been effectively used for differentiating mangroves from other vegetative cover. Contextual editing is performed wherever necessary to improve the classification accuracy. Further details are available in SAC (2012).

Sea Grass Ecosystems

Sea grass ecosystems in the tropics, particularly in India, have been given low priority by the scientific community and environmentalists (Jagtap 1996). The expanse and density of sea grasses have significantly declined in most of these regions, including India (SAC 2006; Thangaradjou et al 2008; Sridhar et al 2010). Although they extend over less than 1% of the ocean, they play an important role in the coast zone and provide ecosystem services and goods that have higher values compared with other marine habitats (Costanza et al 1997; Duarte et al 2005). Furthermore, recent studies have demonstrated that sea grasses can reduce the impacts of ocean acidification (Bjork & Beer 2009) and act as an important carbon sink in the marine environment (McKenzie & Unsworth 2009).

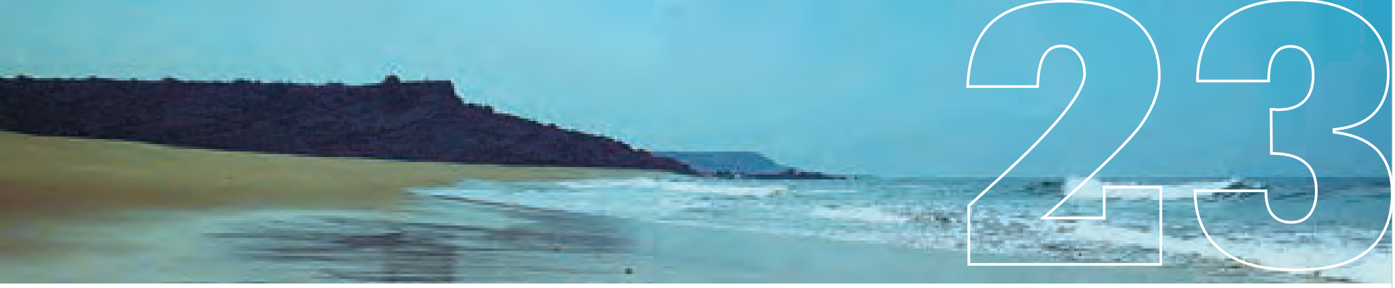
The global distribution and abundance of sea grasses have changed over evolutionary time in response to sea level changes, physical modification of coastlines and global climate changes (Crowley 1990; Short & Echeverria 1996; Berner & Kothavala 2001). Multiple stresses, including sediment and nutrient runoff, physical disturbances, invasive species, diseases, commercial fishing practices, aquaculture, overgrazing, algal blooms and global warming, cause sea grass declines at scales ranging from a few square metres to hundreds of square kilometres (Orth et al 2006).

Sea Grass Habitat Assessment

In order to visualize data relating to sustainable management and conservation of sea grass ecosystems, systematic mapping and continuous monitoring are needed at different intervals (Wabnitz et al 2008). Studies on temporal and spatial changes in the distribution of sea grasses have still not been conducted, particularly around remote islands. Currently, satellite imagery, coupled with GIS techniques, is considered to be one of the best tools for understanding changes in sea grass coverage (Wabnitz et al 2008; Nobi 2010). It is cost-effective and reliable.

Recently, studies were conducted using aerial photos and IRS-P6 LISS-III sensor imagery to gain an understanding of the geomorphology and coastal resources of the Rameswaram group of islands. Visual interpretation techniques were employed, and the satellite data were geocoded. These data were again used in the field for collecting ground control points (using handheld GPS). The satellite imagery were geocorrected using these ground control points. Based on the image characteristics, tone, texture, pattern and association, various coastal geomorphic categories and resources were identified and mapped (Nobi et al 2010).

Another study was conducted by Fletcher et al (2009) in Texas, USA to evaluate and monitor the landscape changes in the sea grass beds related to human and natural disturbances using aerial photography. High-resolution aerial colour film photography, colour space transformation, pixel threshold models and GIS technology were integrated to detect, assess and monitor 1-m ground feature changes and disturbed areas of shallow sea grass beds. The procedure entailed transforming digitized aerial colour film transparencies from the red, green and blue colour space to the intensity, hue and saturation colour space; analysing the saturation and/or intensity of the imagery and their histograms to identify



bare areas; and developing threshold models to separate bare areas from vegetated area. Maps created using this semi-automated approach had classification accuracies ranging from 75% to 100%. In a recent study, Nobi et al (2013) estimated the extent of restored sea grass habitats at selected islands of Lakshadweep using satellite maps, GIS and field observations. Sea grass maps were integrated for the year 2000-2008 specific areas and buffer zones were generated to delineate the restoration sites.

Attempts have been made to use different site selection models around the world (Kopp et al 1994; Short et al 2002) as mitigation projects for sea grass losses. Of the possible factors that can directly influence the survival of transplanted sea grasses, poor site selection has been identified as the major cause (Harrison 1990; Fonseca 1992). Thus, it is better to select areas where sea grasses were present in the past for restoration as conflicts over site selection, habitat requirements and invasion of other habitats will be avoided (Calumpong & Fonseca 2001; Campbell 2002; Katwijk et al 2009).

Estuaries

An estuary can be defined as a partially enclosed body of water that is open to the sea (permanently or periodically) and within which there are variations in salinity due to dilution of seawater with freshwater from land drainage (Pritchard 1967). Although estuaries are considered short-term features of the landscape on a geological timescale, they are often highly productive areas that play important roles at the boundary between land and sea. They also play a vital role in global ocean processes due to their intricate habitat structure (Smith et al 2003). Estuarine systems are considered to be highly exploited due to continuous human disturbances as a result of the availability of natural resources. These water bodies are ill-treated through domestic, agricultural and industrial wastes. They have the capacity of self-purification due to the diurnal tidal cycle and other ecological interactions. However, the exponential growth of urbanization and industrialization together is of major concern because of the degradation of habitats and loss of ecosystem services and socio-economic values caused (Kulkarni et al 2011). Tropical estuaries are influenced by the monsoon, which produces significant changes in the physio-chemical and biological characteristics of the system (Sivadas et al 2011).

Successful management of estuaries and their catchments for sustainable use in the future requires us to focus our knowledge and efforts on developing simple, defensible and cost-effective strategies to assess and monitor estuary conditions and predict the results of management actions. However, despite the great amount of research on estuaries, our ability to predict the consequences of change or even develop a set of cost-effective monitoring indicators of estuary conditions is limited. The reasons for this include a lack of funding to determine the monitoring indicators, the complexity of estuaries and the fact that most research has focused on local estuary problems and cannot be applied easily to other sites. Thus the development of management techniques to assess estuarine habitat status and change is currently a major resource management priority within India.

Estuarine Habitat Assessment

Three potential assessment tools were developed by Robertson et al (2002) to represent different scales of investigation in an estuarine monitoring protocol:

(1) Preliminary assessment includes development of a decision matrix that allows managers to prioritize estuaries for monitoring and provide a defensible basis for their long-term planning.

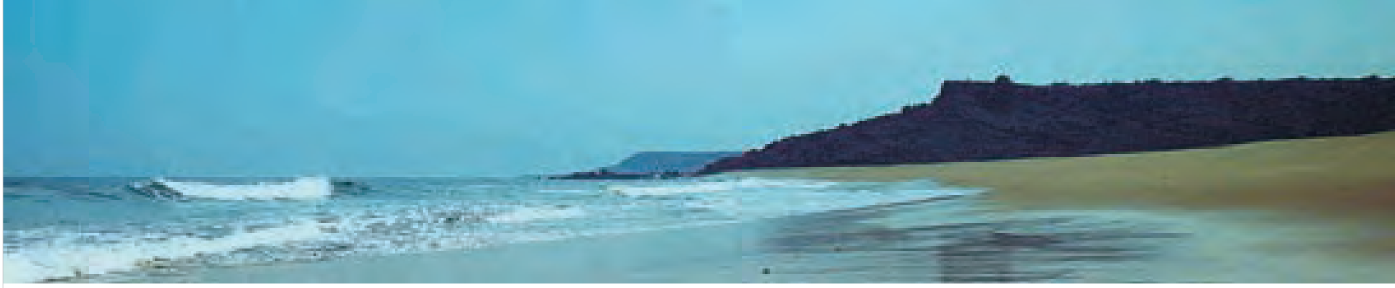
(2) Broad-scale habitat mapping includes the development of robust GIS-based methodology for mapping the spatial distribution of intertidal estuarine habitats.

(3) Fine-scale environmental monitoring includes development of methodology to measure the spatial variations and inter-relationships of a suite of commonly measured indicators.

Beach Ecosystems

Tremendous population and developmental pressures have been building up in coastal areas for the last four decades. The urbanization and the rapid growth of coastal cities have been dominant population trends over the last few decades, leading to the development of numerous mega cities in all coastal regions around the world (Srinivasa Kumar et al 2010). Furthermore, global climate change and the threat of an accelerated sea level rise exacerbate the high risks of storm surges, severe waves and tsunamis. Over the last 100 years, the global sea level rose by 1.0-2.5 mm per year. Present estimates of the future sea-level rise induced by climate change range from 20 to 86 cm for the year 2100, with a best estimate of 49 cm. It has been estimated that a 1-m rise in sea-level could displace nearly 7 million people from their homes in India (IPCC 2001). Study the natural hazards and coastal processes of the Indian coast scientifically has assumed greater significance after the December 2004 tsunami because the country learned lessons about the impacts of natural hazards in terms of high potential for damage to life, property and the environment.

Several recent studies indicate that beach protection strategies and changes in the behaviour or frequency of storms can



be more important than the projected acceleration of the sea level rise in determining future beach erosion rates (Ahrendt 2001; Leont'yev 2003). Thus there is no simple relationship between the rising sea level and the horizontal movement of the shoreline, and sediment budget approaches are most useful in assessing beach response to climate change (Cowell et al 2006). The combined effects of beach erosion and storms can lead to erosion or inundation of other coastal systems. The impacts of an accelerated sea level rise on gravel beaches have received less attention compared with sandy beaches. These sandy beach systems are threatened by the rising sea level (Orford et al 2001, 2003; Chadwick et al 2005).

Beach Assessment

Beaches and dunes are in constant motion, continually changing shape and shifting position in response to winds, waves, tides, the relative sea level and human activities. The most significant changes occur seasonally and after storms. During summer, beaches are generally higher and sandier than they are in winter. During the winter, the 'missing' sand moves from the beach to near-shore areas to form sandbars. This happens as a result of changing wave shape due to more intense storm activity. Comparing season-to-season profiles and profiles taken before and after a significant storm clearly illustrates the important changes taking place along the shoreline and how quickly coastal landforms change (Figure 6) (WHOI 2000).

Fig 6 : Typical summer and winter beach profiles (WHOI 2000)

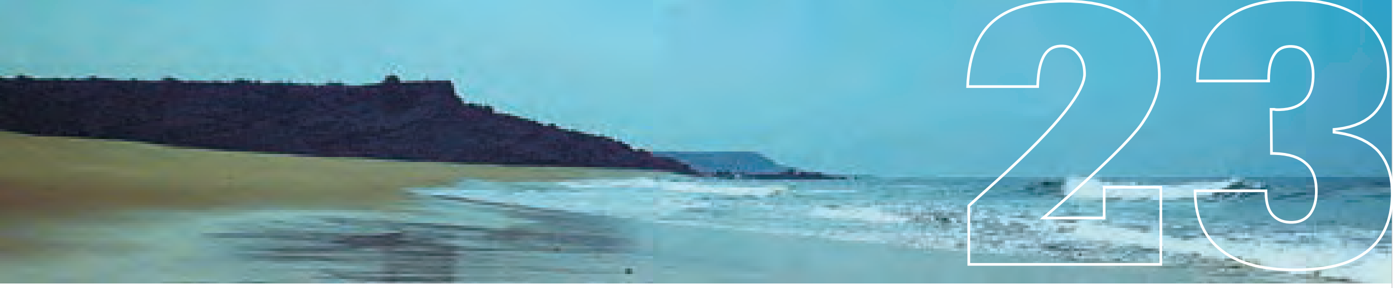
Two-dimensional on-shore models are ideal for management applications as they are simpler and have fewer inputs compared with three-dimensional models or models that include long shore interactions. By definition, stable dynamic beaches do not experience a significant net long shore transport and as such lend themselves to a two-dimensional on-offshore model approach. The impact of concern is the potential increase in offshore sediment transport due to higher water levels (IJC 1993). Currently available models for determining impacts of different water level scenarios have been provided by Geomorphic Solutions (2009). These models are used for estimating short-term shoreline evolution, such as changes during individual storm events, making them ideal for a 'worst case scenario' approach. The models vary in complexity and approach; however, they are limited by the current understanding of the physics of near-shore sediment transport.

Further, the use of a two-dimensional model such as SBEACH (Storm-Induced BEAch CHange model), which was developed by USACE for simulating cross-shore beach, berm and dune erosion produced by storm waves and changes in water levels (Larson & Kraus 1989, 1990), can be validated with field data. Physical processes represented in the model include varying wave conditions and water levels, irregular initial profile shapes, bar formation and movement and setup and run up. The model has been refined over time to include irregular waves and dune over-wash (Larson 1996; Wise et al 1996). In fact, it is continuously being updated and extensively evaluated and widely used (Larson et al 2004).

Recently, the impact of tourism on the beaches of Kovalam was evaluated by Ghosh and Datta (2012). The field activities and assessment of the beach morphology and interviewing of tourists and citizens were as in the methodology of Breda (2005). To study the geo-environmental profile, the values of several environmental parameters related to beach pollution and water quality status were obtained as primary and secondary level data. In addition, Dora et al (2012) studied the beach dynamics of Devbag, an island-sheltered estuarine coast, by observing the cross-shore beach profiles and textural characteristics of foreshore sediment to understand the annual cycle of intertidal beach dynamics.

Conclusions

Coastal ecosystems are considered to be among the most productive ecosystems around the world. They harbour a diverse range of floral and faunal elements. Ecological and socio-economic impacts of climate change have already



threatened the services and goods provided by these ecosystems in several countries in the Asia-Pacific region. Some indicators suggest that the global warming phenomenon has been triggered: extreme weather events, increased agricultural losses, sea ice melt, retreating glaciers, a rise in the sea level, coral bleaching and a decline in biodiversity. Communities in both developed and developing countries are also suffering from these impacts, and tropical countries are likely to be more vulnerable. Future efforts to build the resilience of the local community and the ecosystems should take into account a concerted and integrated approach. Hence, a multi-disciplinary approach involving several stakeholders on a common platform can stimulate integration of climate change concerns in the overall development and planning process.

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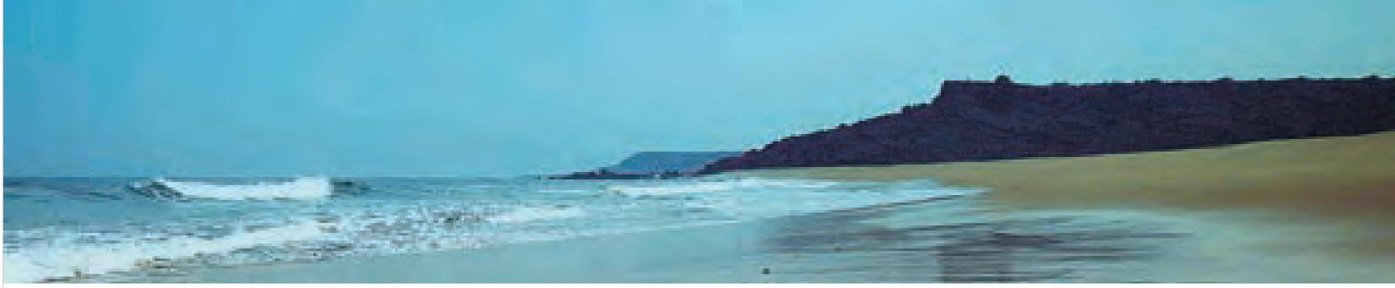

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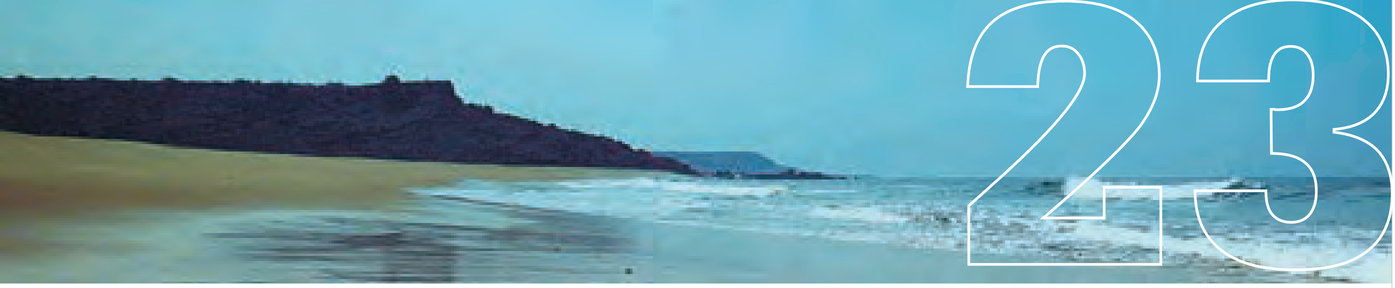

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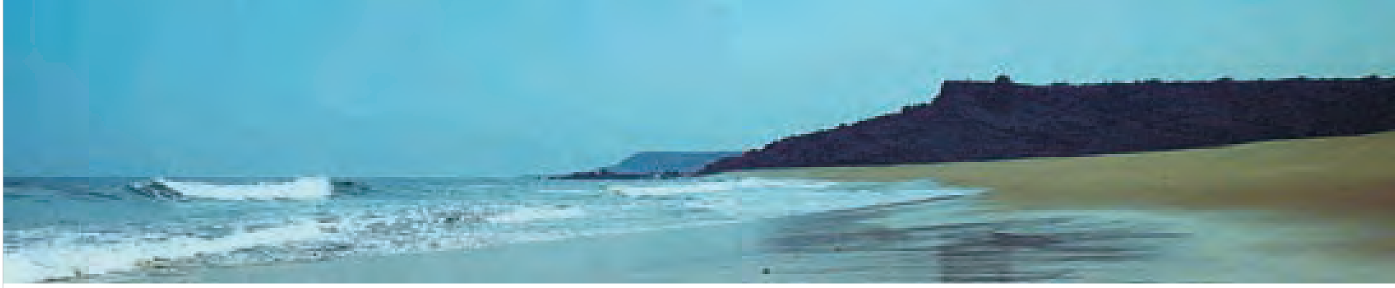

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