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True Mangrove Mapping in Coastal Environs of Minnie Bay, South Andaman, India, using geo-spatial Approach

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ABSTRACT: Environmental research is essential for monitoring and managing the ecological status of the mangrove environment. Due to the difficulty of accessing and penetrating the mangrove area along the coast, a remote sensing technique can be used to analyse the mangrove. The present study was carried out to assess the true mangrove species in the coastal vicinity of Minnie Bay, South Andaman, for developing a spatial map in order to conserve the coastal resources. The result revealed the presence of 15 true mangrove species from an area of 4.81hectare of land and also illustrated the dominance of three species (91.4 %) of *Avicennia marina*, *Rhizophora apiculata* and *Rhizophora mucronata*. The study suggests the revival of the mangrove resources after the tsunami of 26th Dec 2004. Spatial map developed through ground truthing process will help in developing a proper mitigation and conservation management strategy to protect the mangrove are sources in the islands.

Keywords: GIS, GPS, True mangrove, Conservation, Andaman.

INTRODUCTION

Mangroves are the coastal plants that survive in the relatively high range of water salinity and form an evergreen ecosystem in inter-tidal zones. Mangroves prefer to grow in river deltas, lagoons and estuarine complexes (Thom, 1984); also occur on colonized shorelines and islands in sheltered coastal areas with locally variable topography and hydrology (Lugo and Snedaker, 1974). In 2000 it wasestimated that the world's total mangrove forest cover was 137,760 km^2 distributed in 118 countries and territories (Giri *et al.*, 2010). The largest extent of mangroves is found in Asia (42%) followed by Africa (20%), North and Central America (15%), Oceania (12%) and South America (11%) (Giri *et al.*, 2010). Mangrove wetlands are dominant coastal ecosystems in tropical and subtropical regions throughout the world (Leeand Yeh, 2009). The knowledge and information of the exact floral species composition in any country or places is a basic and important pre-requisite in understanding all the aspects of structure and function of mangroves, as well as their bio-geographical affinities and their conservation and management (Jayatissa *et al.*, 2002). After West Bengal (East coast), and Gujarat (West coast), Andaman and Nicobar Islands (A&N) are flourished with good mangrove ecosystem. Recently it was reported that about 38 true mangrove species belonging to 13 families and 19 genera are present in the A&N Islands (Ragavan *et al*., 2016). The mangroves population in many geographical areas is declining with time as a result of the destruction of mangrove forests and exposure to various anthropogenic stresses (Hamilton and Snedaker 1984). The continued decline of forest area is caused due to conversion to agriculture, aquaculture, tourism, urban development and overexploitation (Alongi, 2002; Giri *et al.*, 2008). Mangroves species found primarily in the high intertidal and upstream zones, which often have specific freshwater requirements and patchy distributions, are the most threatened because they are often the first cleared for the development of aquaculture and agriculture (Polidoro *et al.*, 2010). About 35% of mangroves were lost from 1980 to 2000 (MA, 2005). If the loss is continued in this rate after sometime important ecosystem goods and services (e.g. natural barrier, carbon sequestration, biodiversity) provided by mangrove forests will be diminished or lost (Duke *et al*., 2007). Major threats to mangrove of A&N Islands are due to natural disaster, human interference whereas the grazing of animal is limited. Due to tsunami like other areas of A&N Islands the mangroves of Minnie Bay were also severely affected and considerable damage occurred due to direct hit by tsunami after earth quake. The subsidence of entire South Andaman approximately by meters and continues submergence of stilt roots and pneumatophores, due to this mangroves degraded and new mangrove diversity evolved during recent years that is after more than a decade. This study was carried out to know the current scenario of true mangrove species richness and also to trace land-cover occupied by true mangrove species at Minnie Bay coast.

MATERIALS AND METHODS

Study Area Description. Minnie Bay (MB) coast is falling in between lat11°38' N and long 92°42' E, which is located in the Port Blair Bay, South Andaman. The study site (Fig. 1) MB was selected which had well developed mangrove cover before tsunami however it degraded due to earthquake (Mw 9.3) and subsequently tsunami on 26th Dec 2004. It is tsunami affected area of South Andaman zone surrounded by human settlements and plantation. The coast is deep inside the land and form a shape like U which runs for a 3.6 km with sandy to muddy coastline. The entire cost is occupied with dense to scattered mangrove patches which form a unique ecosystem.

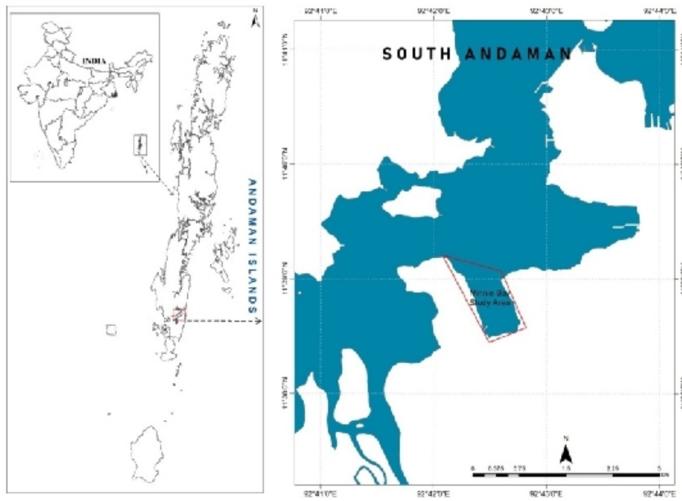

Fig. 1. Map showing the study area at Minnie Bay mark with red line.

The mangrove vegetation cover was studied during tidal phase using quadrate method (Sutherland, 1996; Archaux *et al.,* 2007) to estimate the species composition and density. A quadrate (10×10 m) by tape measure was marked evenly along the entire coast. In each quadrates all species were identified, counted and each individuals was tagged with GPS (Garmin eTrex Vista H, ±3 m). Seedlings were didn't consider for mapping. When a tree split beneath breast height (1.3 m), each branch was recorded as a separate stem (http://www.monumentaltrees.com). The species were identified using standard identification keys (Kathiresan and Bingham, 2001; Rajendran and Baskara 2004).

Data Analysis. We adapted a diverse approach for the study of mangrove forest cover, global positioning system (GPS) incorporated with geographic information system (GIS). Usually for mapping of mangroves high-resolution satellite image is used, to show the mangrove cover of the entire areas. Remote sensing has played an important and effective function in the assessment and monitoring of mangrove forest cover dynamics (Giri *et al.,* 2007). Generally this type of areal estimation does not provide detailed information about the type of species composition and also quality of the mangrove forests. Decline in mangrove forests due to natural disaster or anthropogenic activities are one of the most serious problems of the world's coastal ecosystems. To overcome this problem we should have detailed mangrove maps at the species level for monitoring of mangrove ecosystems and their diversity. To know the proper species composition and distribution of a particular area there is a need to do some extensive field survey from which the ground-truth measurement will be helpful to validate the satellite image derived data.

To create a geo-spatial map of true mangrove species, all mangrove strands coordinates were marked with GPS, later the data was processed in ArcGIS (version-10.4.1). Unique colour code was adopted to represent each species and its distribution. The high tide line was drawn using the Survey of India (UTM-87a10-5-a14-2) toposheets on 1:25,000 scales. Density and abundance were analyzed using Microsoft Excel 2007 package. Apart from this, univariate measures [Shannon-Wiener diversity index (H´), Margalef's species richness (d) and Pielou's evenness (J´), Simpson dominance (D)] were also analysed using Microsoft Excel 2007. Vegetation analysis was restricted to true mangroves only, mangrove associates and specialised groups were not included in this survey because they did not meet the criteria of true mangrove species as specified by Tomlinson (1986).

RESULTS AND DISCUSSION

Remote sensing image analysis is a critical but difficult endeavour; however, digital image classification provides a variety of methodologies for image analysis that may be combined to extract and evaluate numerous spectral, spatial, and textural properties (Khushbu *et al.,* 2021). Based on the assessment of true mangrove study at Minnie Bay coast, a total of 4.81 hectare mangrove cover was recorded, excluding of mudflat area as depicted in Fig. 2 with grid view. Yuvaraj *et al.* (2014) estimated the mangrove cover at Minnie Bay was 7.13 hectare excluding of mudflat area through Remote Sensing and GIS techniques, in which 2.32 hectare is highas compare to our ground truthing data. This result shows field data required to validate the satellite image derived data. The true mangrove diversity at the study site is 15 species, belonging to 13 genera and 11 families. The species occur in each family were, Acanthaceae (1), Arecaceae (1), Avicenniaceae (1), Bignoniaceae (1), Euphorbiaceae (1), Malvaceae (1), Meliaceae (1), Pteridaceae (1), Rhizophoraceae (5), Rubiaceae (1) and Sonneratiaceae (1).The total density of mangrove strand at Minnie Bay was found 0.087 Nos./m^2. *Rhizophora apiculata* (43.02 %) is dominated species followed by *Avicennia marina* (26.31 %), *Rhizophora mucronata* (22.07 %), thus this three species occurrence rate contribution is 91.4 % and rest 12 others mangrove species made up of 8.60 %. The least distributed mangrove species recorded at Minnie Bay during study period are *Acrostichum aureum* (0.02 %) followed by *Scyphiphora hydrophyllacea* (0.07 %), *Rhizophora stylosa* (0.09%). The results of mangrove density and relative abundance are presented in Table 1.Overall distribution of true mangrove species at MB is presented in Fig. 3 with unique colour code in scale range of 1:4494. Univariate diversity indices were applied to study the species abundance in this study sites and the results are presented at Table 2. Margalef's species richness was found (d=15), Shannon Wiener's diversity index was (H´=1.444). Due to stable and enclosed bay environment (J´=0.533) morenumber of species diversity was observed which showed that the individuals in the community are distributed more equitably. From the site out of 15 species recorded, percentage cover of *Rhizophora apiculata*, *Avicennia marina* and *Rhizophora mucronata* was 91.4 %, thus the Simpson's dominance (D) shows (0.304).

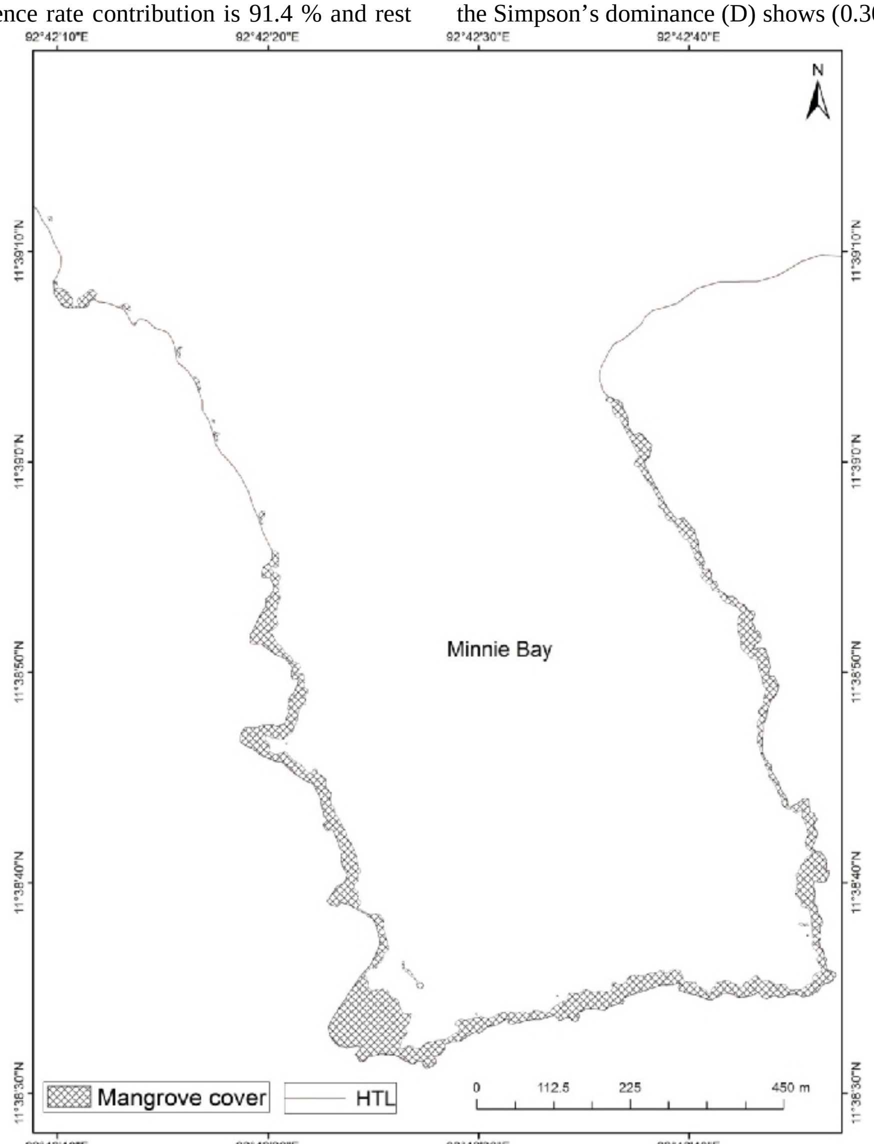

Fig. 2. Representation of total mangrove cover in grid view after survey at Minnie Bay.

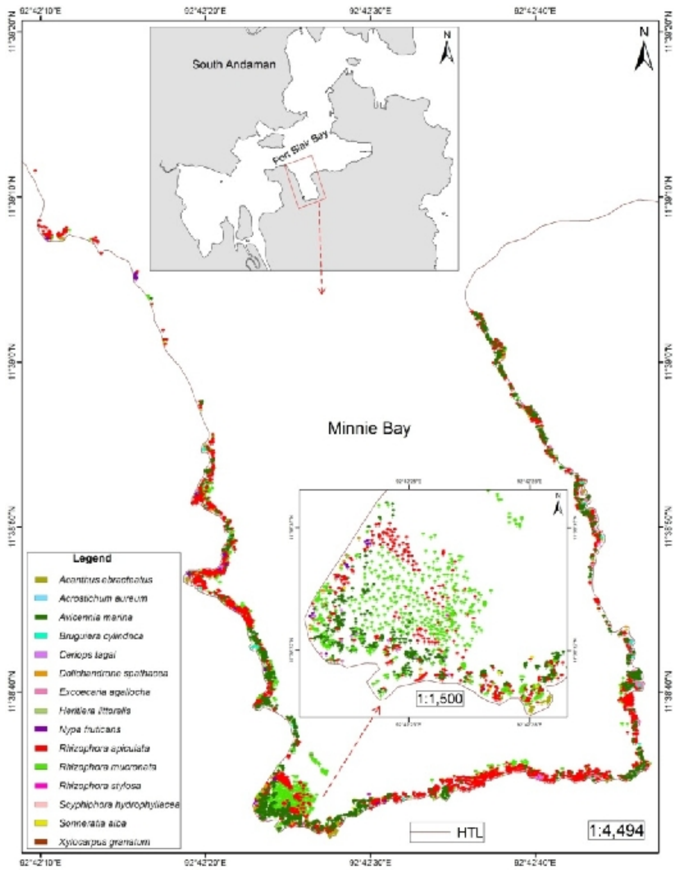

Fig. 3. Thematic map showing the distribution of true mangrove species at Minnie Bay, each species represented with unique colour code.

Table 1: Density and Relative Abundance of true mangrove species at Minnie Bay.

Sr. No.	Species	Family	Den (m^2)	RA (%)
1.	*Acanthus ebracteatus* Vahl	Acanthaceae	0.00098	1.11
2.	*Acrostichum aureum* Linn.	Pteridaceae	0.00002	0.02
3.	*Avicennia marina* (Forssk.) Vierh	Avicenniaceae	0.02305	26.31
4.	*Bruguiera cylindrical* (L.) Blume.	Rhizophoraceae	0.00064	0.73
5.	*Ceriops tagal* (Perr.) C. B. Rob.	Rhizophoraceae	0.00044	0.50
6.	*Dolichandrone spathacea* (L.f.) Seem.	Bignoniaceae	0.00058	0.66
7.	*Excoecaria agallocha* Linn.	Euphorbiaceae	0.00189	2.17
8.	*Heritiera littoralis* Aiton	Malvaceae	0.00035	0.40
9.	*Nypa fruticans* Wurmb	Arecaceae	0.00106	1.21
10.	*Rhizophora apiculata* Blume.	Rhizophoraceae	0.03769	43.02
11.	*Rhizophora mucronata* Lamk.	Rhizophoraceae	0.01933	22.07
12.	*Rhizophora stylosa* Griff.	Rhizophoraceae	0.00008	0.09
13.	*Scyphiphora hydrophyllacea* C. F. Gaertn.	Rubiaceae	0.00006	0.07
14.	*Sonneratia alba* J. Smith.	Sonneratiaceae	0.00056	0.64
15.	*Xylocarpus granatum* J. Koenig	Meliaceae	0.00087	1.00
	Total		**0.08761**	**100**
Density (Den), Relative Abundance (RA)				

Table 2: Diversity indices of mangrove.

Univariate diversity indices	Minnie Bay (MB)
Marglef's species richness (d)	15
Shannon Wiener diversity index (H´)	1.444
Pielou's evenness(J´)	0.533
Simpson's dominance (D)	0.304

To get apparent view of the distribution of each species Fig. 4 illustrate the distribution of three dominant species *Avicennia marina* (a), *Rhizophora apiculata* (b), *Rhizophora mucronata* (c)and followed by other 12 true mangrove species (d). The thematic map clearly shows that population of *Avicennia marina* is partly dominant in east and west coast and sparsely distributed at southern side with density of 0.023 m^2, while *Rhizophora apiculata* is dominant all over the coast with highest density of 0.037 m^2, whereas *Rhizophora mucronata* is partly dominant in west coast and sparsely distributed in east and south coast with density of 0.019 m^2. In tail end of west coast where high tide line went deep inside the land (Fig. 3 in scale range of 1:1500) species distribution is high it might be due to deep enclose area with less tidal action and rich availability of organic matter. Other 12 species of mangrove sparsely distributed all over the coast. During tsunami in 2004, the mangrove stands of Minnie Bay area were inundated by tidal waves of about 3 m height due to this mangrove stands were severely affected, about 40% of *Rhizophora* sp. was affected and most of them died due to continuous inundation (Roy and Krishnan, 2005). Habitat loss may occur in some species with continuous inundation, afterward new habitat will form and it will be conducive for new mangrove propagules (Das *et al.*, 2014). There is little known about the effects of either widespread or localized mangrove area loss on individual mangrove species or populations due to a lack of information about the distribution of individual species (Polidoro *et al.,* 2010). To overcome such problem this type of mapping will definitely serve as a baseline data for the monitoring of mangrove species and its population.

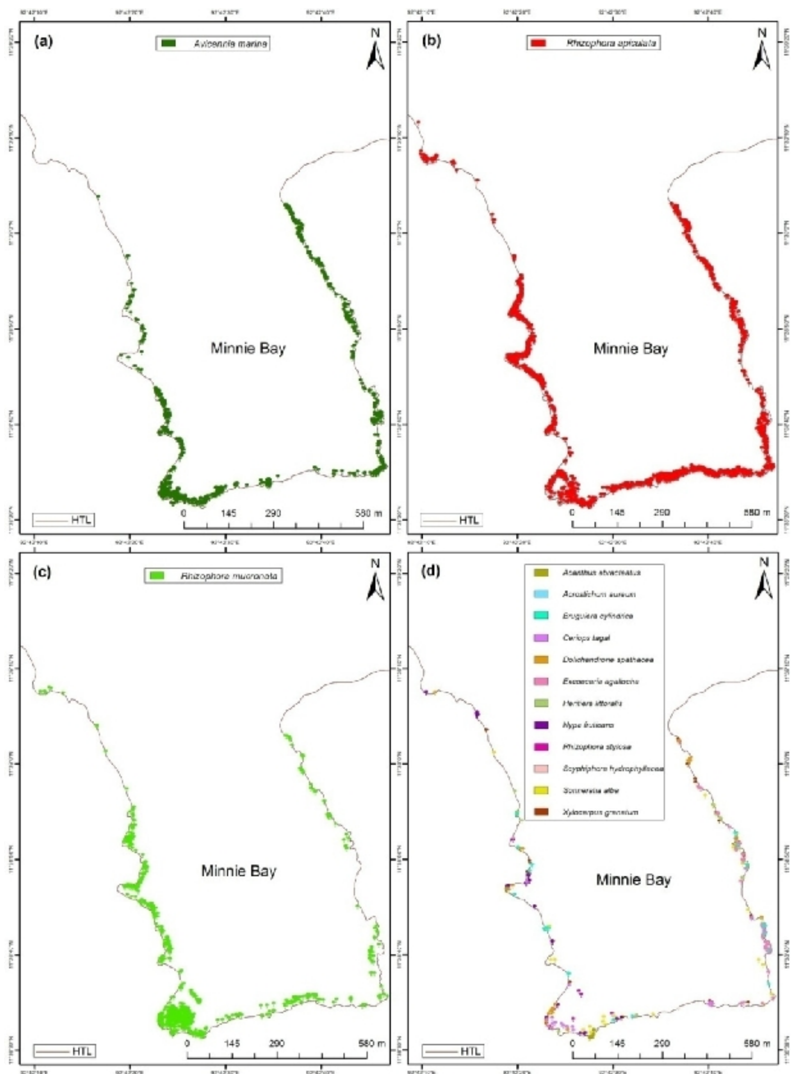

Fig. 4. Thematic map of dominant mangrove species occurrence at Minnie Bay such as *Avicennia marina*, *Rhizophora apiculata*, *Rhizophora mucronata* and followed by other true mangrove species.

From the decades it's observed that mangrove ecosystems are under threat due to various anthropogenic activities and global warming. Relative sea-level rise could be the greatest threat to mangroves (Gilman *et al.*, 2008). The geography of these islands is with undulated hilly terrain, which is surrounded by oceanic water. Mostly human habitation mask is near to the coast only; if we can sustain healthy mangrove forest it can save lives and property from natural disaster such as tsunami and high oceanic waves. The database presents a latest and consistent overview of the extent and distribution of mangrove cover at Minnie Bay with spatial analysis. This is the first documented attempt to map and analyse spatiotemporal changes in the Andaman mangroves using remote sensing. Through this study thematic map was created to provide information on the total area of mangrove coverage and species composition. The information generated from this mapping study will serve as a baseline to get current and reliable data on total mangrove coverage and each species population to develop adaptive management strategies to set conservation priorities, restoration of mangrove species at deforestation or degradation site and for future monitoring and study. Our strategy can be used to research and analyse similar mangrove ecosystems in coastal India and elsewhere, where a lack of auxiliary data may be a constraint. We demonstrated how remote sensing may give robust and critical information on fragile mangrove habitats in a simple manner through the study of the Minnie mangrove zone, especially where there is an apparent lack of forest data and occasional monitoring. This is still required to evaluate ecosystem state, identify stressful conditions, and warn of imminent degradation.

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