CHAPTER 6
USE OF REMOTE SENSING TO PREDICT HABITAT PREFERENCES OF REEF ORGANISMS

6.1 Introduction

As discussed in previous chapters coral reefs are one of the most richly diverse and highly productive ecosystems of the world. Various threats prevailing throughout the world have exerted pressure on their health and existence. It is thus important to study coral reefs and identify different reef regions and their association with other reef biota. This chapter discusses the use of remote sensing to study coral reef geomorphology and tidal fluctuations, in order to identify existing biota.

In modern times, remote sensing has proved to be an important tool for studying repetitive, synaptic views of any area. This technique has been used to analyse reefs since the 1970s (Bina et al., 1978;Nayak et al., 1989; Zainal et al., 1993; Green et al., 2000; Mumby and Green, 2000; Deshmukh et al., 2005; Sharma et al., 2008). Advances in technology and improvements in sensor facilities have made the study of reef ecosystems even easier. With better spatial and spectral resolutions, it is now possible to create an eco-geomorphological map with finer details of reef features (Chauvaud et al., 1998; Mumby and Green, 2000; Deshmukh et al., 2005). Better temporal resolution also helps by increasing the chances of capturing low tide data, which are essential for such an investigation. This current study used remote sensing images from various years to analyse the eco-geomorphology and tidal contours of the Bural Chank reef of the GoK.

6.2 Study Area

Corals prefer clear, warm water with low nutrients and slow to moderate currents (Hyman, 1956; Spalding, 2001). These features can be well studied with optical remote sensing. Research in the past has shown that coral reefs in India can be mapped using previously available satellite data (Bahuguna et al., 2010). Other studies analyzing the use of remote sensing have focused mainly on mapping the geomorphology of the reef (Green 1996, 2000). Mapping of biological components of the reef appears to be difficult using conventional orbital imagery (Bainbridge and Reichelt, 1988). This is because coral colonies are not big enough to be detected by the remote sensing data, and obtaining a pure signal for a particular species is not possible in such a diversified reef system. With a classification system that evolved at the SAC (ISRO), mapping of the geomorphology was made possible (Bahuguna and Nayak, 1998; Nayak and Bahuguna, 2003). Based on this classification system, tidal contours, and previous literature (Hopley, 1982; Holthus and Margos, 1995; Mumby and Harborne, 1999; Green et al., 1996, 2000), classification of Bural Chank reef eco-geomorphologically was designed.

Bural Chank Reef is the biggest platform reef complex of the GoK. It is located between 69° 15'E to 69° 26'E longitude and 22° 33'N to 22° 24'N latitude near the southern margin of the GoK, north east of Poshitra Bay. It is away from the coast and this location decreases anthropogenic pressure (**Figure 6.1**). There are five overlying islands, namely (from east to west) Chank, Noru, Bhaidar, Khara Chusna, and Mitha Chusna. All are rich in

mangrove cover and diversity. Apart from the continuous platform reef and islands, there are small, submerged reefs on the southern side of the platform reef. All of this together makes up the "Bural Chank Reef Complex".

This study focuses on remote sensing data that reflects the radiance emitted by various substrates, and their biological residents. In addition, different tidal levels provide different exposure times at different locations according to tidal fluctuations, and this was also an added feature of the study. Each organism adapts to its surroundings, and hence its habitat contributes to its presence at particular locations.

This is the first study of its kind that combines eco-geomorphology and tidal contours to obtain habitat preferences of various reef organisms. Although the GoK is one of the four major coral reef regions of India, Bural Chank reef has not been the subject of a scientific study of reef biota. It is clearly important to know the habitat preferences of various inhabitants of this reef.

A detailed analysis of this reef will enhance understanding of the conditions of the reefs of the GoK, and emphasise the importance of technology during this process. Previous such studies have provided valuable input on the health of reefs and their biodiversity (Sharma et al., 2008). These results can be useful for reef managers and administrators in implementing coral reef conservation projects, and can act as baseline data for the scientific world to conduct future research.

6.3 Materials and Methods

At the present time, various satellites and sensors are available depending on the type of study desired (Mumby et al., 1998, 2004; Andrefoü et al., 2002). This current study utilized RESOURCESAT (IRS-P6) satellite data from two different sensors – LISS III and LISS IV. All data were corrected geometrically and radiometrically, processed separately, and then combined to make a habitat preference map for the area. The RESOURCESAT (IRS-P6) LISS IV is the best sensor among Indian satellites for mapping coral reefs as it has the highest resolution available. It has a high spatial resolution of 5.8 metres, with 3 spectral bands – Green, Red, and Near Infra Red (NIR). It also has a high temporal resolution of 24 days. This eco-geomorphological classification study used LISS IV data from 2005 because of the very low tide conditions in that year. This meant that all the reef features were clearly visible above the water level, hence leading to an image of the highest quality. The image was then processed for geographical and atmospheric corrections. This was followed by supervised classification, with 50 classes and 10 iterations, and a convergence threshold of 0.950, to get an image with differential classes. The next step involved applying symbology to each class, and 16 classes were identified. It was observed that due to the similarities in pixel values, a few classes were merging with each other. To remove this conflict, contextual editing was performed using previous literature and field visits (Deshmukh et al., 2005). Subsequently, a distinct colour code was given to each class to

distinguish it from others. Accuracy assessment showed overall accuracy at 85.33% and the kappa statistic at 0.8343.

Tidal contours were prepared using multi-date images from the LISS III sensor from the years 1997, 1999, 2001, 2002, 2006 and 2008. As the images from these years were at different tide levels, accurate tidal contours were mapped. All the images were vectorised for the exposed reef area at a scale of 1:5000. All the vectors were merged to create a common platform, and the contours were assigned different symbology to identify each class separately. These tidal contours were superimposed with the eco-geomorphological classified map of Bural Chank reef in order to obtain a final habitat preference map. The scale of the map was 1:75,000. Ground verification was then carried out. The data collected, and correlation with existing literature, was tabulated according to bottom features, water levels, and characteristic organisms.

The diversity of the GoK reefs has been studied by many researchers and field data has been reported in the literature (Nair, 2002; Venkataraman and Wafar, 2005; Vaghela et al., 2010; Dave, 2011). This information was correlated with ground data collected in order to create a habitat preference map of Bural Chank reef.

6.4 Results

This study highlights the importance of the eco-geomorphological classification of Bural Chank reef and its tidal contours, as well as the association between various substratums and their inhabitants.

The reef area was divided into 15 different regions, with each region having its own characteristic features. All the regions were defined according to the spectral signature of the baseline substrate and its inhabitants. Different tidal contours were then overlaid onto this. Each tidal line provides information on the water flow direction during tides, including the time of water inundation. The combination of these two data gives the habitat preference map of Bural Chank reef (**Figure 6.2**). The preferred location of inhabitant organisms, numbered as points on the map, is represented with the possible biota in **Table 6.1**.

Although Bural Chank reef is considered to be in a relatively pristine condition among the GoK reefs, it was found that major live coral colonies were limited to reef front, outer reef flat, moat, pools, and submerged reefs only.

HTM was the first zone present in the center of the island. Water reaches this zone only once or twice a month, depending on the tide conditions. As this is a highly saline area, some salt encrustation was seen at certain places.

Further outward was a zone of mangroves, which contained stabilized mud as the baseline substrate. The mangroves receive their water supply through a network of creeks that pass through subtidal mudflat and reef flat. Although the creeks act as a constant water reservoir, small creeks drain out during low tides.

Outside the islands, there lies Reef flat. However, between the mangroves and reef flat, there were narrow beaches. There were also small sand patches on reef flats, providing harbour to fishing boats.

Reef flat starts adjacent to the island and beach, and can be further divided into the inner and outer reef flat. The inner reef flat starts directly adjacent to the beach. It contained mostly dead coral boulders and rocks, often covered by mud or algae. Due to the tidal direction, some parts of the inner reef flat are exposed for longer duration and others for shorter duration. The biota present varies according to the exposure time. Those organisms with adaptations that resist desiccation survive well in regions with longer exposure time.

Outer reef flat borders inner reef flat and was located towards the seaward side of the reef. It was biologically richer than inner reef flat, and had live coral colonies on it. Similar to inner reef flat, this region can also be divided into two parts according to the level of sun exposure and corresponding water levels. The inhabiting coral species also varies accordingly.

Water pools were present all over the reef flat, and their depth ranged from 0.5 to 2 feet. More coral colonies were found in these pools. A good amount of algal diversity was also seen. Tide pools on the inner reef areas are exposed to higher water temperatures and high salinity, and thus were home to organisms able to withstand such harsh conditions. On the other hand, peripheral tide pools contained organisms less resistant to desiccation.

Near Chank Island, there was a very big tide pool filled with seagrass and sargassum. The depth of this pool varied from 1 to 3 feet. It had a sandy bottom, and hence a large amount of seagrass patches had grown there. Two genera of seagrass were observed – one with needle-like leaves of the genus *Thalassia*, and the other with oval small leaves of genus *Halophila*. Dugongs have also been reported during high tides near this island (Singh, 2003).

At some places on the reef, fleshy algae have taken over the reef area, and such places have been classified as algae over reef. It had mostly dead coral boulders covered with fleshy algae and a thin veneer of mud.

Moats are small water bodies that were created due to the depression formed in between algal ridge and reef flat. The average depth of moat is 1 foot. They were located close to the seaward side of the reef and received fresh sea water supply regularly.

The next region identified was the Algal Ridge. This is a prominent wave-resistant slightly elevated seaward margin of the reef flat, which arises from the reef edge and culminates into the steep sea-facing side of the reef front zone. This ridge is mainly composed of actively growing calcareous algae. The algal pavement of encrusting coralline algae provides a hard resistant surface which bears the main force of the breaking waves and reduces their impact before they sweep into the reef flat behind the rim (Maxwell, 1968). On the South Eastern side and on the north western side of Bural Chank reef, there were big mud flats. These were thick mud areas, with some mud layers being as deep as 5-6 feet. In some locations, there was a layer of thin

micro algae on top of the mud, which indicated stabilization of the mud flat. This was a highly inundated area due to presence of numerous creek networks.

Reef front refers to the outermost part of the seaward slope of a reef, and has the highest coral growth (Hopley, 1982). In the case of Bural Chank reef, it was a highly diverse zone covered under water, and was exposed only 4 to 5 times a year during very low tides.

Finally, there were a few submerged reefs in the southern side of Bural Chank reef, and together, the area was called the Bural Chank reef complex. Although these submerged reefs remain under a water column, they were detected with remote sensing. They are expected to have good coral diversity and are likely to be in a more pristine condition than the main platform reef itself.

Field observations have allowed this diverse ecosystem to be examined more closely, and a variety of biota with their preferred habitat are depicted in **Plate 6.1**.

6.5 Discussion

This was the first study that investigated the accuracy of remote sensing data in predicting the habitat preferences of organisms on Bural Chank reef. It shows that there is a good correlation between the predicted habitat preference map and actual field data. In the process, it has validated the accuracy of remote sensing in the study of coral reef ecosystems. Furthermore, this study demonstrates the importance of reef

geomorphology in understanding its biota. It demonstrates that tidal contours are an important feature of the GoK reef research, and tide amplitude variations effect reef biota significantly.

The large area of Bural Chank reef, and limited exposure during low tides has made things difficult for researchers. Remote sensing was hence used to provide a synoptic view of the complex reef structures, and hence guide analysis of the field data.

LISS IV images were used to classify Bural Chank reef eco-geomorphologically. Various reef substrates were extracted to differentiate the reef into different categories. The difference in tide levels lead to different environmental conditions, causing variations in the inhabiting biota. This study shows that tidal fluctuations and baseline substrates determines the species present. Remote sensing can help in saving valuable time as local area characteristics can be predetermined prior to field visits. This can allow greater focus on the areas of interest during field expedition. Results from this study can be used for future research on Bural Chank reef. Although this study provides details on the geomorphology and habitat preferences of Bural Chank reef, a further study can undertake a quantitative analysis of all the organisms on the reef.

Till date, previous researchers have studied reef geomorphology independently, and various classification systems have evolved (Bahuguna et al., 2003, 2007; Deshmukh et al., 2005). However, no previous studies co-related the biology and tidal fluctuations with the geomorphology of the reef itself. As tidal fluctuations have a major impact on the GoK reefs, tidal

fluctuations must be taken into consideration. They are equally important in the adaptability and existence of the organisms. The remote sensing approach helps in overcoming the problem of low exposure time and turbid water conditions.
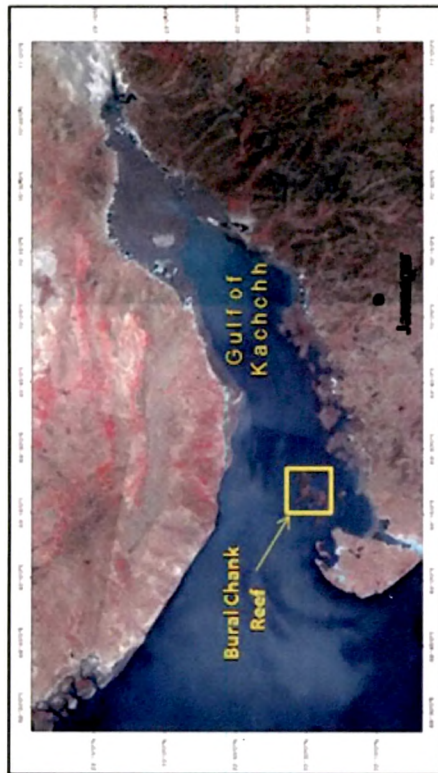
The GoK region has received less attention despite its rich diversity and easy accessibility. Managers and developers may be able to use this research to mark the preferred locations for future conservation and development. In the future, such information can be incorporated into a computerized model, and used to obtain the preferred habitat map for different regions as well. In such a model, the geographical location and regional biological information can be incorporated to take it to the global level.

Although the study has obvious strengths and advantages, there are also some limitations that prevent it from being an access model to study all reefs. First and foremost, it is important to have good quality, low tide, cloud free satellite images. In the reef-containing tropical regions of the world, there can be major problems with obtaining such images. Furthermore, remote sensing technology is more costly compared to traditional field based methods. There are also specialized skills required to understand, analyse, and interpret remote sensing data. Finally, this study is focused at the level of the coral reefs, and not at the level of corals. This means that only an overall and generalized idea of the biota can be predicted, not individual species. Particular species of the organisms would need to be confirmed by personal field surveys.
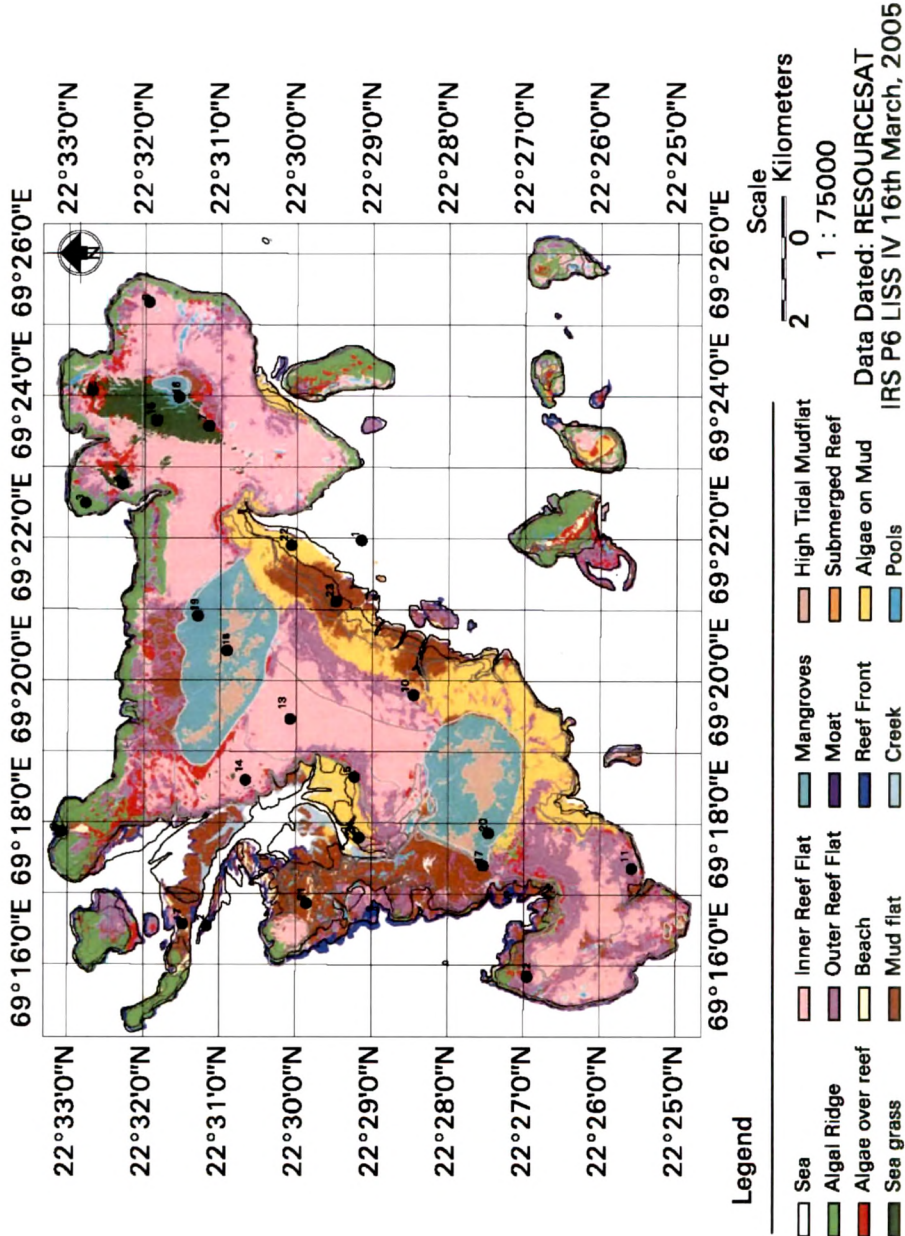
However, despite these limitations, findings from this study can still act as a useful guide for future research into the habitat of these ecosystems. The study also adds on to the existing literature on the reefs of the GoK (Pillai & Patel 1988; Deshmukh 2004; Misra and Kundu, 2005; Dave, 2011). The linkage between corals and other associate organisms is very much interrelated. They all together act as a complex ecosystem, and hence corals cannot be differentiated from their associated habitats and habitants (Dave, 2011).

Figure 6.1 Location of Bural Chank Reef Complex

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Figure 6.2 Tidal contours with Eco-geomorphologically classified map of Bural Chank Reef

Legend

Sea	Inner Reef Flat	Mangroves	High Tidal Mudflat		
Algal Ridge	Outer Reef Flat	Moat	Submerged Reef		
Algae over reef	Beach	Reef Front	Algae on Mud		
Sea grass	Mud flat	Creek	Pools		

Scale

1 : 75000

Data Dated: RESOURCESAT
IRS P6 LISS IV 16th March, 2005

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Table 6.1 Possible Biota at point location on Bural Chank Reef

BOTTOM FEATURE	POINT NO.	OBSERVANT FEATURE	POSSIBLE BIOTA
REEF	1	SUBMERGED REEF	LIVE CORALS, APLYSIA, TURBELLARIA, NUDIBRANCHS, GYMNODONT FISHES, CRABS, ECHINODERMS, OCTOPUS,
	2	REEF FRONT	LIVE CORALS, ASCIDIANS, SPONGES, NUDIBRANCHS, HYDROID COLONIES, SEA URCHINS,
	3	ALGAL RIDGE	BRITTLE STAR, CRUSTACEANS (FAIRY SHRIMPS), NEREIS, PLATYHELMINTH, APLYSIA, STAR FISH, ROCK GOBIES, ULVA & CHLOROPHYCEAE
	4	MOAT	LIVE CORALS, PALYTHOA, ZOANTHUS, SPONGES, OCTOPUS, CORALLINE ALGAE, ALL ALGAE,
	5	ALGAE ADJOINING TO MUDFLAT	GOBIES, MUD SKIPPERS, NEMERTINE WORMS, CERIANTHUS, TUBEWORMS, ALGAE
	6	ALGAE OVER REEF	CHLOROPHYCEAE, CYANOPHYCEAE, RHODOPHYCEAE, ARENICOLA, SEA ANEMONES, CRABS, GASTROPODS,
	7	ALGAE ON REEF NEAR POOLS	PALICEPODS (BIVALVES-FOUND ON SURFACE OF ALGAE),BARNACLES, HYDROID COLONIES, CORALLINE ALGAE,
	8	TIDAL POOL ON REEF	CORALLINE ALGAE, ULVA, PADINA, SARGASSUM, CAULERPA, ENTEROMORPHA, CLADOPHORA, GRACILARIA, GELIDIELA, CODIUM; GASTROPODS, HYDROID COLONIES, PATELLA, CHITON, APLYSIA, LIVE CORALS, ZOANTHUS, CRABS, REEF GOBIES,

	9	PERIPHERAL TIDE POOL	ECHINODERMS, CRABS, FISHES- GYMNODONT, SPONGES, OCTOPUS, SHRIMPS, TUNICATES, LIVE CORALS: GONIOPORA, SYMPHYLLIA, PORITES, MONTIPORA
	10	INNER TIDE POOL	CERITHIDEA MOLLUSK, PATELLA, CHITON, TROCHUS, TURBO, HERMIT CRABS, SPONGES, CORALS- MILLEPORA,
	11	LESS EXPOSED OUTER REEF FLAT	LIVE CORALS: GONIOPORA, HYDNOPHORA, MONTIPORA. SYMPHYLLIA; ZOANTHUS, NUDIBRANCHS, DORIES, APLYSIA, ONCHIDIUM, STAR FISH, BRITTLE STAR, FEATHER STAR, SEA CUCUMBER, PUFFER FISH
	12	MORE EXPOSED OUTER REEF FLAT	CRABS, GASTROPODS, SABELLA, SERPULA (TUBICOLOUS WORMS), LIVE CORALS: PORITES, TURBINERIA, PSEUDOSIDERASTREA, FAVIA, FAVITIES; ZOANTHUS, SEA ANEMONES, OCTOPUS, PUFFER FISH
	13	LESS EXPOSED INNER REEF FLAT	MUD SKIPPERS, TUBE WORMS, CERIANTHUS, MOLLUSK- PINNA, PERNA OYSTERS, BIVALVES- MYTILUS
	14	MORE EXPOSED INNER REEF FLAT	AMPHIOXUS, GOBIES, SHRIMPS, CRABS, SEA URCHIN, PATELLA, ONCHIDIUM, CHITON
SAND	15	SEAGRASS AND SARGASSUM	GASTROPODS, CRUSTACEANS, GYMNODONT FISHES, GOBIES, SEA ANEMONES, TURBELLARIA, SEA GRASS, SARGASSUM, DUGONG, SHRIMPS
	16	ENCLOSED TIDE POOL	GASTROPODS, HERMIT CRABS, ECHINODERMS, CRUSTACEANS,
	17	BEACH /SAND PATCH	CRABS, ISOPOD, AMPHIPOD, MICRO MOLLUSK,
MUD	18	HIGH TIDAL MUD FLAT	CRABS

19	MANGROVES	AVICENIA, RHIZOPORA, BURGERIA, CERIOPS, SONNERATIA, AEGICERAS, LUMNITZERA, ACANTHUS, EXOCARIA, EGRATES, DARTER, HERONS, PAINTED STORKS, MUD SKIPPER, BARNACLES, CERITHIDEA MOLLUSK, MANGROVE CRABS
20	CREEKS IN MANGROVES	HERMIT CRABS, CERITHIDEA MOLLUSK, FISHES,
21	SAND OVER MUD	NEMERTINE WORMS, TUBICOLOUS WORMS, PHORONIDS, CHAETOGNATHA, LINGULA (BRACHIOPODA), DENTALIUM, CERIANTHUS, PINNA
22	MATTY ALGAE OVER MUD	AMPHIPODS, BRITTLE STAR, CERITHIDEA MOLLUSK,
23	SUBTIDAL MUDFLAT	SOLEN, SIPUNCULUS, SEA CUCUMBER, MUD SKIPPER, CRAB,
24	CREEKS IN SUBTIDAL MUDFLAT	GOBIES, CRABS, BIVALVES, MYTILUS,

Plate 6.1: Photographs of the organisms in their preferred habitats; a) Live coral colonies in Reef front, b) Bed of Ulva sp. in Algal Ridge, c) Sea anemone resting on sand with Seagrass and sargassum, d) Live coral colonies in Outer Reef flat, e) Dead coral boulders in Inner reef flat, f) Various algal species with live corals, Molluscans, crabs in shallow tidal pools, g) Intertidal mudflat, h) Turbo mollusk on sand patch near Chank island and i) Mangroves found on island of Bural