CHAPTER 2: THE STUDY AREA

Gujarat state is located on the west coast of India and lies between 20° 02' and 24° 41' North latitudes, and 68° 08' and 74° 23' East longitudes covering a land area of 196, 024 sq km. It has a coastline measuring approximately 1650 km, which is the longest among all the coastal states of the country. The long coastline together with over two lakh sq km of Exclusive Economic Zone (EEZ) and about 1.6 lakh sq. km of the continental shelf provides an important resource for the overall development of the state. The most prominent feature of the coastline are the two Gulfs (of a total of three for the country), the Gulf of Khambhat and Gulf of Kachchh (earlier spelt as Kutch) which together cover around two-thirds of the coastline of the state and which teem with marine life, coastal wetlands, natural land forests, geologic, physiographic and climatic diversities.

2.1 GEOGRAPHICAL LOCATION

The Gulf of Kachchh, an inlet of the Arabian Sea in India is located between 22° 15' to 23° 40' North latitude and 68° 20' to 70° 40' East longitude (Figure-2.1). It has a length of over 170 km (NNE-SSW) and a width of about 75 km (NNW-SSE) at the mouth covering an area of approximately 7350 sq. km with a mean depth of 30 m. The coastline and the intricate network of 42 islands situated in the Gulf have an assemblage of different ecologically sensitive ecosystems supporting over 800 species of different organisms (Shah, 1997). Plate 2.1 gives a satellite view of the Gulf of Kachchh and the location map is given in Fig. 2.1.

The Kachchh and peninsular regions of Saurashtra surrounding the Gulf of Kachchh fall under the administrative boundries of Rajkot, Jamnagar and Kachchh Districts. The Jamnagar district is situated on the Southern boundary of the Gulf of Kachchh. Jamnagar city, the district headquarter is situated in the eastern part of the district, close to the coast. It lies on the Broad-gauge railway line of Ahmedabad-Rajkot-Okha section of the Western Railway. A new national highway passes through the area to Dwarka. State highways measuring about 580 km in length connect major towns and talukas in the district. All weather

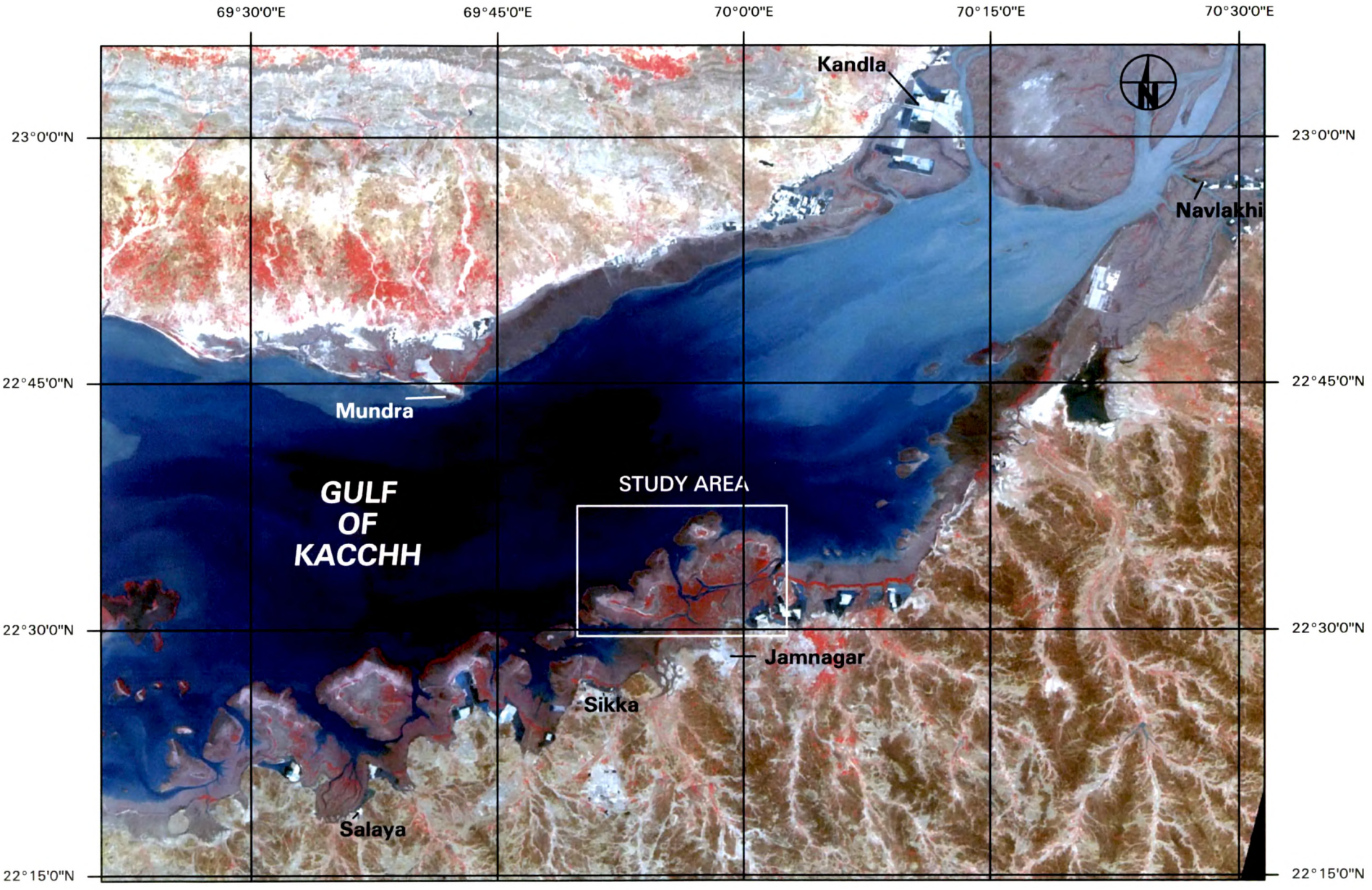

Plate 2.1 IRS 1D LISS III image of the study area and its environs

motorable roads of coastal villages connect the various ports with the state highway running parallel to the coast of Jamnagar Jamnagar is also connected with other parts of the country through airways.

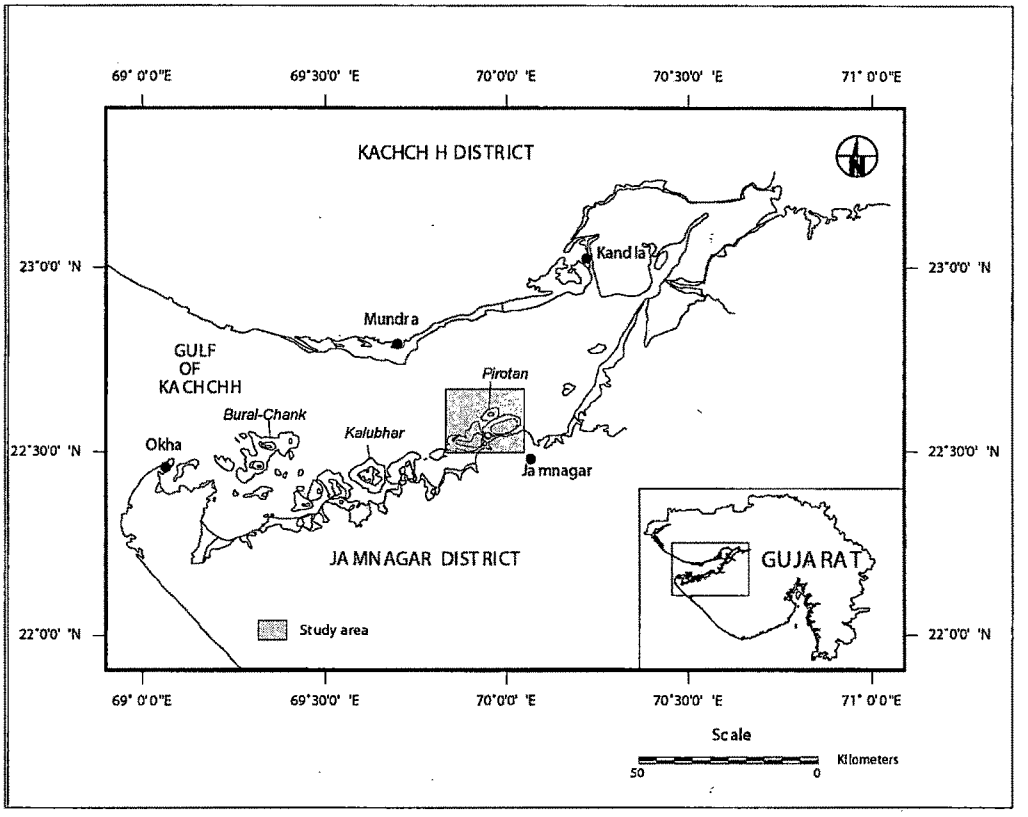

Fig 2.1. Map Showing the Location of the Study area

The present study area comprises of the long east-west coastal strip on the Southern part of Gulf of Kachchh which lies between 69° 49' 49" E and 70° 02' 32" E longitudes and 22° 38' 10" and 22° 29' 18" latitudes. The major part of the study area consists mainly of the intertidal zone and of the intricate network of creeks, coral reefs and mangroves forests. The study area includes the Islands of Pirotan, Jindra-Chhad, Dide Ka Bet, Munde ka Bet, Bhains bid and the fringing mainland mangrove areas south of Hadde Creek. The study area falls within the Jamnagar taluka of Jamnagar district of Gujarat. The area falls under the jurisdiction of the Jamnagar Range of the Marine Protected Area. In the entire Gulf of Kachchh the mangroves of Pirotan, Jindra-Chhad, Dideka-Mundeka bet

and of Hadde Creek are the richest in diversity and density and are therefore chosen for the present study, which primarily aims at zoning mangrove communities. Plate 2.2 gives the location of the important landmarks of the study area. The area is intersected by a large number of small and large creeks. The creek network in the study area has been depicted in Plate 2.3.

The Pirotan Island is the northern most part of the study area, having a lighthouse and a dargah (a high density pilgrimage place). The Island has a very large reef area and has good live coral reef patches on the North and Northeastern parts. It also has a highly diverse reef flora and fauna. The island is surrounded by sand beach on all the sides except for the Southeastern part, which has mudflats and a luxuriant patch of mangroves. The mangroves of this island had borne the brunt of the 1998 cyclone. The endemic grass *Urochondra setulosa* is found growing on a small patch on the northern part of the island.

The Jindra-Chhad Island is to the North-West of Nava Bandar, North of the Hadde Creek. The Island is oriented East-West with the Mogri Chheja Creek dividing the island into Jindra on the East and Chhad on the West. Two other long creeks, the Raman and the Raman Chheja Nar run across the Island of Jindra. They share their large coral reef area along with the islands of Pirotan and Bhains Bid. Jindra has a large mangrove area to the South East, the Kanakiya Jungle which perhaps has the largest patch of *Ceriops tagal* in the Marnie National Park. A large mangrove plantation located to the North of the Island is one of the sites where plantation by the forest department has been most successful. Both the islands have a vast expanse of high tidal mudflats in their centres. Mangrove vegetation is found all along the periphery of both the islands except for small patches in the East of Jindra and in the West of Chhad.

Dideka-Mundeka bet is a large island North-East of Sikka. A large creek, the Chankhdi Mata ni nar divides the island into roughly two parts the Dide ka bet and the Munde Ka bet. Munde ka Bet is also locally known as Chankhdi. Good natural mangrove patches are present only on Dide ka bet on the North and South of the Island. Large salt marsh patches are located towards the back of the mangrove area. The Westernmost region of Munde ka bet is also a major

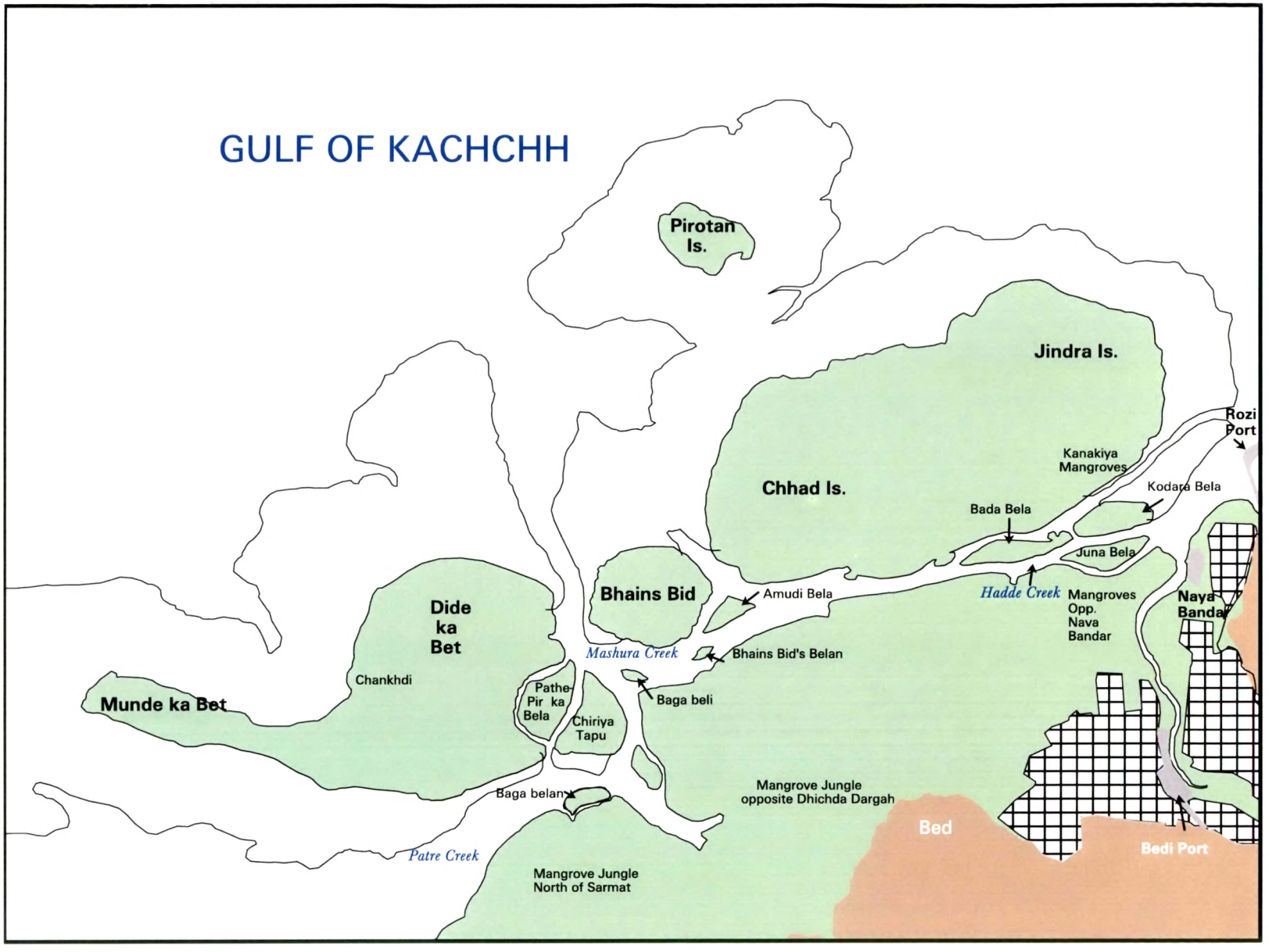

Plate 2.2 Map of study area showing location of major islands

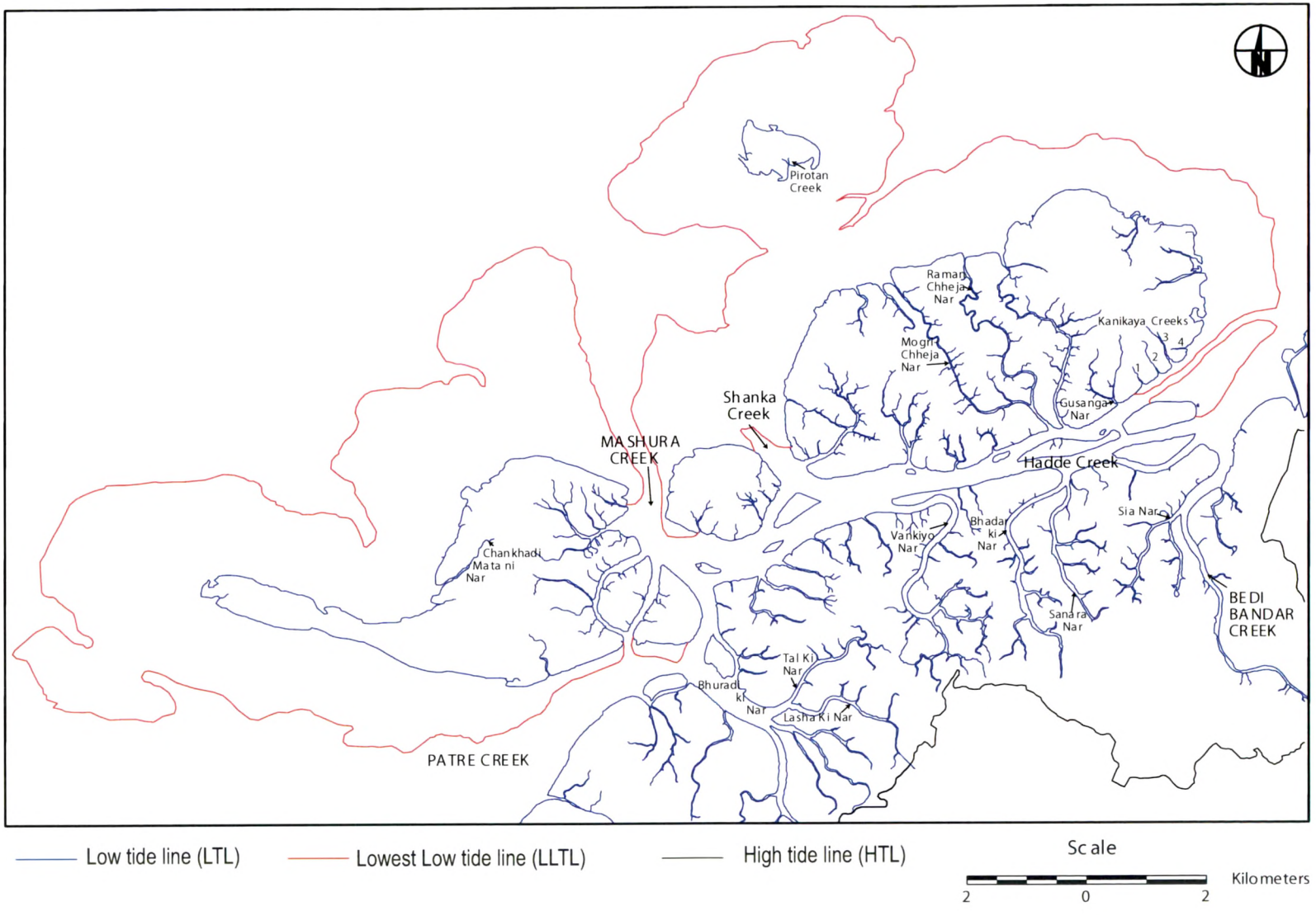

Plate 2.3 Creek network in the study area **(Source: IRS 1D PAN data of 1999)**

plantation site of the forest department, having significant areas occupied by sand with a diverse sand flora. During extreme low tides, this island is connected to the mainland. Towards its Eastern side there are two small islands the Chiriya bela and Pathe pir ka bela. These two islands have among the most diverse mangroves in the Gulf of Kachchh. All the six mangrove species recorded in the present study were present on both the islands in significant numbers.

Bhains bid, situated between the Chadd and Dide ka bet Islands is mostly a mangrove dominated island. It is intersected by a large number of creeks and has a large high tidal mudflat at its centre. Also known as the Ragwari Bela by the local fishermen it is along with the Chiriya and Pathe pir ka bela among the least disturbed mangrove habitats of the region.

The region to the South of the Hadde creek including the mangrove areas adjoining the villages of Rozi, Bedi, Bed and Sarmat have also been included in the study area. Five large creeks dissect this area into several large mangrove areas. One of the creeks, the Bedi Bandar Creek provides the way of transit to the Gulf from the Bedi Port. Other important creeks in the area are the Sia Nar, Sanara Nar, Vankiyo Nar and the Bhadar ki Nar. The area to the West and North of Bedi port is used for the manufacture of salt with one of the larger salt-manufacturing units on the Jamnagar coast being located here. This unit, which shares a boundary with the mangrove forest to its North, employs a large number of people that frequent the mangrove forests to the north and to the west for several of their basic requirements.

2.2 GEOLOGY

Gujarat provides a wide spectrum of rock types of different ages ranging from the oldest Precambrian (Aravalli in the north) to the Recent (unconsolidated alluvial and beach material in its central and western parts). However, the Saurashtra region consists of Mesozoic to Cenozoic rocks. Geologically, the study area comprises of a terrain made up of Deccan Trap lava flows and the overlying Tertiary and Quaternary sediments. The stratigraphy in the region has been

reported to be incomplete due to the absence of Oligocene and Eocene rocks and the sequence begins with Cretaceous to be followed upwards by Deccan volcanics. The Cretaceous rocks are mainly sedimentary (sandstone, clay, limestone, grit, sandy and silty clays, conglomerate and miliolites, shales, coastal deposits, *etc.*) and Deccan trap basalts. Coastal geology is considered to have been greatly influenced by the regressive-transgressive phases of the sea.

The developments of structural features of the Western Indian continental margin are related to the history of the Indian subcontinent. The spreading of Indian ocean floor and the consequent northward drift of the Greater India with counter clockwise rotation after its separation from Gondwanaland during Cretaceous-early Tertiary times (Smith and Hallam, 1970; Dietz and Holden, 1970; Biswas, 1982) gave rise to various rift basins namely Kachchh, Cambay and Narmada during late Triassic-early Jurassic, early Cretaceous and late Cretaceous times respectively (Biswas, 1982). It is believed that the Kathiawar penensula along with the Gulf of Kachchh and the Gulf of Khambhat stood 150 feet lower than at present and was probably in the Pleistocene time an island or group of Islands (Fairbridge, 1968).

2.3 GEOMORPHOLOGY

The Gujarat coast measuring about 1650 km forms an important portion of the West Coast of India. It comprises of three distinct coastal zones viz. Kachchh, Saurashtra and Mainland Gujarat. The coast of Gujarat is geologically and geomorphologically distinct from the rest of the West Coast of India. Its various segments provide an insight into the role played by the coastal processes prevailing during the Quaternary period. The northern coast of Saurashtra (Navlakhi-Dwarka segment) trending E-W, overlooks the Gulf of Kachchh. The shoreline is rocky and its configuration is highly crenulated and characterised by extensive mudflats, offshore islands and rocky platforms with narrow beaches. Its subtidal zone comprises a wide variety of landforms like channels, shoals, submerged island, sand bars, coral reefs, mangroves, etc. It has prominent drainage between Jodia and Salaya. There are several sluggish streams with subsiding mouths. The substrate is uneven and formed of coralline rocky

subcrops of hard trappean basalts and soft Tertiary sedimentries. The littoral zone has a low gradient and covered with a veneer of calcareous mud. The zone has a variable width, about 5 to 10 km between Navlakhi and Salaya but less than a kilometer between Salaya to Dwarka (Merh, 1995 and Patel, 1997). The northern coast of Saurashtra block is considered as a submergent coast against the background of the nature of the emergent coast of Southern Kachchh (Thorat, 1980).

2.4 CLIMATE

The Tropic of Cancer passes through the Gujarat. The state, thus, falls in the sub-tropical climatic zone and has a major part of it lying between the 35° C and 45° C isotherms. Climatic variations within the limits of Gujarat state are most striking. As we move from North to South the rainfall shows a progressive increase, changing over from arid to humid within a distance of a few hundred kilometres only. Gujarat can be divided into five climatic zones of which the study area falls in arid low rainfall zone (Patel, 1997).

2.4.1 Rainfall

The study area receives rainfall mostly from the southwest monsoon (with an average rainfall of about 400 mm) during the period between June to September with maximum intensity in the month of July and August. Quite often insufficient rainfall has lead to famine conditions. In Jamnagar district, rainfall during last 33 years has fluctuated between 35 and 1370 mm per year. The average annual rainfall in the district varies from about 340 mm at Dwarka in the West to about 665 mm at Dhrol in the east. Fig 2.2. shows the isohyte map of Gujarat

2.4.2 Temperature

Temperature variations are equally prominent along the Gujarat coastlines. The range of temperature variation is more in northern Gujarat as compared to southern parts of the state. The various seasons of the year are: *monsoon* - from middle of June to September, *winter* - from middle of November to the end of

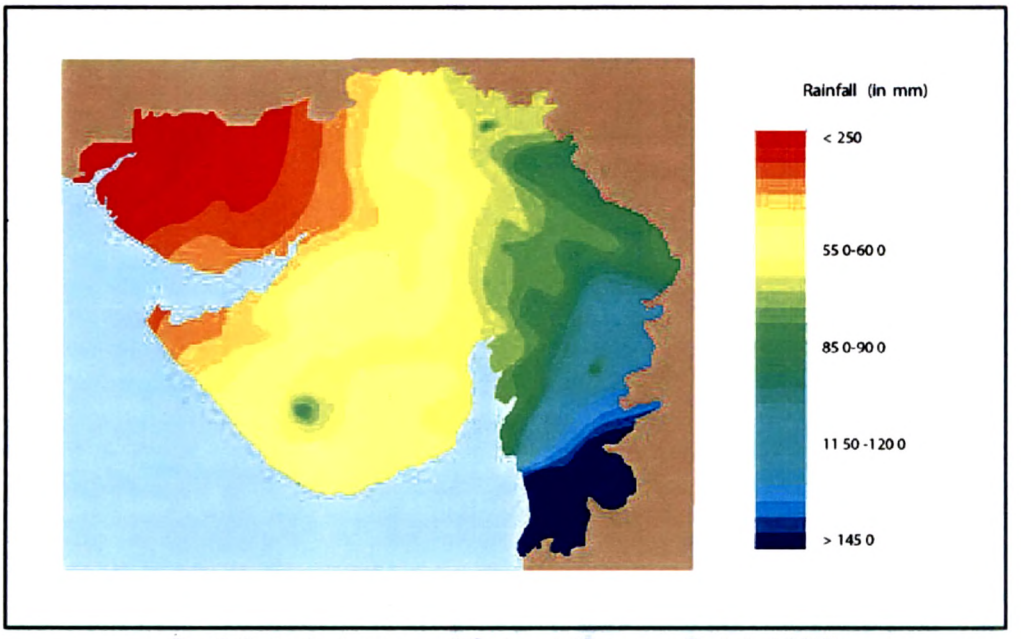

Fig 2.2. Isohyte map of Gujarat (Source: Patel, 1997)

February and *summer* - from March to middle of June. In winter months, temperature drops down to around 11-12° C, sometimes reaching as low as 6° C. It starts rising in the month of March till it reaches the maximum, which is as high as 45° C, in some parts of the State. The Maximum temperature in Jamnagar district during May-June remains around 35° - 36° C, which at times goes as high as 44° C. October and November is the post monsoon transition period from rainy to cold season when the days are hot and oppressive with cool night breezes after mid night. May and January are the hottest and coldest months of the year, respectively.

2.4.3 Wind

In general, the winds are weak over Gujarat but coastal areas experience stronger winds during the monsoon period. Monsoonal winds are mostly southwesterly but during winter season the winds are northerly or northeasterly. In summer, wind blows mainly from West and South-west. Intensity of the wind effects along the coast varies in different coastal segments depending upon the trends of the coastline. The effects of winds are much less in the Gulfs of

Kachchh and Khambhat in comparison to the open coasts of Saurashtra and southern mainland.

2.5 TIDES

Tides of the Gujarat coast are of mixed semi-diurnal type. The coast experiences very high tides. Because of its nearness to the Tropic of Cancer, unique funnel shape of the Gulfs and resonance effects, the heights of tides is believed to increase tremendously from mouth upstream. Tidal range at the mouth of the Gulf of Kachchh is about 4 m, which amplifies to about 7 m in the creeks (Shogal, 1985). Tidal expanse in the Jamnagar-Okha segment varies from one km to more than five km. The low tides leave vast coastal area completely exposed, which get submerged during high tides.

2.6 CURRENTS

Longshore currents with low wave energy have been reported to dominate the open coasts along the Arabian Sea. However, tidal currents dominate the flow in the Gulf. Maximum velocities occur during mid-tide, which has been measured around 4 knots in the Gulf. Spring currents are 60 to 65% stronger than neap currents. Bottom currents are strongly periodic and flow parallel to the bottom contour. Currents in the Gulf of Kachchh, though tidal, are monsoonal in origin. The flow adjusts its directional orientation with the changing direction of wind affected by changing seasons of the year. In the Gulf, tidal currents are fairly strong and bimodal in nature having two dominant directions: upstream during flood and downstream during ebb.

2.7 DRAINAGE

Drainage pattern of an area is a reflection of geological, geomorphic and climatic processes acting on that area. The drainage development in this area is on account of the headward erosion of channels (Thorat, 1978). Though the area is cut by a dyke almost parallel to coast, it does not seem to have any effect on the stream courses of any of the river or its tributary. The drainage map of Gujarat is

given in fig 2.3. Around 50 very small to medium rivers drain into the Gulf both from the Kachchh and Saurashtra regions. The streams, which discharge into the gulf, especially those at the head, are short and estuarine. The streams (accounting more than 20 in numbers) of Saurashtra flowing in to the Gulf of Kachchh are restricted to the Northern part of Saurashtra. Most of the rivers originate in the central part of the Saurashtra on a ridge parallel to Latitude 22° 5' N. The altitude of this ridge reduces from 232 m in the east to 30 m in the west. The length and order of mainstream channels also reduces from 53 km to 14 km and the order from 6th to 3rd respectively from east to west (Thorat, 1978).

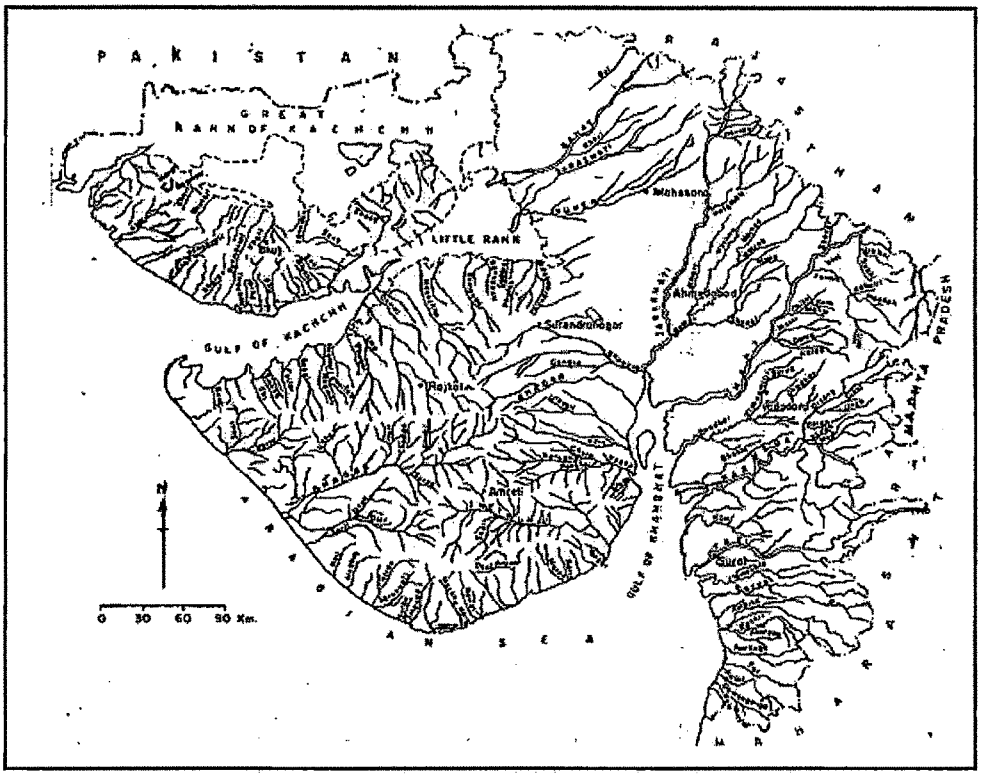

Fig 2.3. Drainage Map of Gujarat (Source: Patel, 1997)

The rivers are comparatively small and more or less seasonal but form potential drainage basins. These include Ghee, Sihan, Fuljar, Sasoi, Rangmati, Nagma, Ruparel, Kankavati, Und, Aji, Demai, Machhu, Godadhro, Bambhan, Phulka and Chandrabhanga. Among these rivers Machhu and Aji rivers are relatively larger. River Machhu originates in the highlands near Anandpur, flows for about 110 km through the town of Morvi and meets the Little Rann. River Aji is similar to

Machhu but smaller in length. It originates near Sardhar, flows across Rajkot and empties in the Gulf. All the rivers except, Gomti and Khari, flow towards north-northwest (NNW) almost perpendicular to the coast. The drainage pattern is dendritic and is uniform all over the area. He also noted that the gradient is low and rivers are flowing almost on horizontal plane. A few rivers, mainly because of man-made reservoirs, have wet channels in downstream direction from the reservoirs. The annual potential evapotranspiration have been reported to range between 1500 and 1650 mm, three times the precipitation, resulting in no flow in the ephemeral channels for much of the year. The sediments contributed by these rivers are considered insignificant because the area is arid. Due to the arid nature of the region almost all the rivers large and small have reservoirs built on them. They range from medium sized dams to small check dams.

2.7 COASTAL POPULATION AND SOCIO-ECONOMIC PROFILE

The total population of the Jamnagar district according to 2001 census is 19.63 lacs and more than half of them are urban inhabitants. Density of the population varies from around 100 to around 2000 per sq km in rural and urban areas respectively.

As far as infrastructure facilities such as education, health, drinking water, communication, transportation and power are concerned the region has seen poor or moderate development. Though primary school facilities cover around 85% of the villages, secondary education is limited to only 10%. Health facilities are modest. Compared to the two other coastal districts of the Gulf of Kachchh, Jamnagar faces the greatest problem in terms of drinking water.

The coastal region of the Jamnagar district adjoins an ecologically sensitive marine area. The district only has 2% forest cover, which is much lower than the minimum limit of 11% recommended in the National Forest Policy (Desai, 1997). Around 16% of the cultivable coastal land of the district is irrigated, 90% of which is irrigated through groundwater, which has not only affected the groundwater balance in the region but has also caused salinity problems.

2.8 PORTS IN GUJARAT

The strategic position of Gujarat on the West Coast of India and its proximity to the Middle East countries helps it to service the vast North and Central Indian region. The state in addition to the Major Port at Kandla-Vadinar presently has 40 minor and intermediate ports geographically dispersed across South Gujarat (13), Saurashtra (23) and Kachchh (4) regions. These minor and intermediate ports of Gujarat handle about 70 % of the total cargo handled by the minor ports of India (Anon, 1999).

The Gulf of Kachchh which has favourable hydrographic conditions for the development of ports has in addition to the major port Kandla, 11 minor ports along its vast coastline. These ports are administered, managed and controlled by an autonomous body, the Gujarat Maritime Board (GMB). The location of the major ports in the Gulf of Kachchh are shown in Fig. 2.1.

2.9 DIVERSITY IN THE GULF OF KACHCHH

The Gulf of Kachchh is considered to be one of the richest biological habitats in Gujarat. Lying between Kachchh and Saurashtra peninsulas, it is characterised by the presence of a vast diversity of habitats in the form of extensive mudflats, occasional narrow sandy/shelly beaches, rocky/muddy coastlines, offshore islands, marsh vegetation, lush green patches of mangroves, seagrasses and numerous coral reefs. Mangroves and coral reefs of the Gulf are considered as the richest biotic habitats along the west coast of India.

Blatter (1907 and 1908) was among the first to work on the vegetation of the Gulf of Kachchh. Hornell (1916) was the first to report on the marine Biology of the Gulf of Kachchh in General and the Okhamandal coast in particular. Santapau (1950 & 1962) in his work on the flora of Saurashtra mostly concentrated on the flora of the terrestrial region including the plants found on the coast, He gave little information on the mangrove vegetation of the region. After Blatter, the mangroves of the region were studied only after a gap of about half a century studied by Kulkarni in the 1950s. T Anand Rao in his classical work on the coastal vegetation of the Saurashtra coast has not included the Islands of the Gulf of Kachchh except the Island of Byet Shankhodar in his study. The1970s

saw substantial work on the mangroves of the region by several workers viz. Blasco, Parulekar and Untawlale.

The marine floral components of the Gulf are most varied and cover sand dune vegetation, mangroves, sea grasses and marine algae. The dominant mangrove species in the area are *Avicennia marina* and *Avicennia alba*. Other mangrove species reported from the area are *Avicennia officinalis*, *Rhizophora mucronata*, *Ceriops tagal*, *Aegiceras corniculatum*, *Bruguiera gymnorrhiza* and *Sonneratia apetala*. The dominant species of the sand dune flora are *Euphorbia caudicifolia*, *E. nerrifolia*, *Aloe vera*, *Ephedra foliata*, *Urochondra setulosa*, *Sporobolan madraspeteneus*, *Indigofera sp.* The common seagrasses found growing on the mudflats are *Halophila ovalis*, *H. beccari* and *Zosterea marina* (Parulekar, 1988). The most common algal species of the Gulf of Kachchh are *Ulva fasciata*, *U. reticulata*, *Enteromorpha intestinalis*, *Hypnea musciformis*, *Sargassum tennerimum*, *S. ilicifolium*, *Gracilaria corticata*, *Padina tetrastomatica*, *Cystocera* sp. and *Codium* sp.

2.10 THE MARINE NATIONAL PARK AND SANCTUARY

The conservation significance of the biologically rich regions of the southern Gulf of Kachchh led the State Government to declare it as a Marine Sanctuary in 1980. This was subsequently expanded in 1982 to cover a total area of 457.92 sq. km. Intertidal regions of Dwarka, Kalyanpur, Khambaliya, Lalpur, Jamnagar and Jodiya Talukas along with 42 Islands in Jamnagar District have been included in the marine protected area (Singh, 2002). With a view to provide additional protection 162.89 sq. km of area which included 33 islands and some coastal areas were notified as a Marine National Park, which is the first Marine National Park of the country. The additional area of 259.03 sq. km which includes the area of 5 islands and intertidal zone of the mainland falls under the Marine Sanctuary (Singh, 1994). Out of the 42 islands in the Gulf, 20 have mangroves while 33 support coral reefs.