CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The coastal environment is very dynamic with many cyclic and random processes owing to a variety of resources and habitats. Further the coastal ecosystems are the most productive ecosystems on earth. About 60 percent of world population lives near the coast and in one way or other depends directly or indirectly on the coastal zone and its resources. Thus the coastal zone plays a vital role on the nation's economy. As a result of increasing human population and the trend for a greater proportion of people to live close to the sea, the economic activities on coastal environment are also increasing. Hence there is an urgent need to protect the coastal environment and ensure its sustainable production and development.

1.2 DESCRIPTION OF INDIAN COASTS

The coastline along the peninsular Indian mainland stretches about 6000 km and it also comprises the islands of Andaman, Nicobar, Lakshadweep and Maldives, which extend to about 1500 km. The state wise length of the coastline is shown in the Table 1.1.

The mainland coast consists nearly 2500 km length of sandy coasts in Orissa, Andhra Pradesh, Tamilnadu, Kerala, Karnataka and part of Goa coast, 670 km long rocky coasts with cliffs in Maharastra part of Gujarat, northern part of Rann of Kachchh, Kanyakumari and Visakhapatinam; 2100 km long

mud flats in Gujarat and parts of Andhra Pradesh, West Bengal, Tamilnadu and Maharastra; and 600 km long marsh coast in parts of Gujarat and West Bengal. While the deltas are confined to the east coast, estuaries largely occur along the west coast. In addition to sand spits, inlets, river mouths and estuaries, beaches are found to be more common and extensive along the east coast. Steeper cliffs beaches, headlands and pocket beaches are widely noticed on the west coast.

Table 1.1 Description of the Coastline in India

States	Sandy Coast (km)	Rocky Coast (km)	Muddy Coast (km)	Marsh Coast (km)	Approximate Total Length (km)
Gujarat	440	319	444	352	1555
Maharashtra	95	201	250	-	546
Goa	66	31	54	-	151
Karnataka	224	33	41	-	298
Kerala	459	23	88	-	570
Tamilnadu	574	31	394	-	999
Andhra Pradesh	354	32	512	74	974
Orissa	292	-	171	53	516
West Bengal	-	-	125	121	246
Total	2504	670	2074	600	5853

Source: Basanta Kumar Jena 1997

1.3 COASTAL AND OFF-SHORE MORPHOLOGY OF INDIA

The coast of Gujarat is characterised by a wide continental shelf and a few major rivers. Beaches in the neighborhood of Daman are found to be a combination of shells, corals, pebbles and sands cemented together. Between

Daman and Hazira, rocky shores with sandy pocket beaches and marine tracks are noticed. Gulf of Khambhat is a formation of large gulf with high tidal variation. Numerous sand, shoals and spits are seen in this region. Long and wide beaches with number of offshore bars are prominent between Veraval and Dwaraka (Ahmad 1972). Gulf of Kachchh is a low-level plain with deep inlets, offshore islands and several estuarine mouths. The large tidal variation induces the tidal flats to drain 1 to 2 km widths during low tide. The southern shore of the Gulf of Kachchh has numerous islands and inlets surrounded with mangroves and coral reefs. The northern shore is predominantly sandy or muddy with numerous shoals (Vora *et al* 1987). Streams drain into Rann of Kachchh and become broad pools of water due to ill-defined channels. It is flooded during the southwest monsoon, and becomes dry, and barren mud flat during the rest of the year.

The coastal region of Maharashtra is hilly, narrow, highly dissected with transverse ridges of the Western Ghats, and at many places extending as promontories in to Arabian Sea (Ahmad 1972). The shoreline is very irregular, associated with features like mangroves, raised coral, cliffs, notches, promonotories, sea caves, and wave cut platforms, embayment, submerged shoals and offshore islands. Numerous west flowing rivers form estuaries, bays, mud flats, creeks and tidal marshes. The continental shelf of this area is a narrow.

The coastal zone of Goa is estimated to have an area of 30 sq.km and a length of 151 km. The coastline is varied with a large estuarine area, with raised limestone and mangrove islets and extensive intertidal mudflats and sandy beaches. Panoramic views of these beaches attract thousands of foreign and domestic tourists, who largely use this area for water sports and surfing. There are mainly 17 beaches in Goa having significant importance for tourism (Chandramohan *et al* 1997).

The coast of Karnataka has a narrow continental shelf with strong upwelling and mud banks. Fast flowing rivers descending from the western Ghats to the Arabian Sea slow down as they reach the coast and spread out in to wide estuaries and lagoons with extensive mudflats and many small patches of mangrove forest. Much of the intervening coastline is sandy beach backed by coastal dunes with short stretches of rocky shore.

The coast from Kerala south to Kanyakumari is known as the Malabar Coast and consists largely of sandy beaches. The coastal zone of Kerala is backed by the Nilgiri and Anamalai Hills (Nair 1987). The rivers rising in the Western Ghats abundantly water the coastal plain. The coast is exposed to heavy surf in many areas and is largely eroded with long continuous rocky and sandy shores broken by small creeks with remnant mangrove scrub and an intensively exploited and polluted internal lagoon system protected by seaward sand bars (IUCN 1993).

The southern coast of Tamilnadu has a very narrow continental shelf, a rocky shore and strong wave action. There are mangroves, sandy beaches, mudflats, coral reefs and seagrass beds. The Gulf of Mannar and Palk Strait are fairly sheltered waters owing to the presence of Mandapam Peninsula, Rameswaram Island, and the Talaimannar Islands. The coastline between Tuticorin and Rameswaram in Gulf of Mannar, and between Rameswaram and Vedaraniyam in Palk Bay are partially protected from monsoon waves due to the proximity of Sri Lankan Island. Palk Bay is a shallow bay and is largely occupied by sandy banks and shoals (Agarwal 1988). Abundant growth of corals, Oysters, Sponges and other sea bottom communities flourish in the relatively calm waters of Gulf of Mannar. Beach formation disappears in the vicinity of Kanyakumari, and is replaced by rocky shore. The great Vedaranayam salt swamp is situated further north on the east coast and it extends up to Point Calimere. The eastern shore is flat and sandy, and the sea is

very shallow. The swamp itself comprises a vast area of open mudflats and lagoons behind a long sand bar breached at various areas by tidal channels. North Tamilnadu coast comprises of long sandy beaches, as one of the most magnificent in the world.

Long sandy beaches backed by rows of high sand dunes mark Andhra Pradesh coast. It has been frequently attacked by devastating cyclones and inundated by storm surges. The unique feature of this coast is the formation of 15 km long sand spit off Kakinada owing to heavy sediment load brought by Godavari River (Ahmad 1972 and Chandramohan *et al* 1988). Various estuaries interconnected with the lengthy Buckingham canal have created ideal regions for shrimp culture at south.

Long sandy beaches with high and wide backshore mark Orissa. Except a short stretch north of Paradeep Port, the rest of the Orissa coast is an accretion trend. Chilka Lake, the largest lagoon in Asia, is the unique formation in this region. The large volume of littoral sediment transport causes the inlet mouth to continuously migrate in the northerly direction (Chandramohan and Nayak 1994). Wide sand beaches with elevated rows of sand dunes are seen between Gopalpur and Mahanadi mouth.

Most of the West Bengal coast consists of the Sundarbans region of Ganges mouth with many shoals, sand spits, mud flats and tidal swamps (Ahmad 1972). Mud flats are exposed during low tide near Digha, part of Sundarban and opposite to the Hoogly mouth. Sagar Islands, Bhangadun Island, Dahlhousie Island, Lothian Island and Mahisand Island are present opposite to the mouth of the river Hooghly.

The Andaman and Nicobar Islands are emergent remnants of a Tertiary mountain chain, the Andaman Ridge, (Ahmad 1982) and are located

off the Asian continental shelf in Bay of Bengal between India and Myanmar. There are about 500 islands and most of them are composed of rock like fossiliferous beds, conglomerates, sandstones and lime stones (Ahmad 1972). Some islands are of volcanic origin. Coralline limestones are the predominant rock formation in the shelf region of these islands. Corals had uninterrupted life during the Tertiary and Quaternary.

The Lakshadweep archipelago lies on the northern part of the Laccadive-Chagos Ridge and is the second largest group of atolls in the Indian Ocean (UNEP/IUCN 1988). It consists of 36 islands, 12 atolls, 3 reefs and 5 submerged coral banks. Reef formation in the Lakshadeep is of the atoll type generally elliptical in shape, not exceeding 10 km in the longest axis, with one and often several islands on the atoll (Chandramohan *et al* 1996). The islands are generally narrow and arcuate and situated on the eastern rims of the atoll (IUCN 1993). These islands are encircled by fringing reefs with the formation of lagoon on the western side (Basanta Kumar Jena 1997).

1.4 OCEANOGRAPHY OF INDIAN COASTAL REGION

Three seasons viz., southwest monsoon (June to September), northeast monsoon (October to January) and fair weather period (February to May) dominate the oceanography of the Indian coastal region. While southwest and northeast monsoons have equal impact along the southern part of the East Coast, only the southwest monsoon has a significant effect on the West Coast. The West Coast of India experiences high wave activity during the southwest monsoon, while relatively calm sea conditions prevailing during the rest of the year. On the east coast, the wave activity is significant both during southwest and northeast monsoons. Extreme wave conditions are however, found to occur under severe tropical cyclones, which are frequent in Bay of Bengal during the monsoon period (Chandramohan *et al* 1989).

In general, tides in Indian coastal region is semi diurnal, with tidal ranges varying from place to place. While Sundarban, Gulf of Khambhat and Gulf of Kachchh experience large tidal variations exceeding 5 m, the peninsular tip of India is subjected to relatively low variation of tides around 0.5 m (Basanta Kumar Jena 1997). The variation of tide level at some places along the Indian coast based on tide tables is shown in Table 1.2.

The current patterns near the river mouths are greatly influenced by tides. The regions along the open coast with 2 km from the coastline are mostly dominated by wind and seasonal circulation pattern. Current beyond 2 km distance from the coastline are once again significantly influenced by tides. Surface currents tend to follow the monsoon winds. For several months at the end of each year current comes from the northeast, the Bay of Bengal and along the coast of India, rather than from the open ocean. The typical current pattern at some places measured by NIO are shown in the Table 1.3.

Table 1.2 Tidal variations along the Indian coast

Place	Spring Tidal Range (M)	Neap Tidal Range (M)
Kandla	5.86	3.90
Mumbai	3.66	0.73
Goa	1.69	0.56
Mangalore	1.22	0.56
Cochin	0.63	0.23
Tuticorin	0.70	0.16
Chennai	1.01	0.41
Visakhapatnam	1.43	0.54
Paradeep	1.87	0.70
Calcutta	4.21	2.10

Table 1.3 Near shore Current Characteristics along the Indian coast

Place	Southwest Monsoon (Jun-Sep)			Northeast Monsoon (Oct-Jan)			Fair Water Period (Feb-May)		
	Speed (M/S)	Predominant Direction (Degree)		Speed (M/S)	Predominant Direction (Degree)		Speed (M/S)	Predominant Direction (Degree)	
		Ebb	Flood		Ebb	Flood		Ebb	Flood
Kandla	-	-	-	0.10-1.30	180	360	0.10-1.20	180	360
Mubdai High	-	-	-	0.10-0.40	35	300	-	-	-
Goa	-	-	-	0.15-0.25	290	110	-	-	-
Mangalore	-	-	-	0.20	180	180	0.25	180	180
Tuticorin	-	-	-	0.05	135	-	-	-	-
Nagapattanam	0.15-0.2	360	360	-	-	-	0.20	180	360
Chennai	0.12	210	360	-	-	-	0.20	180	360
Visakhapatnam	0.10-0.5	90	225	0.02-0.08	270	90	0.10-0.70	60	135
Gopalpur	0.2	60	235	-	-	-	-	-	-

Source: Basant Kumar Jena 1997

1.5 COASTAL ENVIRONMENTAL PROBLEMS IN INDIA

The coastal area in India faces a wide range of problems. A recent regional survey conducted by International Ocean Institute, Operational Center at Chennai revealed several problems. As per the survey, in India, population pressure has been considered as the most important problem. Environmental degradation such as destruction of mangroves along with pollution and urbanisation is considered as the next serious problem.

Traditionally, coastal areas are highly populated and developed. In India, out of the 3-mega cities with population more than 10 million, Delhi (13.2 M), Bombay (16 M) and Calcutta (16.5 M) two are coastal cities i.e., Bombay and Calcutta (Sinha 1996). The population density is also more in coastal areas than the national average. For example, in the state of Tamilnadu, the population density in coastal area is 528 per sq.km. against 372 per sq.km which is state average. In parts of coastal metros like Bombay, Calcutta and Madras, the population density ranged from 20,000 to 50,000 per sq.km. The increased population pressure led to resource depletion and environmental degradation (Ramachandran 1999).

The major activities that are responsible for coastal pollution in India are discharge and disposal of domestic and industrial wastes, discharging of coolant waters, harbour activities such as dredging, cargo handling, dumping of ship wastes, spilling of cargo's such as chemical and metal ores, oil transport and fishing activity, etc. Domestic waters are discharged mostly in untreated conditions due to lake of treatment facilities in most of the cities or towns. (Ramachandran *et al* 1991).

India is one of the largest industrialised nations in the world. Major industrial cities and town such as Surat, Bombay, Cochin, Chennai,

Vishakapatnam and Calcutta are situated on or near the coastline. The estimated total quantity of waste discharged by these industries is estimated to be approximately 700 million cu.m. (DOD Report 1996).

The coastal erosion is caused by wave breaking, reduction in sediment input to coast, tectonic upheavals and rise in sea level. These causes are not only natural, but also, due to human influence. In west coast, erosion is very severe along Kerala coast. In Karnataka, about 73 km of the coast is affected by erosion. Along the east coast the coastal erosion is moderate (Ramachandran 1999). In Tamilnadu, about 80 km of the coastline is affected. In Orissa, about 30 to 40 km are affected. In West Bengal, erosion occurs in 180 km, along the coastline stretching from the confluence of the river Hooghly in the west to the confluence of the river Jadgan in the east. The rate of erosion is as high as 30 m/year (Joshi 1995).

In India, nearly 150 million people are prone to natural hazard in coastal areas. Bay of Bengal is one of the five cyclone prone areas of the world. The coastal regions surrounding this bay are frequently affected by flooding from the sea as well as the rivers due to tropical cyclones and related storm surges and heavy rainfall. Between the year 1990 and 1995 in the state of Andhra Pradesh, more than 1100 human lives were lost and property worth of Rs.23, 000 million were damaged. In Tamilnadu during the year 1990 to 1995, the damages caused to property were worth of Rs.5, 800 million and the loss of human lives was more than 500 (Ramachandran 1999).

1.6 CORAL REEF ECOSYSTEM AND PROBLEMS

Coral reef ecosystems are of high biological diversity, having the greatest number of species of any marine ecosystem (Grassle *et al* 1990; Wells 1988). Reefs are equivalent to tropical rain forests for their rich biological

diversity. It is considered as one of the most important critical resources for various ecological, environmental and socio-economic reasons. Coral reefs act as a barrier against wave action along the coastal areas, thus preventing the coastal erosion. In addition, coral reefs protect mangroves and seagrass beds in some areas, which are breeding and nursing grounds of various fauna that are economically important. Coral reefs are also important breeding, nesting, birthing and feeding areas for many varieties of economically important fishes and organisms. Coral reefs are considered an important economic resource that has been used by coastal people for thousands of years. People in the coastal areas are depending on coral reef for their livelihood (Salvat 1992). Corals are used as building material in the construction of roads and as lime in cement industries. Due to these multifaceted uses of coral ecosystem they are facing many threats, of which some are natural like storms and waves particularly tropical storms and cyclones that cause major damages to coral reef. In recent years majority of damage to coral reefs around the world has been through direct anthropogenic stress due to the pressures applied by human beings on the coral reefs (Grigg and Dollar 1990). Excessive pollution by inorganic nutrients, organic matter from industrial effluents and agricultural waste, poor landuse practices, excessive sedimentation and over exploitation in the form of fishing and mining are the major stresses to the coral reefs (Smith and Buddemeier 1993; Wilkinson 1983). The recent estimates on areal extent of coral reef degradation are 85% in Gulf of Mannar, 65-80% in Andaman and Nicobar Islands and 74% in Lakshadweep (Arjan Rajasuriya 1999). Hence mapping and monitoring of the coral reefs are urgent needs for protecting coral reefs from degradation.

1.7 APPLICATIONS OF REMOTE SENSING IN COASTAL AND MARINE AREAS

Satellite remote sensing is widely used as a tool in many parts of the world for the management of resources and activities within the continental shelf containing reefs, islands, shoals and nutrient-rich waters associated with major estuaries. The recent developments in the use of remote sensing data in India under National Natural Resources Management System (NNRMS) and National Drinking Water Mission Project have proved to be important and useful in mapping the natural resources for sustainable utilization and management.

The continuous reception of Landsat, NOAA, IRS-1A, IRS-1B, IRS-1C, IRS-1D, IRS-P3 and IRS-P4 data from National Remote Sensing Agency (NRSA), Hyderabad is helpful to many users to undertake coastal ocean resources mapping for various applications in India. Preliminary studies carried out in India by Space Application Center (SAC) Ahmedabad, have proved the importance of remote sensing data in mapping and monitoring the coastal processes and coastal environments like coral reef, wetland, mangrove, shoreline changes etc. (Muley *et al* 1986; Nayak *et al* 1986a, 1986b &1987).

French remote sensing satellite SPOT has shown its ability to image some ocean processes of interest for the scientific community and for the offshore industry. SPOT XS image are very useful for coastal pollution studies. Wadsworth and Piau (1987) identified man-made oil slick in the Madras harbour.

Using airborne thermal band data collected during spring and summer period (1993) in UK, a quantitative study on cooling water discharges from a coastal power station was carried out by Davis and Mofor (1993).

Studies on suspended sediments concentration was carried out extensively for shallow, high latitude embankments, river wetlands, near shore and offshore waters using the surface colour of near-coastal waters (Barale and Fay 1986; Maynard *et al* 1987; Mertes *et al* 1993). Studies carried out in Tamilnadu coastal water by applying digital chromaticity techniques using IRS satellites data showed that the suspended sediments concentration in Coastal waters were very much influenced by the discharges from the thermal power plants in Ennore and Tuticorin (Chauhan *et al* 1993). Mapping and quantitative estimation of chlorophyll concentration were carried out in different parts of coastal waters in India using CZCS and Landsat MSS data (Beenakumari *et al* 1985; Chaturvedi 1985; Jagadev *et al* 1985). To retrieve chlorophyll from satellite and air borne data many types of Algorithm have been developed by various authors especially from the Arabian Sea and Bay of Bengal (Muralikrishna 1983; Prasad *et al* 1987). Satyendranath *et al* (1987) have evaluated the problems of chlorophyll retrieval from ocean colour. Tassoan (1987) has evaluated the potential use of the Landsat- TM data for marine applications. He has indicated that the chlorophyll estimation is unreliable close to the coast where sediment influence will be high due to river plumes and bottom suspension. Chlorophyll and suspended sediment concentration retrieval algorithms have been developed with reference to Landsat-5 TM bands covering the coastal water of Vishakapatnam and off Paradip in the Bay of Bengal (Mishra 1994). Mapping of nearshore features particularly coral reefs, suspended particulate matter and influence of industrial discharges into the coastal waters and ocean colour were carried out by digital analysis of TM, SPOT and IRS LISS –2 data of Tamilnadu coast (Krishnamoorthy *et al* 1992 & 1995).

Coastal wetlands are highly productive zone between the continental slope and shoreline. Several investigations on coastal wetland have been carried out using spectral relationship. Ground-based spectral studies are

important, as the solar energy reflected from the surface must propagate through the atmosphere before reaching the sensor. In case of ground-based measurement, the small volume of the atmosphere between the surface and the sensor does not play a significant role in alteration and scattering of the reflected upwelling solar energy.

Kuchler (1983) devised a standard classification system for classifying and labeling geomorphological information on reef cover and zonation. He followed four principle steps to interpret remote sensing data for coral reef mapping. They are:

1. Detection of features
2. Recognition and identification of features
3. Analysis and delineation

Mapping of Gulf of Mannar, Gulf of Kutch, Palk Bay, Lakshadweep and Andaman and Nicobar Islands has been carried out using remote sensing data (Anjali Bahuguna and Nayak 1998). The degraded coral reefs have been identified using multi-date satellite data (Anjali Bahuguna and Nayak 1994a).

High-resolution optical remote sensing data were useful for coral reef zonation studies. Making comparisons between the ability of different sensors for coral studies is different because of differences in reef terminology and study sites (Green *et al* 1996). The high-resolution optical sensors especially TM, SPOT and IRS LISS-2 were compared with airborne SAR data for coral reef mapping in Andaman and Nicobar islands. Optical sensors were found to be suitable to demarcate living and non-living corals and its depth of occurrence based on tonal characteristics (Krishnamoorthy *et al* 1993).

1.8 OBJECTIVS OF THE STUDY

The objectives of the present study are to

1. Assess the current status of coral reefs in Gulf of Mannar based on remote sensing and GIS approach
2. Assess the changes that have occurred in the spatial distribution of coral reefs during the period 1988-1998 using multidate remote sensing data
3. Study the coastal geomorphology and its influence on the coral reefs
4. Study the influence of landuse/landcover changes on the coral reefs
5. Suggest suitable management measures for sustainable management and preservation of coral reefs in Gulf of Mannar region