CHAPTER 10: LONG TERM MANGROVE HABITAT MONITORING

This chapter gives the results of the change detection exercise carried out using GIS analysis. The first part of the chapter gives the results of each change study. The generated maps have been presented and the area statistics have been calculated and have been put up in a tabular form. The next part of the chapter enumerates the major ecological factors that are affecting the mangrove vegetation of the area using archived satellite imagery and field photographs. They have been broadly divided into factors that are responsible for degradation as well as improvement of the vegetation. The last part of the chapter tries to analyse the results in the light of relevant literature on the environment of the area. They try to explain the current status of the mangroves in the Gulf of Kachchh that has experienced a high amount of industrial activity in the past few decades, which includes the setting up of the largest refinery in the world near Jamnagar, and the development of Kandla port that is now the largest transit point for liquid cargo transport in India.

10.1 Mangrove Vegetation Change- Maps

Four Mangrove vegetation change maps were prepared using the methodology described in chapter 6. These maps indicating the changes from 1966 to 1975, 1975 to 1990, 1990 to 1998 and 1998 have been given in plates 10.1 to plates 10.4 respectively. The maps have been generated and presented at a scale of 1:1,00,000.

10.2 Mangrove Vegetation Change - Statistics

The statistics showing the change in the area of the various mangrove categories have been given in tables 10.1 to 10.4. With the emphasis being on the mangrove vegetation, the changes in the area of other non-vegetated areas though generated have not been given. As the number of classes in the 1966 and 1975 maps were less, the number of change classes in maps, is comparatively less than those of the 1990 map which had the highest number of classes.

Table 10.1 Change in Mangrove Categories from 1966 to 1975

Sr. No.	Category (1966-1975)	Area (km^2)
	No Change Areas	
1.	Mangrove	50.039029
	Improving Areas	
2.	Sea to Mangrove	8.053443
3.	Sand to Mangrove	2.154634
4.	Mud to Mangrove	0.303540
5.	Land to Mangrove	0.038376
	Sub-Total	**10.549993**
	Degrading Areas	
6.	Mangrove to sea	0.348543
7.	Mangrove to sand	0.908831
8.	Mangrove to mud	22.303757
9.	Mangrove to land	1.766607
10.	Mangrove to reef flat	1.186351
	Sub Total	**26.514089**
	Total Change Area	37.064082

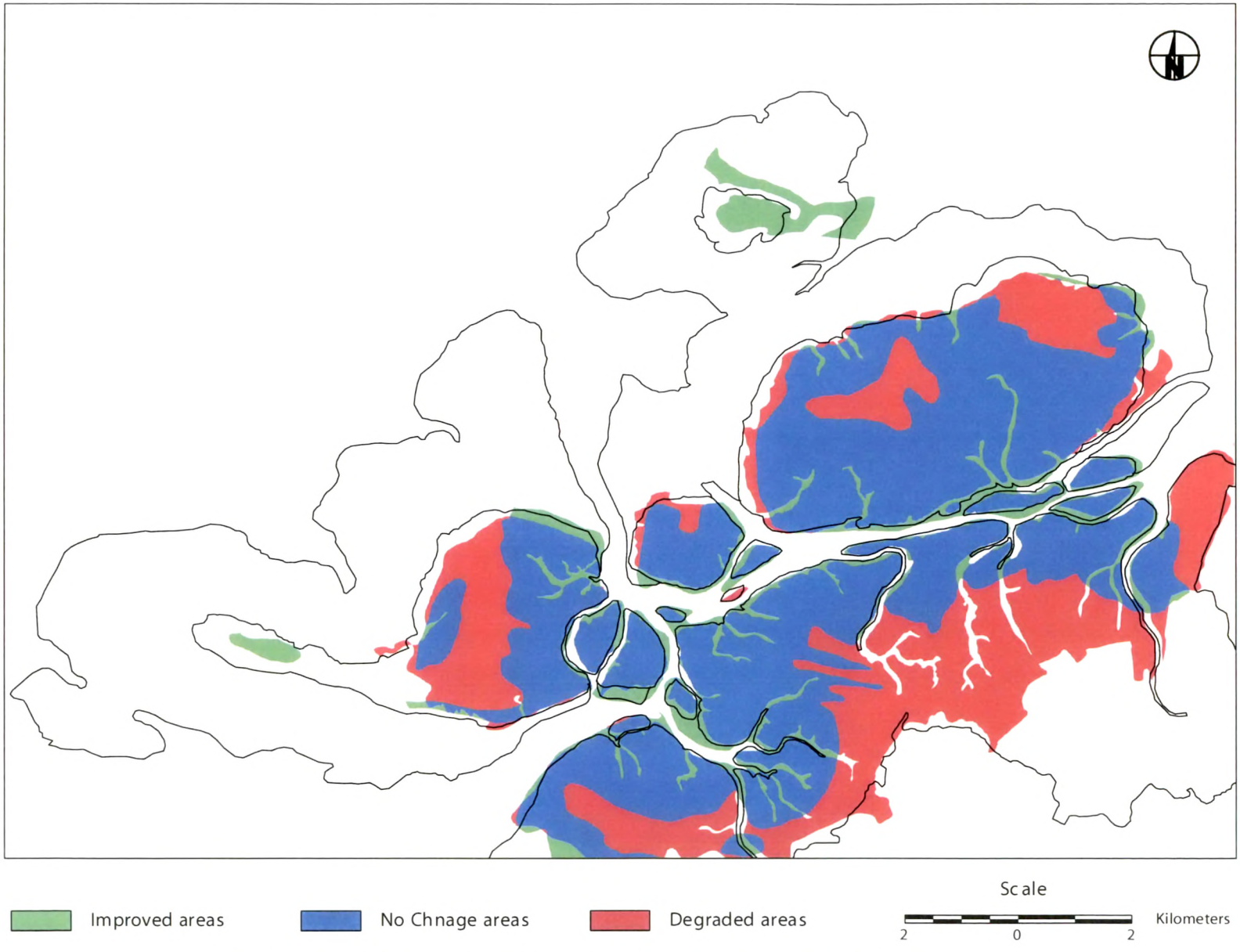


Plate 10.1 Change in Mangrove habitat from 1966 to 1975

Table 10.2 Change in Mangrove Categories from 1975 to 1990

Sr. No.	Category (1975-1990)	Area (km^2)
	No Change Areas	
1.	Dense Mangrove	35.787160
	Improving Areas	
2.	Sea to Mangrove Dense	0.639125
3.	Sea to Mangrove Sparse	0.059110
4.	Mud vegetation to Mangrove Dense	4.888256
5.	Mud vegetation to Mangrove Sparse	5.732799
6.	Sand to Mangrove Dense	0.359994
7.	Sand to Mangrove Sparse	0.273619
8.	Reef area to Mangrove Dense	0.428182
9.	Reef area to Mangrove Sparse	0.013959
10.	Saltpan to Mangrove Sparse	0.524620
11.	Saline Area to Mangrove Dense	0.016406
12.	Saline Area to Mangrove Sparse	0.069180
	Sub-total	13.005250
	Degrading Areas	
13.	Mangrove Dense to Sea	1.887434
14.	Mangrove Dense to Mud	6.592597
15.	Mangrove Dense to Mud Vegetation	5.740786
16.	Mangrove to Sand	2.360680
17.	Mangrove Dense to Sand vegetation	0.314537
18.	Mangrove Dense to Reef area	0.000121
19.	Mangrove Dense to Mud over Reef	0.001692
20.	Mangrove Dense to Reef Vegetation	0.455513
21.	Mangrove Dense to Mangrove Sparse	6.043201
22.	Mangrove Dense to Saltpan	0.207734
23.	Mangrove Dense to Saline Area	0.025255
	Sub-total	23.629550
	Total Change Area	36.634800

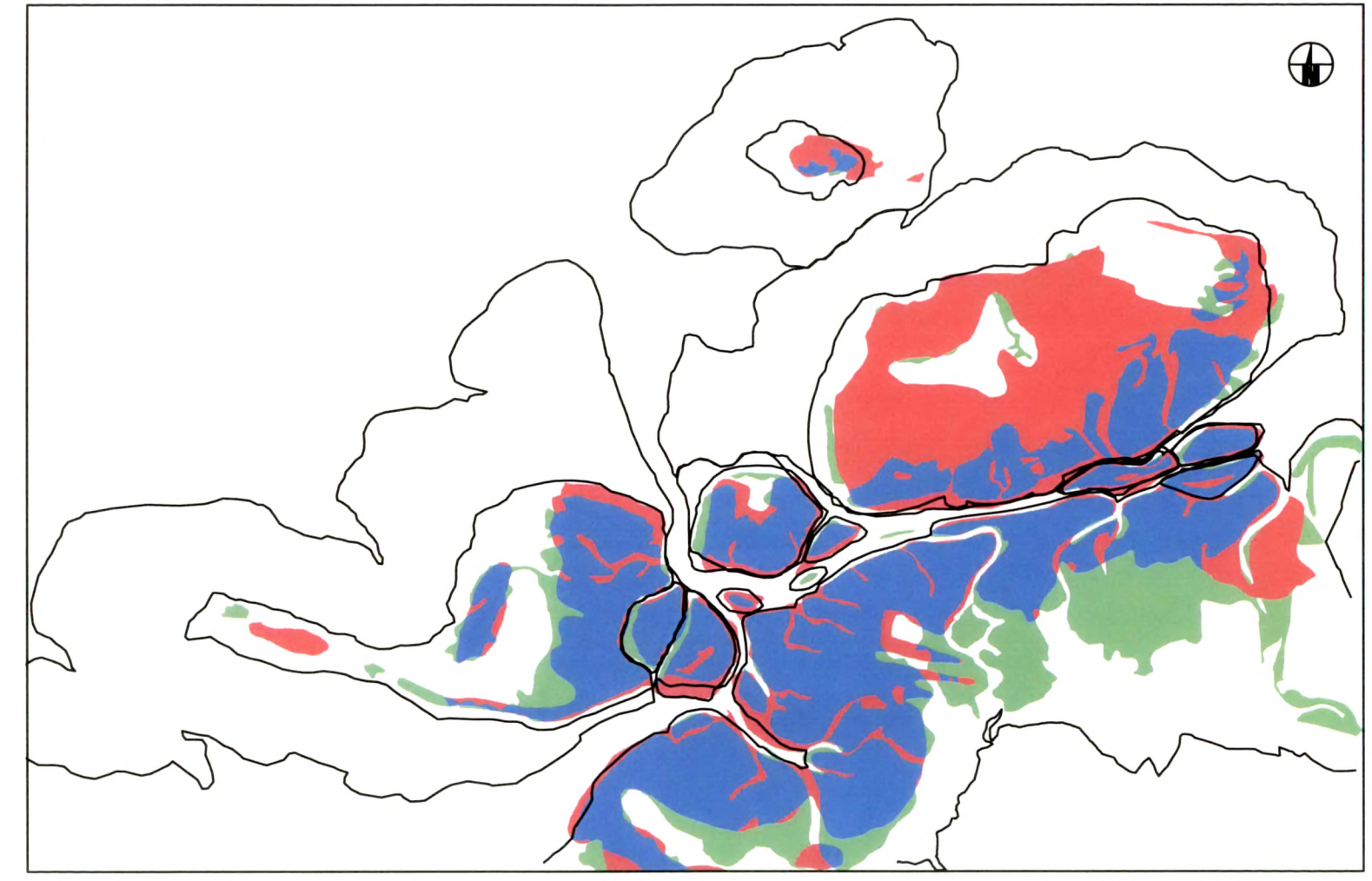


Plate 10.2 Change in Mangrove Habitat from 1975 to 1990

Table 10.3 Change in Mangrove Categories from 1990 to 1998

Sr. No.	Category (1990-1998)	Area (km^2)
	No Change Areas	
1.	Mangrove Dense	19.452568
2.	Mangrove Sparse	2.259982
		21.712550
	Improving Areas	
3.	Sea to Mangrove Dense	0.099471
4.	Sea to Mangrove Sparse	0.130552
5.	Sea to Mangrove Degraded	0.115943
6.	Sea to Back Mangrove	0.002340
7.	Intertidal Mudflat to Mangrove Dense	1.471402
8.	Intertidal Mudflat to Mangrove Sparse	0.769549
9.	Intertidal Mudflat to Degraded Mangrove	1.323056
10.	Intertidal Mudflat to Back Mangrove	0.063247
11.	Hightidal Mudflat to Mangrove Dense	1.163750
12.	Hightidal Mudflat to Mangrove Sparse	0.664591
13.	Hightidal Mudflat to Degraded Mangrove	1.459834
14.	Hightidal Mudflat to Back Mangrove	0.161986
15.	Sand to Mangrove Dense	0.301145
16.	Sand to Mangrove Sparse	0.142790
17.	Sand to Degraded Mangrove	0.169286
18.	Sand to Back Mangrove	0.011174
19.	Sand Vegetation to Mangrove Dense	0.426313
20.	Sand Vegetation to Mangrove Sparse	0.175406
21.	Sand Vegetation to Degraded Mangrove	0.061379
22.	Reef Vegetation to Mangrove Dense	0.149554
23.	Reef Vegetation to Mangrove Sparse	0.038355
24.	Reef Vegetation to Degraded Mangrove	0.009122
25.	Mangrove Sparse to Mangrove Dense	3.598457
26.	Saltpan to Mangrove Dense	0.123704

Sr. No.	Category (1990-1998)	Area (km^2)
27.	Saltpan to Mangrove Sparse	0.072785
28.	Saltpan to Degraded Mangrove	0.061524
29.	Saline Area to Mangrove Dense	0.003716
30.	Saline Area to Mangrove Sparse	0.004373
31.	Saline Area to Mangrove Degraded	0.046710
	Sub-total	12.821514
	Degrading Areas	
32.	Mangrove Dense to Sea	1.216339
33.	Mangrove Dense to Intertidal Mudflat	3.881992
34.	Mangrove Dense to Marsh	0.385764
35.	Mangrove Dense to Sand	0.191465
36.	Mangrove Dense to Sand Vegetation	0.029833
37.	Mangrove Dense to Reef Area	0.043024
38.	Mangrove Dense to Mangrove Sparse	11.436137
39.	Mangrove Dense to Degraded Mangrove	4.948026
40.	Mangrove Dense to Back Mangroves	0.547769
41.	Mangrove Dense to Saltpan	0.028853
42.	Mangrove Dense to Saline Area	0.031704
43.	Mangrove Sparse to Sea	0.141214
44.	Mangrove Sparse to Intertidal Mudflat	3.816590
45.	Mangrove Sparse to Marsh	0.402007
46.	Mangrove Sparse to Sand	0.068034
47.	Mangrove Sparse to Reef Area	0.126460
48.	Mangrove Sparse to Degraded Mangrove	1.926104
49.	Mangrove Sparse to Back Mangrove	0.194380
50.	Mangrove Sparse to Saltpan	1.559390
51.	Mangrove Sparse to Saline Area	0.014262
52.	Mangrove Sparse to Saline Area	0.014262
	Sub-total	31.003609
	Total Change Area	**43.825117**

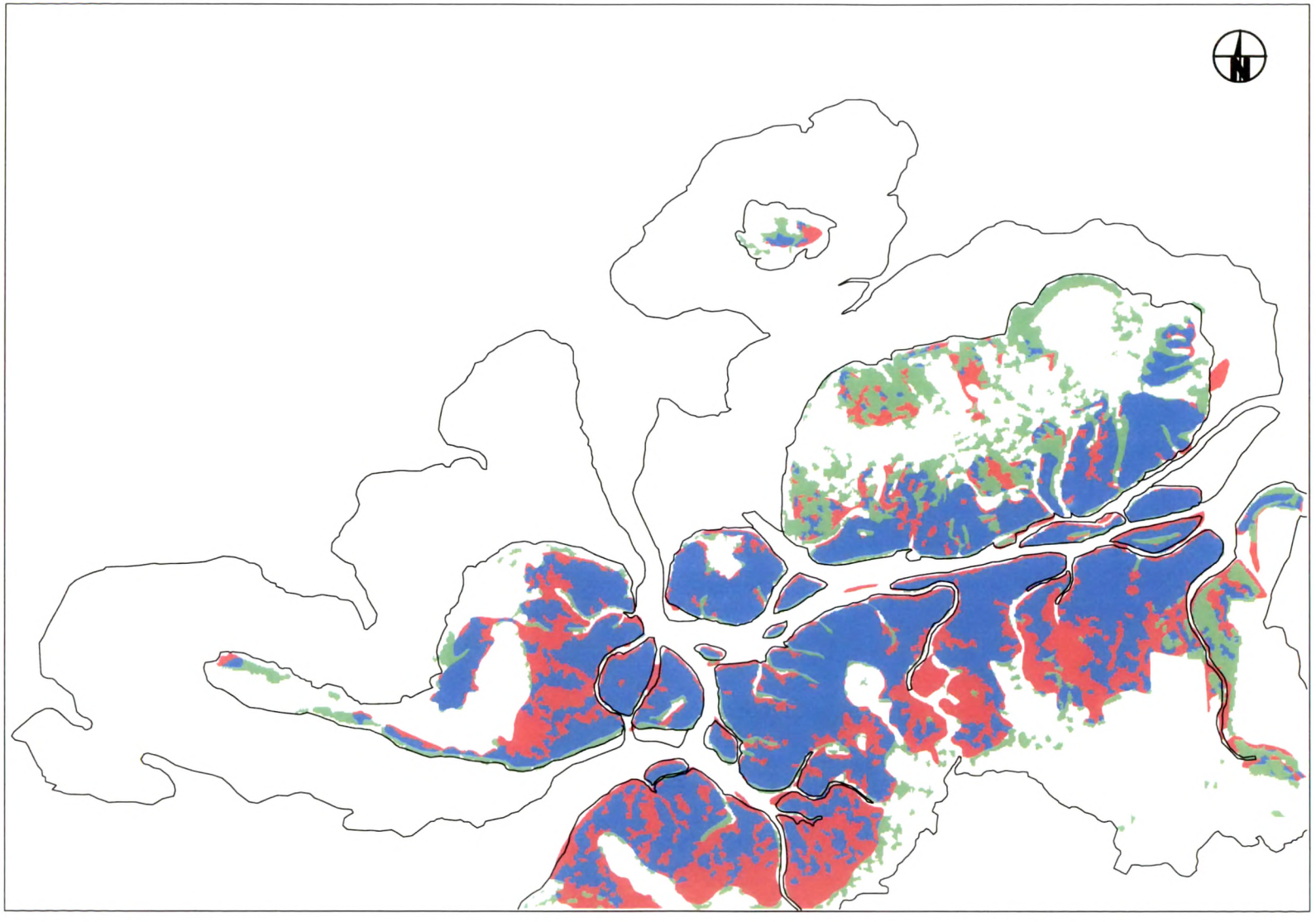


Plate 10.3 Change in Mangrove habitat from 1990 to 1998

Table 10.4 Change in Mangrove Categories from 1998 to 2001

Sr. No.	Category (1998-2001)	Area (km^2)
	No Change Areas	
1.	Mangrove Dense	18.819306
2.	Mangrove Sparse	7.811991
3.	Degraded Mangrove	2.392718
4.	Back Mangrove	0.062582
	Sub-total	29.086597
	Improving Areas	
5.	Sea to Mangrove Dense	0.463263
6.	Sea to Mangrove Sparse	0.052824
7.	Sea to Mangrove Degraded	0.037534
8.	Sea to Back Mangrove	0.009915
9.	Intertidal Mudflat to Mangrove Dense	0.958039
10.	Intertidal Mudflat to Mangrove Sparse	0.914943
11.	Intertidal Mudflat to Mangrove Degraded	3.057848
12.	Intertidal Mudflat to Back Mangrove	0.230395
13.	Marsh to Mangrove Dense	0.047609
14.	Marsh to Mangrove Sparse	0.086283
15.	Marsh to Mangrove Degraded	0.407905
16.	Marsh to Back Mangrove	0.031571
17.	Sand to Mangrove Dense	0.073637
18.	Sand to Degraded Mangrove	0.048605
19.	Sand Vegetation to Mangrove Dense	0.023916
20.	Reef Vegetation to Mangrove Dense	0.041112
21.	Reef Vegetation to Mangrove Sparse	0.017888
22.	Reef Vegetation to Degraded Mangrove	0.398345
23.	Mangrove sparse to Mangrove Dense	3.224212
24.	Mangrove Degraded to Mangrove Dense	0.416900
25.	Mangrove Degraded to Mangrove Sparse	3.155105
26.	Back Mangrove to Mangrove Dense	0.023457
27.	Back Mangrove to Mangrove Sparse	0.056951
28.	Back Mangrove to Mangrove Degraded	0.082107
29.	Saltpan to Mangrove Dense	0.043430
	Sub-total	13.903794

Sr. No.	Category (1998-2001)	Area (km^2)
	Degrading Areas	
30.	Mangrove Dense to Mangrove Sparse	5.621480
31.	Mangrove Dense to Mangrove Degraded	1.614071
32.	manf Dense to Back Mangrove	0.061512
33.	Mangrove Dense to Marsh	0.198238
34.	Mangrove Dense to Intertidal Mudflat	1.053282
35.	Mangrove Dense to Sand	0.030311
36.	Mangrove Dense to Reef Vegetation	0.016860
37.	Mangrove Dense to Water	0.489939
38.	Mangrove Sparse to Mangrove degraded	2.319054
39.	Mangrove Sparse to Back Mangrove	0.215576
40.	Mangrove Sparse to Marsh	0.023075
41.	Mangrove Sparse to Sand Vegetation	0.018223
42.	Mangrove Sparse to Intertidal Mudflat	1.763847
43.	Mangrove Sparse to Sand	0.011829
44.	Mangrove Sparse to Water	0.189124
45.	Mangrove Degraded to Back Mangrove	0.439199
46.	Mangrove Degraded to Marsh	0.140290
47.	Mangrove Degraded to Intertidal Mudflat	1.957150
48.	Mangrove Degraded to Hightidal Mudflat	0.020747
49.	Mangrove Degraded to Sand	0.017326
50.	Mangrove Degraded to Water	0.050886
51.	Back Mangrove to Marsh	0.062349
52.	Back Mangrove to Intertidal Mudflat	0.076912
53.	Back Mangrove to Sand	0.010399
	Sub-total	16.401679
	Total Change Area	**30.305473**

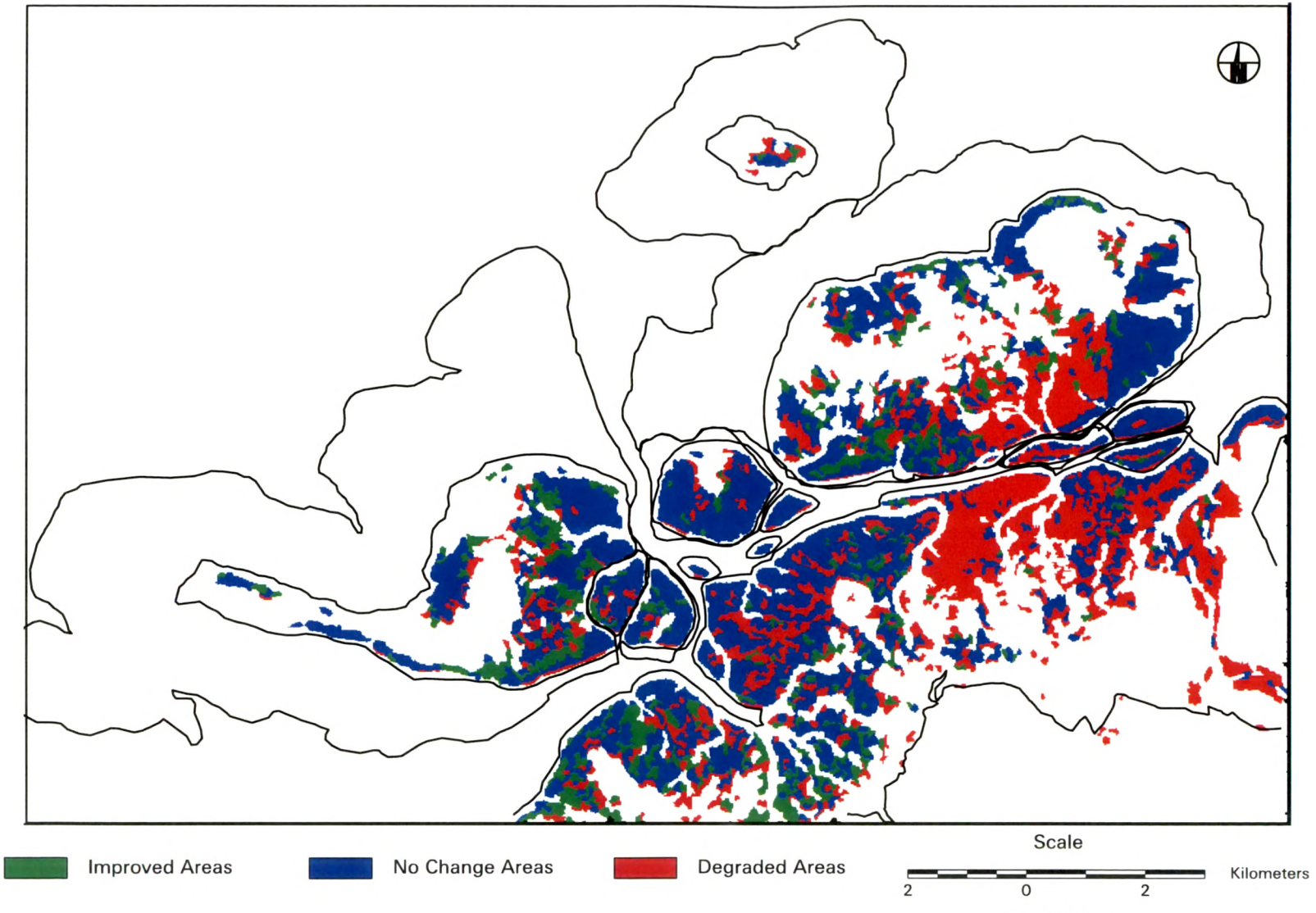


Plate 10.4 Change in Mangrove Habitat from 1998 to 2001

10.3 Major factors affecting the mangroves of the area

This part of the chapter will describe major ecological factors acting on the vegetation of the area, which can be easily studied using optical remote sensing. The factors have been broadly divided into two categories. They are, factors that cause degradation as well as improvement in the vegetation. For comparative basis, Landsat TM imagery of 1986 has been used. This imagery though available in digital format could not be used directly in the change detection analysis as the study area fell in the corner of the imagery and at that region there was a problem of pixel shifting that has been indicated in the following figure 10.1,

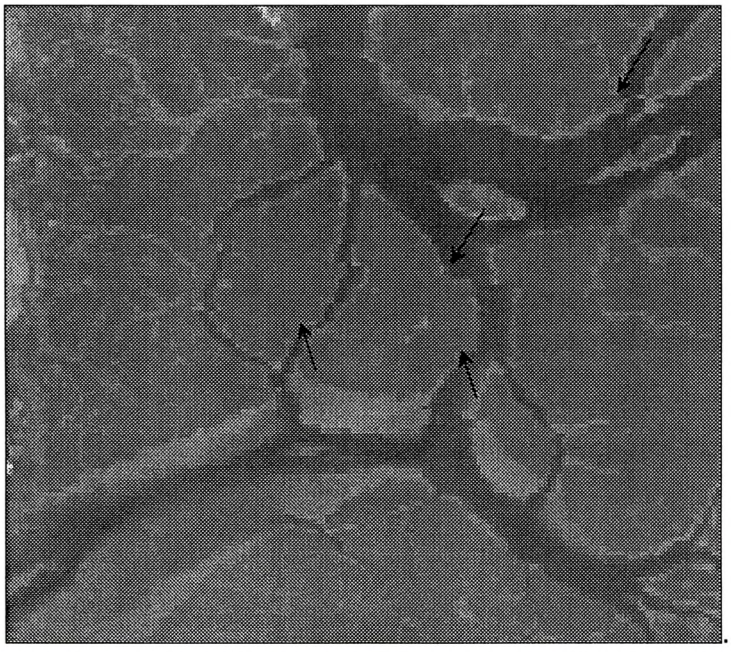


Fig 10.1 Pixel shifting in the 1986 image (arrows indicate regions where the problem can be seen prominently)

10.3.1 Factors causing improvement in mangrove cover

The major factors that have resulted in the improvement of the mangrove vegetation of the area are natural regeneration and plantations by the forest department.

10.3.1.1 Natural Regeneration

Several authors have described that the mangroves of this region being at the edge of their geographical extent will be of short height and the extremities of the climate and the aridity of the area will cause their natural regeneration to be slow. (Blasco and Aizpuru, 1997; Untawale and wafar, 1988; Kulkarni, 1959b) However trees as tall as 14 m (Chavan, 1985) have been described from the area and the fact that if left undisturbed the vegetation can naturally regenerate which can be observed in plate 10.5. It shows the condition of the mangrove vegetation at the Kanakiya region of Chhad Island and at Baga Beli islet to the Southwest of Bhains Bid at two different dates i.e. 1986 and 2001. At Kanakiya it is seen that the mangroves have spread extensively in the south and southeast parts. At Baga beli it is observed that by 1986 the mangroves had colonized a few portions of the mudflat but by 2001 most of the mudflat had been colonized by mangrove vegetation.

10.3.1.2 Plantation by the Forest Department

The forest department has carried out extensive plantations of mangroves in the whole Marine National Park and the Sanctuary. They have been responsible for the emergence of dense mangroves at several new areas. Within the study area most of the plantations by the forest department have been along the sandy beaches that had deposition of mud towards the seaward side. Though not all plantations have been successful, Plate 10.6 shows two locations where plantations have been very successful. The first set shows the condition towards the northern part of Chhad Island. This site represents among the first plantation sites in the area and by 2001 the mangroves at this plantation site had not only become dense but the height of a several trees had exceeded 2.5 m. The second location shows the status at the northern side of Dide ka Bet. This is a recent plantation site and the mangroves here have reached a height of about 1.5 m. This location has been chosen for extensive plantation for a few years so as to repeat the success obtained at North Chhad.

10.3.2 Factors causing degradation in mangrove cover

The vegetation of this region has been subjected to severe stress not only by anthropogenic causes but also by several natural causes. Among the natural causes are the impacts of cyclones, which are frequent in the region and sand movement.

10.3.2.1 Impact of Cyclones

Cyclones have been a frequent feature in the Gulf of Kachchh. While most of the cyclones reaching the area have lost most of their energy as they have to cross the Saurashtra region to reach here some cyclones have retained their energy. One such cyclone hit the Gulf of Kachchh in June 1998. It imposed severe damage not only to life and property in the region but to the mangrove vegetation, particularly on Pirotan Island, which was severely damaged. A large dense patch of mangroves on the northeast of Pirotan was completely defoliated in this event and most of the damaged trees have not regenerated. Plate 10.7 shows the impact of the cyclone, the upper part shows the condition of the mangroves in January 1997 and in October 1998. The lower part depicts the defoliated trees at the location that failed to regenerate.

10.3.2.2 Sand Movement

Sediment transport is the common phenomenon observed along the coasts. However, the rate of transportation depends upon the nature of source rock, transporting agent, availability of favourable site for deposition and their distance from the source rock. Major changes in the sand deposition have been observed in the south and southwest region of Pirotan island over the period 1997-2001. The movement of sand has been a very big factor in the success or failure of the mangorve plantations. The plantation at this site had reached a height of more than 4 m till May 2000, however due to movement of sand, its deposition was observed on pneumatophores due to which the trees were trying up. The upper part of plate 10.8 indicates the degradation of the mangroves due to sand movement while the lower part shows a field photograph that shows the drying trees at the location.

10.3.2.3 Anthropogenic activities

The region has seen a lot of industrial activity in the last few years. However saltpans have been present in the area since at least a century. Due to expansion of saltpans a few mangrove areas have been cleared. The upper part of plate 10.9 shows the expansion of the saltpan to the west of Bedi Bandar. A small extension on the northwest side of the saltpan was seen in the 1986 image, however, the whole strip of mangrove vegetation below it had been converted to saltpan by 1998. The lower part shows a large patch of mangroves that was present till October 1998. In March 1999 it was observed that in this region all the mangroves had become defoliated.

10.4 Discussion

There has been a huge change in the structure of the forest in addition to the loss of several species of mangroves. Chavan (1985) has reported that the mangroves on Pirotan Island reached a height of about 14 m. In his study, Singh (2000) has given a photograph of a single *Avicennia* tree that reached a height of more than 7 m on Pirotan Island and this tree was a few hundred meters away from the present mangrove line which probably indicates the past margin of mangrove vegetation. Also on several islands in the area there are a few large trees reaching a height of more than 4.5 m. One character common in all such large trees is the presence of green flags on them indicating a sacred 'PIR'. Chavan (1985) has mentioned that it is probably because of the religious significance provided to these trees, that they have managed to survive. On the Islands of Dide ka Bet and Chhad several stumps of mangrove trees were observed. While these stumps are now full of wood boring animals and are at an advanced stage of decomposition, they had diameters of up to 30 cm, which point to the tree form of the mangrove vegetation in the past. During the present study I have not encountered any *Avicennia* plant that did not have any religious significance and still had a diameter of more than 10 cm. The mangroves at present are what most authors say 'scrubby' in nature. This nature of the mangrove vegetation of the region has been described by several authors (Blasco, 1975; Chavan, 1985, Untawale & Wafar 1988 etc.). The ecological and

anthropogenic factors which have resulted in the present status of mangroves in the region have been discussed below.

Anthropogenic Factors

The influence of humans on the mangroves of the region has been very prominent. The Gulf is surrounded on both sides by terrestrial areas that have little rainfall. The mangroves are thus the most prominent vegetation component along the coast. The impacts of humans on the mangroves have been divided into two major factors. The impacts due to domestic use and the impacts due to industries. They slightly overlap each other eg. Fisheries can be considered as an industry but as its impact are more due to the fishermen than fishing itself it has been placed under domestic factors.

Domestic factors:

For the coastal population these mangroves are the principle source of firewood and with the increase in coastal populations these mangroves are now at higher risk. For fishermen in the area, the mangroves are the only source of fuel when they move for prolonged fishing trips in the area. Due to their high nutritive value, the mangroves also sever as excellent fodder to the camel population in the area (Chavan, 1985). Also during the successive droughts in the mid 1980s the mangroves were the only source of fodder for the other domesticated animals of the region.

Industrial Factors:

The region due to its geo-political location has several major industries located there. The major industries of the area are broadly divided into the following

1. Salt Industry
2. Petroleum Industry
3. Shipping Industry

Salt Industry:

The region is host to the largest salt industry in the country. This industry is also a major reason for the degradation of the mangroves of the region. Not only have they cleared the mangrove forests for their saltpans, the brine that is produced by them is also released into the Gulf that only compounds the problem. One large spillage of brine during the study period had resulted in the death of several

hundred individuals of mangroves in vicinity of the study area. Also the human population that works in this industry uses mangroves for most its fuel requirements.

Petroleum Industry:

Asia's largest petroleum refinery has been established in the region, which started functioning in 1999. Another refinery of similar size is also in the process of being constructed in the area. In addition to this the Gulf has also been a source of Crude Oil to the Mathura Refinery. There were earlier only two SBMs (Single Buoy Mooring) in the area catering to the oil industry but in the course of the last few years they have now increased to 5. This has also resulted in a several-fold increase in the flow of oil tankers in the region with a corresponding increase in the risk of accidental spilling of oil in the area. This has greatly increased the risk to the mangroves of the area. Extensive damages to mangroves have been reported from oil spills. Jagtap and Untawale (1980) have found significant adverse affects of three kinds of oils on the growth and survival of mangrove seedlings. According to them *Avicennia* is more sensitive to damage than *Rhizophora*. In a recent study Duke and Watkinson (2002) have reported a correlation between petroleum hydrocarbons in sediments and chlorophyll-deficient mutations in *Avicennia marina* in Australia. This resulted in 'albino' seedlings, which could not survive long. During the course of this study a large patch was found to be completely defoliated suddenly and an oil spill is the most probable cause of it.

Shipping Industry:

The development of major ports in the regions like Kandla and Navlakhi has increased the vessel traffic in the Gulf. Several minor ports like Salaya, Bedi and Rozi are also present in the area. This has resulted in two major problems for the study area. Firstly the discharging of 'ballast' in to the Gulf waters results in an increase in the pollution in the area. Not only dose this releases organic and inorganic pollutants in the water they are also a source of alien biological organisms, which may result in an ecological catastrophe. Two ports Nava Bandar and Bedi that are relatively minor ports are present in the study area. Coal has been a significant commodity that is imported through Nava Bandar. During the transportation of coal, the mangroves that surround the port are

covered by coal dust. Naidoo and Chirkoot (2004) have reported that Avicennia marina plants covered by coal dust had a reduced photosynthetic performance.

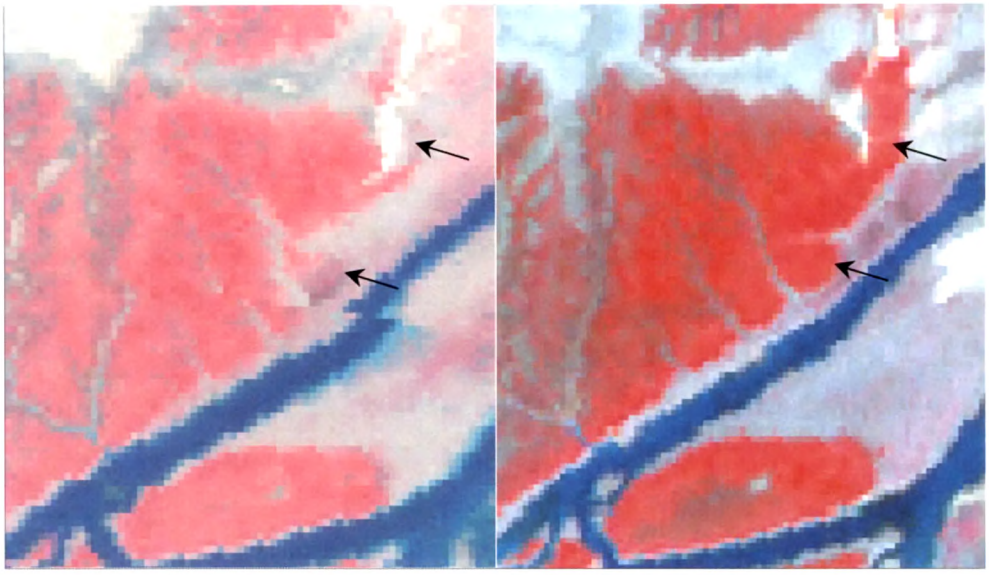
Climatic Factors

The scrubby nature of mangroves is characteristic of mangroves growing near the edges of their distribution (Chapman, 1976; Lugo and Snedaker, 1974). Mangroves have been reported from as far as UAE and hence the mangroves in the study area are not at their latitudinal limits. The distribution of mangroves is limited chiefly by the physiological tolerance of each species to low temperature (Duke *et al.*, 1998). According to him they are restricted generally to areas where mean air temperatures of the coldest months are higher than 20°C, and where the seasonal range does not exceed 10°C. Various studies have also shown that for most mangrove species photosynthesis sharply declines above 35°C (Parnetta, 1993). In the Gulf of Kachchh, not only are the temperature differences very high but in summer the temperatures reach 40°C. This facts show that the mangroves of the region are near their temperature tolerance limits.

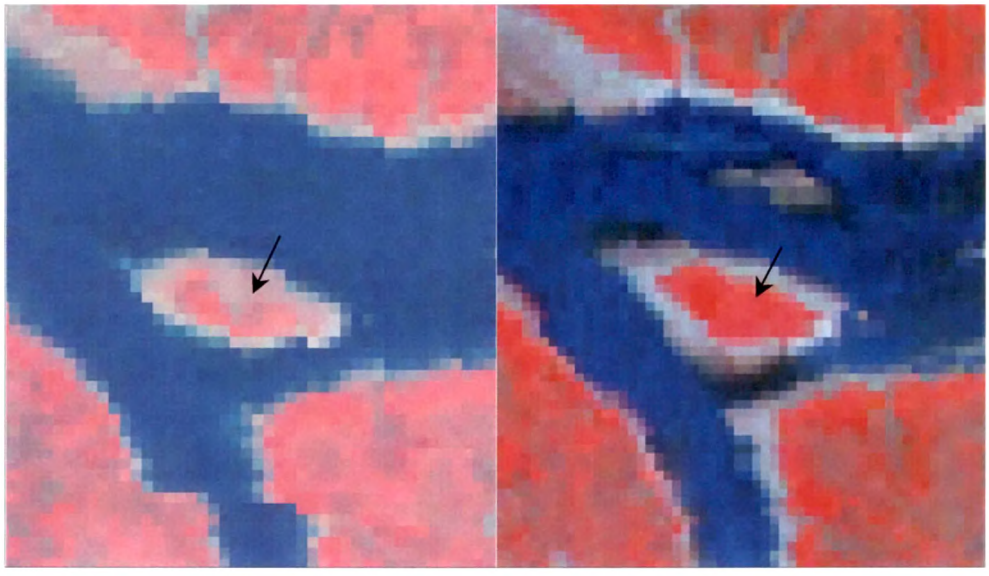
While temperature is the main limiting factor, several other factors like salinity, freshwater influx have also an important role to play in the diversity and structure of mangrove forests. Very high levels of salinity also characterize the Gulf of Kachchh. Another factor is that due to the construction of dams and check-dams on almost all the major rivers and streams flowing into the Gulf, the fluvial discharge in to it has almost been reduced to a trickle. Qureshi (1993) has reported that decrease in fluvial discharge would result in increased salinity of seawater, which reportedly prevents fruiting, and causes senescence of immature flowers and buds. In a part of the Indus delta bordering India, he has reported that of the 9 species of mangroves reported in 1972, only *Avicennia marina, Rhizophora mucronata, Ceriops tagal* and *Aegiceras corniculatum* could be located at that time. A study by Aziz and Khan (2001) on the salinity tolerance of mangroves of the same region, has concluded that the former three of the above mentioned species were highly salt tolerant and among them *Avicennia marina* had the highest level of tolerance. According to him this is the reason that has resulted in *Avicennia* being the most dominant mangrove in the region.

A combination of the above factors have resulted in the present status of the mangroves of the area that have a comparatively reduced diversity as well as a highly stunted growth pattern. That they can grow back to their former levels if proper conditions are made available can be gauged from the fact that at Pirotan within a span of a decade, the plantations had reached a height of more than 4 m.

1986 2001



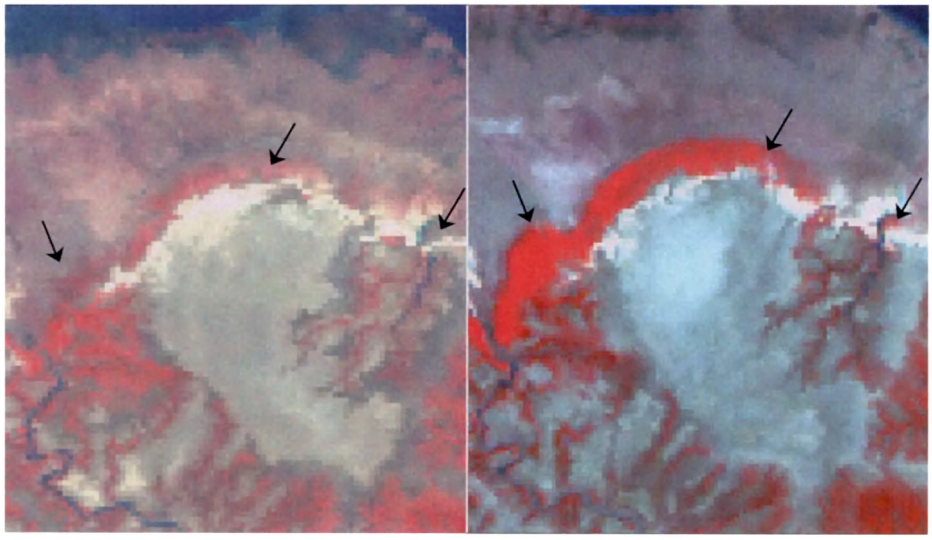
Kanakiya Mangroves



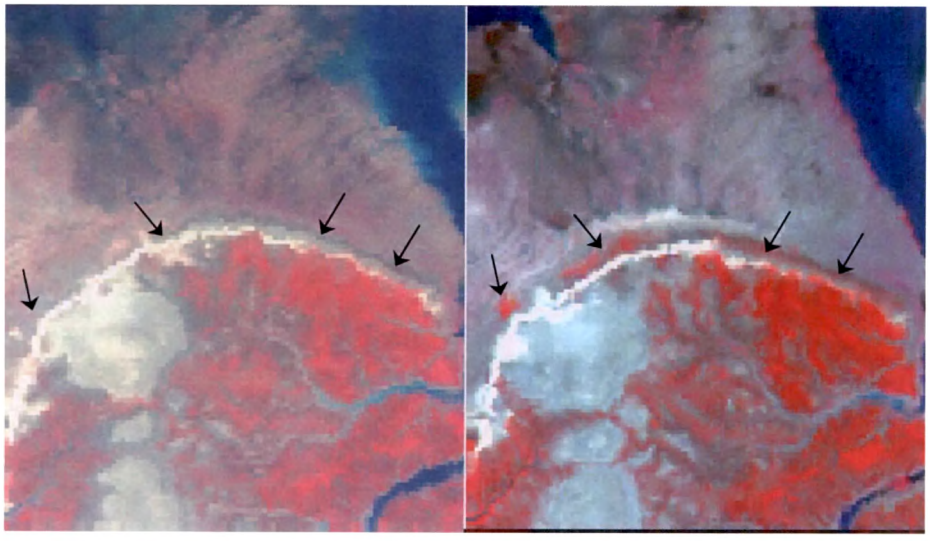
Mangroves at Baga Beli Islet

Plate 10.5 Areas showing Improvement in mangrove vegetation due to natural regeneration

1986 2001

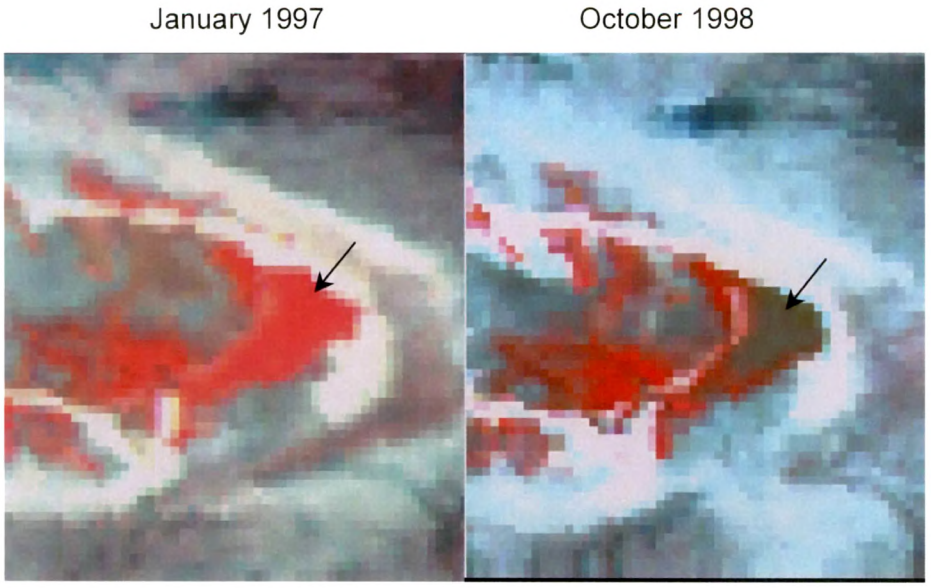


North Chhad Island



North Dide ka Bet

Plate 10.6 Areas showing Improvement in mangrove vegetation due to plantation

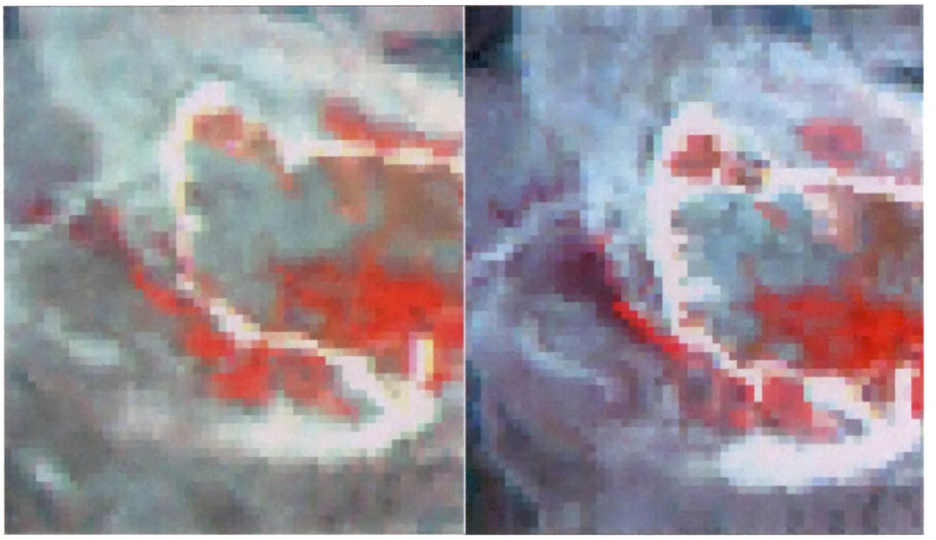


Pirotan Island

Degraded Mangrove Patch at Pirotan

Plate 10.7 Degradation in mangrove vegetation due to the effect of Cyclone

January 1997 January 2001

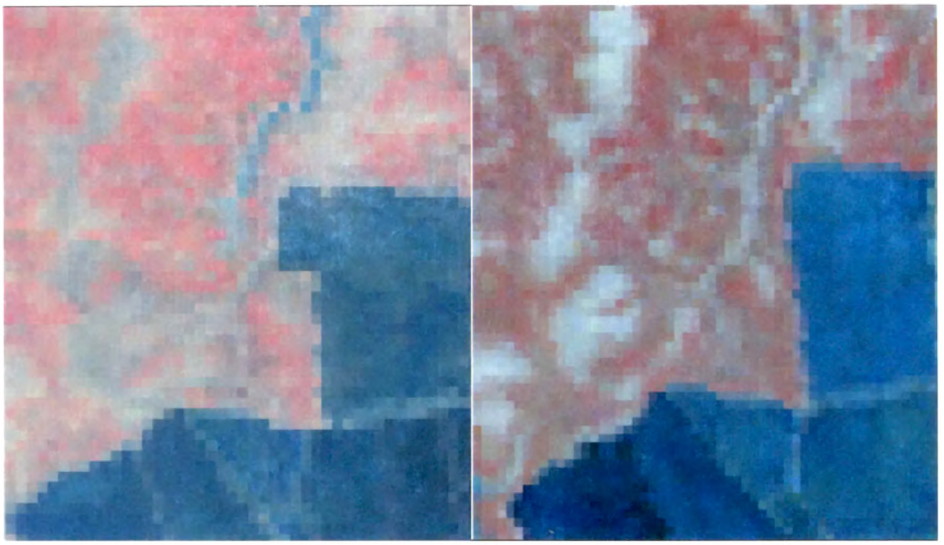


South west Pirotan Island

Mangrove trees drying up due to sand movement

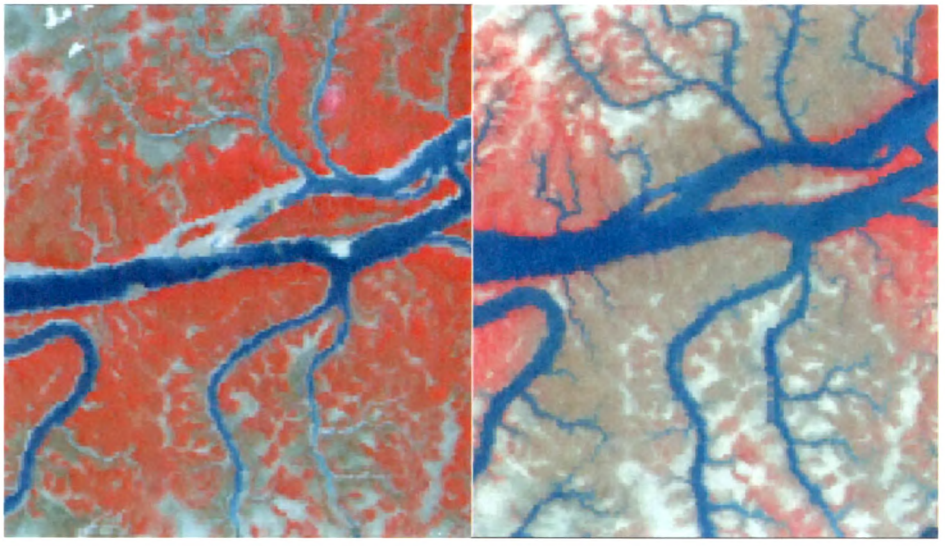
Plate 10.8 Degradation in mangrove vegetation due to sand movement

1986 2001



Extension of Saltpan to the west of Bedi Bandar

October 1998 March 1999



Defoliaton of Mangroves

Plate 10.9 Destruction of mangroves due to anthropogenic activity