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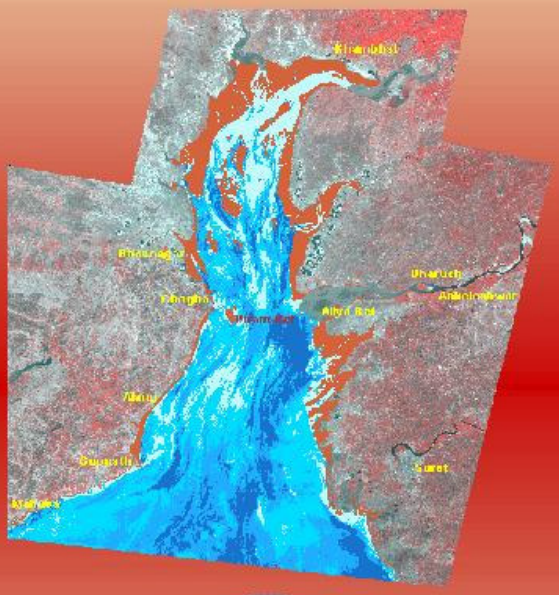
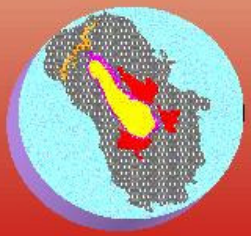
Critical Habitat Information System For Gulf of Khambhat - Gujarat





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1. Introduction

Critical habitats are identified as areas, which are vital to the survival of the species at some phase of its life cycle or to the survival of the community, because of the ecological processes, which occur within it (IUCN, 1976). Critical habitats include nesting, breeding and nursery areas of estuarine and marine animals or areas that are particularly rich in species and highly productive or areas of special scientific interest.

Integrated Coastal and Marine Area Management (ICMAM) Project Directorate of the Department of Ocean Development, Govt. of India has initiated a World Bank funded programme for capacity building in essential areas of ICMAM which encompasses the use of modern tools and techniques like remote sensing and GIS for management of critical habitats. Under this programme, development of Remote Sensing and GIS based Critical Habitat Information Systems for 11 sites along east and west coasts of India has been undertaken, facilitating monitoring and management of habitats by integrating satellite and field data. One of the areas chosen for such studies is Gulf of Khambhat in Gujarat.

The main objective of this study is to create an Information System on the resources of Gulf of Khambhat using Geographical Information System, incorporating components of remote sensing and an external database. This would help the decision-makers in effectively monitoring the biological wealth of this area.

2. Description of Study Area

The Gulf of Khambhat is a south to north penetration of the Arabian Sea on the western shelf of India between the Saurashtra peninsula and mainland Gujarat. It is located approximately between latitude 20° 30' and 22° 20' N and longitude 71° 45' and 72° 53' E (Fig.1). At its northern end between the Sabarmati and Mahi mouths, the Gulf is barely 5 km wide and it opens out southwards like a funnel, reaching its maximum width south of Gopnath point. Its north-south length is approximately 115 km. It covers an extent of about 3,120 km^2 mainly of mudflats with some rocky (sandstone) intertidal area and a volume of 62,400 million m^3. The rocky beaches are common from Mahuva to Gopnath, reducing towards Ghogha and Bhavnagar. A few sandy patches are also observed intermittently. The Gulf is intercepted by several inlets of sea and creeks formed by confluence of major rivers such as Narmada, Tapi, Mahi, Sabarmati, Shetrunji and many minor rivers. All the major rivers form estuaries and their inflow carries heavy load of suspended sediments into the Gulf. A medium sized delta is present near Shetrunji between Gopnath and Ghogha. The ecosystems of the Gulf comprising

mangroves, estuaries, creeks and vast intertidal mud flats are known to have rich biodiversity and a number of endemic flora and fauna.

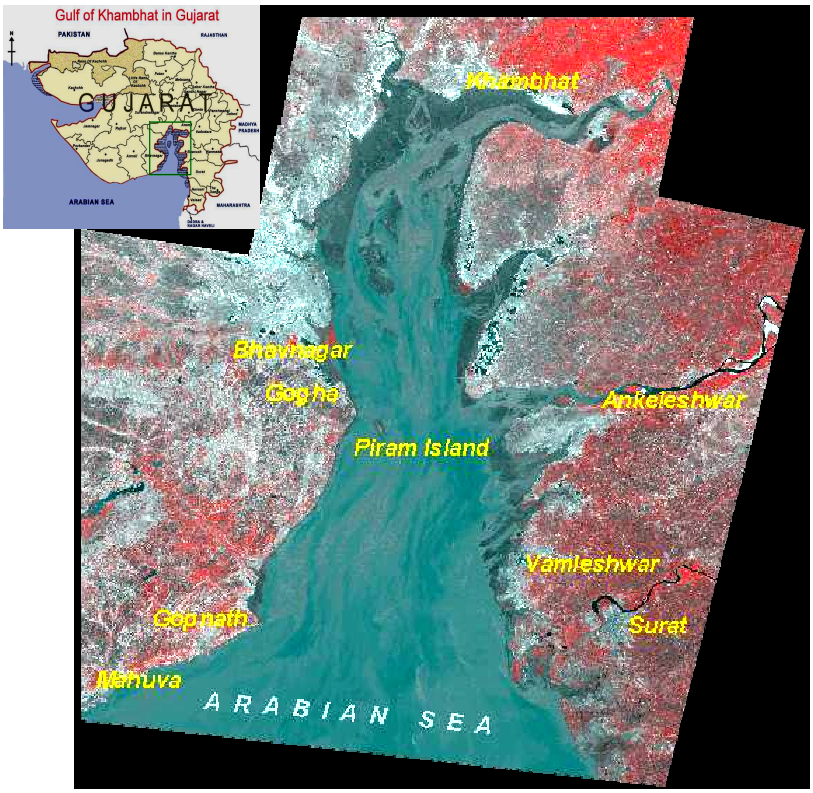


Fig. 1 - Satellite view of Gulf of Khambhat

In the interior of the Gulf, off Ghogha there is a small island viz. Piram Bet and further north there are large shoals which get exposed during low tide. A series of shallow banks run linear at the Gulf mouth, making navigation hazardous even for country crafts. The shoreline of the coast between Bhavnagar and Gopnath provides an assemblage of erosional and depositional features related to tectonic and eustatic factors resulting in gaining of land in between Bhavnagar and Mahuva. Rapid development and heavy industrialisation on the coast line of the Gulf has resulted in the degradation of the environment and decline in biodiversity.

2.1 Physiography

The Gulf receives rains during the southwest monsoon (from June to September), the average annual rainfall varies from 600 mm on the western side to 800 mm on the eastern side. The Gulf has a positive water balance, mainly due to the high volume of river runoff. The relative humidity ranges between 65 and 86% thus offering semi-arid to sub-humid climatic conditions. Temperature in the Gulf is extreme, the lowest being 8.4°C during January and highest of 43.7°C during May.

The depth of the Gulf ranges from 18 to 27 m and is less than 20 m over most of its length. However, the depth at the head is as low as 5 m and in the channel on the eastern side of the Piram Bet it is about 50 m. The tides are of mixed semi-diurnal type, with large diurnal inequality and varying amplitude, which decrease from north to south. Because of its unique position (nearness to the Tropic of Cancer), Gujarat coast experiences very high tides; the highest anywhere along the Indian coast. Because of the funnel shape and the semi-enclosed nature at the head, the tidal height increases tremendously in the upstream. The mean tidal elevation during spring is 4.7 m at Mahuva Bandar which rises to 6.5 m at Gopnath Point and 10.2 m at Bhavnagar. The maximum spring tide recorded at Bhavnagar is 12.5 m, which is second only to that of the highest tide recorded anywhere in the world (around 17 m at the Bay of Fundy on Newfoundland coast of Canada). Because of the high tidal amplitude, especially in the upper Gulf, it has huge inter-tidal expanses of 1.5 to 5 km, perhaps the widest along the Indian coast.

Long-shore currents with low wave dominate the open coasts along the Arabian Sea. However, due to exceptionally strong flood and ebb tides, powerful tidal currents with a speed of 3 to 4 knots dominate the flow. Maximum velocities of 6 knots associated with high wave energy occur during mid-tide. Currents in the Gulf, though tidal, are monsoonal in origin and dominated by barotropic tides (Unnikrishnan *et al.,* 1999). The flow adjusts its directional orientation with the changing direction of wind effected by changing seasons of the year. The turnover residence times are quite short because of its shallow depth, large tidal amplitude and strong tidal current.

3. Development of GIS based Information System

The information system for Gulf of Khambhat integrates the existing diverse coastal and environmental data set collected on the biodiversity with data on land use and developmental activities to facilitate planners to manage and protect the health and wealth of the ecosystem.

The Information System incorporates the following:

- Land use / Land cover and geomorphology of the area
- Present status of mangrove cover in the area and causes of its degradation
- Water and sediment quality
- Present status of distribution of phytoplankton, zooplankton, benthos, seaweeds and fishes.
- Commercial activities in the area and their impact on marine biodiversity.
- Socio-economics of the area

3.1 Methodology adopted

Remote sensing and Relational Database Management System (RDBMS) along with field survey were used in developing the information system for Gulf of Khambhat. Field and satellite data were selected as primary sources of information and GIS and RDBMS were used as tools to analyse and develop the complete information system.

Data on sea water, sediment quality, phytoplankton and zooplankton were extracted from COMAPS reports. Primary data on subtidal and intertidal benthos and seaweeds were collected by Gujarat Ecological Commission, Vadodara. Sampling stations for the study area are given in Figure 2. The data on fisheries were collected from Department of Fisheries, Gandhinagar. The methodologies for samples collection and analysis varies with respect to parameters studied.

Fig. 2 - Sampling stations along Gulf of Khambhat

3.1.1. Remote Sensing

Digital image processing was carried out using ERDAS-IMAGINE 8.4 software. The present study was carried out using two scenes of satellite imageries: IRS 1D 92/57, 13-02-98 and IRS 1D 93/57, 10-2-98 (Fig.1). Also, satellite data path / row : 148 / 45, TM-L5 (Landsat Satellite), 12-01-87 has been processed. The Survey of India toposheets (1:250,000) and NHO charts were used to geocode the maps and to rectify the digital data. The base map, marine and land features like geomorphology, land use pattern, etc., were digitised onscreen using satellite images with an accuracy of about 80%.

3.1.2. Relational Database Management System (RDBMS)

Relational Database Management System (RDBMS) is essential for storing and accessing a set of collected data in the form of tables. A database was developed with the collected non-spatial data on physico-chemical parameters, flora, fauna, microbiological parameters, etc., using Visual Basic and Oracle as front and back ends, respectively. For GIS purpose, the oracle data were converted to Access / dBase tables. The spatial data derived

from satellite image and non-spatial data stored in the data base were integrated in the GIS using ARCVIEW 3.2 software.

4. Description of Information System

4.1 Physical Environment

4.1.1 Geomorphology

The eastern coast of Saurashtra extends upto Bhavnagar, beyond which it becomes a part of the Gulf of Khambhat. The coastline of the Gulf is diverse in geomorphic condition with a number of estuaries, creeks, islands, mudflats and salt marshes. A vast track of saline low land from Bhavnagar to Khambhat is a paleo-mudflat known as 'Bhal' region (Patel, 1996). The coastline from Gopnath to Ghogha is rocky with small narrow non-calcareous sandy beaches and from Ghogha right up to the mouth of Sabarmati river, it is highly muddy and shows extensive development of mudflats and mudbanks (Fig.3). The Shetrunji river which meets the Gulf near Gopnath forms a prominent estuarine delta at Sultanpur. The segment from Khambhat to Bharuch is alluvial, characterised by steep and cliffy river mouths abruptly rising to as much as 30 m above the tidal flats.

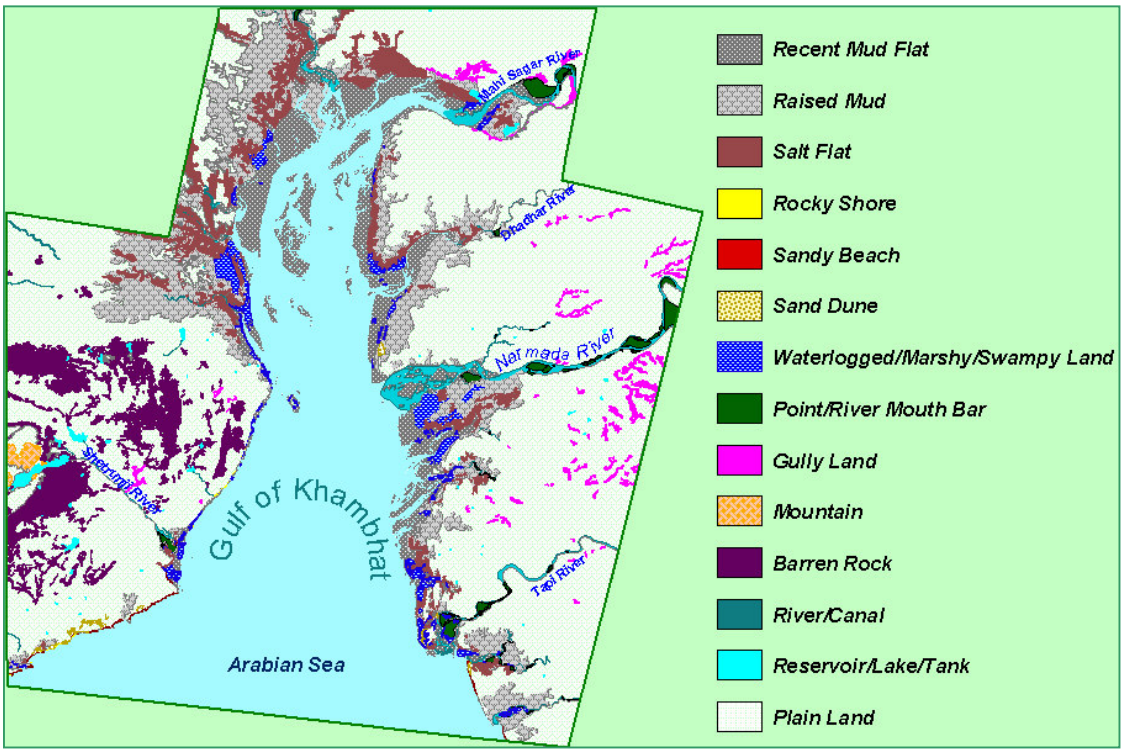


Fig. 3 - Geomorphology of Gulf of Khambhat

Studies on Landsat data indicated significant geomorphological changes in land forms such as shoreline, estuaries, mudflats, islands, mangroves, cliffs, dunes, floodplains, etc., in the past two decades (Naik and Baldev, 1985; Shaikh *et al.,* 1989). These changes were due to erosional and depositional processes not only by natural agents like strong tidal forces, but also through developmental activities such as construction of dams, destruction of mangroves due to human interference and rapid industrialisation. Shoreline changes in Mahi and Narmada estuaries are significant. The erosion processes are predominant in the Mahi estuary, while depositional activities are dominant in Narmada estuary. It is observed that the deposition at the mouth of Narmada estuary is at its maximum, as a result the Aliya Bet island got connected to mainland by gradual expansion in the mudflat area (Fig.3).

4.1.2 Geology

Thick coastal sediments occupied the entire northern Gulf and eastern coast of southern Gulf (Fig.4). Bhavnagar district bears Deccan traps, while Alluviam covered most parts of Ahmedabad, Kheda, Bharuch and Surat districts. Pleistocene sediments are confined only to Mahuva region.

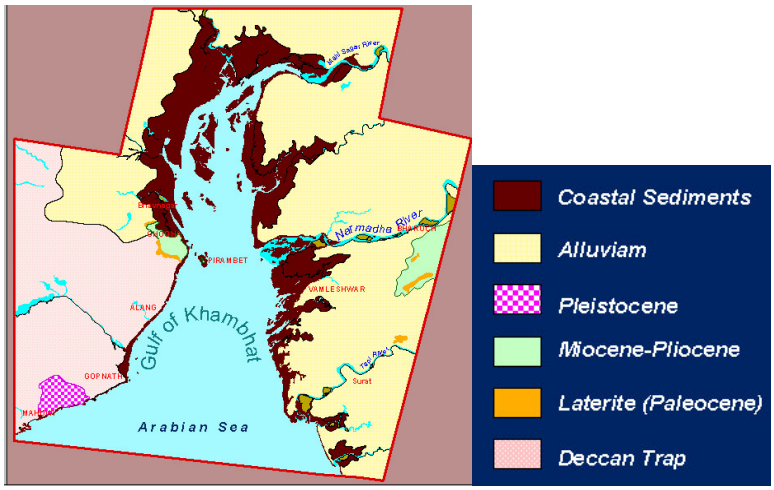


Fig. 4 - Geology map of the Gulf

4.1.3 Land use / Land cover

Gulf of Khambhat receives 600-800 mm rainfall during the south-west monsoon. Out of the total cultivable land in the coastal area, irrigated land is estimated to be about 26%. Irrigation through groundwater does not reveal any alarming situation as only 46% of The total irrigation falls within this category. Forest cover around the Gulf, constitutes a meagre 0.02% of the total study area. Mangrove occupied a total of 53.95 km^2 with distribution of only

three species. A vast stretch of grass land is found on Aliya Bet, an island at the mouth of Narmada. The details of land use and land cover of the Gulf are depicted in Fig. 5 and Table 1.

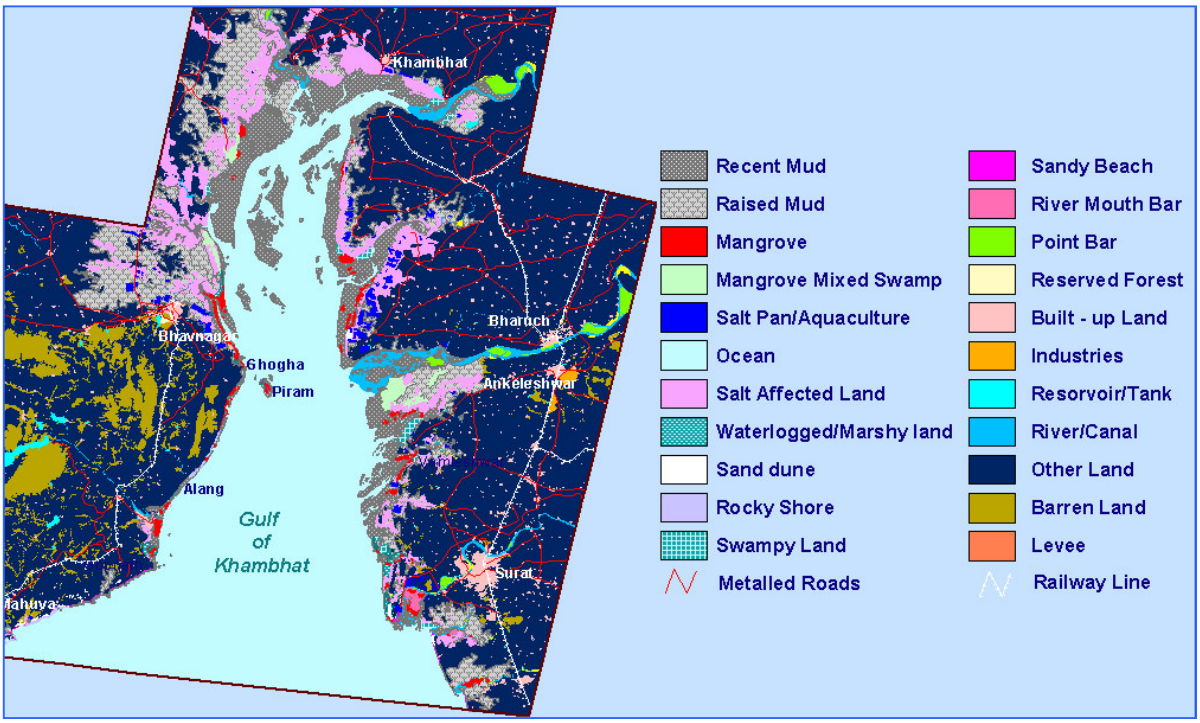


Fig. 5 - Land use/ cover of the Gulf

Table 1 - Area details of Land Use / Land cover of the Gulf

Classification	Area (km^2)	Classification	Area (km^2)
Aquaculture	1.47	Salt Pan	132.52
Barren Land	888.91	Sand Dune	14.48
Salt affected Land	668.87	Sandy Beach	8.36
Industries	33.11	Built-up Land	391.84
Island	0.72	Swampy Land	50.46
Levee	25.24	Water logged / Marshy Land	31.10
Mangrove	53.95	Reserved Forest	2.76
Mangrove Mixed Swamp	67.16	Reservoir / Tank	57.37
Point Bar	77.28	River / Canal	308.87
Raised Mud	1462.87	River Mouth Bar	19.89
Recent Mud	1124.86	Other Land	9234.81
Rocky Shore	5.20	**Total**	**14662.08**

4.2 Coastal and Marine Environment

4.2.1 Ecology

4.2.1.1 Mudflats

The Gulf supports a vast intertidal expanse of 3268 km^2, the maximum along the Indian coast, due to high tidal range. Owing to the conical shape, the intertidal mudflats of northern Gulf extend to about 5 km (Fig.6). However, the mudflats of the southern Gulf are restricted mostly towards eastern side. The mudflats of the Gulf have extended to an area of about 2588 km^2 (Table 1).

Fig. 6 - Intertidal Mudflats of the Gulf

4.2.1.2 Mangroves

Mangroves are the dominant coastal vegetation growing in the clayey, silty intertidal coastal zones, deltaic and estuarine coasts, backwaters and sheltered regions. The coast around the Gulf is indented by estuaries and consists of extensive mudflats and sporadic presence of sandy beaches favourable for mangrove vegetation. However, mangroves in the coastline of the Gulf are stunted and sparse in distribution.

Mangroves are dominant near Bhavnagar, Devla in Bharuch, Mangrol, Pardijankri, Dashariphalia and Dandi in Surat (Fig.7). Piram Island, Ghogha and Mahuva showed high density of *Avicennia marina.* Mangroves in the intertidal mudflats are stunted and sparse particularly near Mahi, Dhadhar, Kim and Sena estuaries. A patch of *Avicennia* is observed in Aliya Bet at the mouth of the Narmada estuary. At most of the places, the growth is stunted and horizontal. Some tall trees were observed at Piram Island. Districtwise details of Mangroves of the Gulf are as follows:

Bhavnagar	-	15.57 km^2
Ahmedabad	-	2.96 km^2
Bharuch	-	22.91 km^2
Surat	-	8.52 km^2
Navsari	-	3.41 km^2
Islands/Islets	-	0.57 km^2
Total	**-**	**53.94 km^2**

Fig. 7 - Mangroves of the Gulf

The total mangrove area estimated is well in agreement with 52.46 km^2 for the period November 1999 (Singh, 2000). Mangroves of Ghogha Jetty, Bhavnagar creek and coastal Ahmedabad district are scrubby, expanding gradually to the surrounding areas due to plantation carried out by the Forest Dept. *Avicennia marina* dominated as a single species in most of the mangrove patches. *Sonneratia apetala* is found either scattered or in dense patches in a few places. General features of the mangroves in the Gulf are presented in Table 2.

Table 2 - General features of Mangrove in the Gulf of Khambhat

Station	Species	Occurrence	Distribu-tion	Habit	Habitat	Av. Ht (m)
Mahuva	*Avicennia marina*	Dominant monotype	Patchy	Stunted	Intertidal in the creeks	0.75
Ghogha	*A. marina*	Dominant monotype	Patchy at places and uniform at plantations	Stunted	Intertidal	0.75 - 1.0
Piram	*A. marina*	Dominant monotype	Random at places and uniform at plantations	Stunted tree	Intertidal	0.75
Vamleshwar (off Aliya Bet)	*A. marina*	Dominant	Scattered	Stunted	Intertidal	0.40

The satellite data of 1987 and 1999 have been compared to study the changes of features around Piram Bet (Fig.8). Mangroves exhibited a marginal decrease in area from 0.74 to 0.57 km^2, marshy land has experienced a reduction of 57% from 0.28 to 0.16 km^2, whereas sandy beach area increased from 0.20 to 0.30 km^2 between 1988 and 1999.

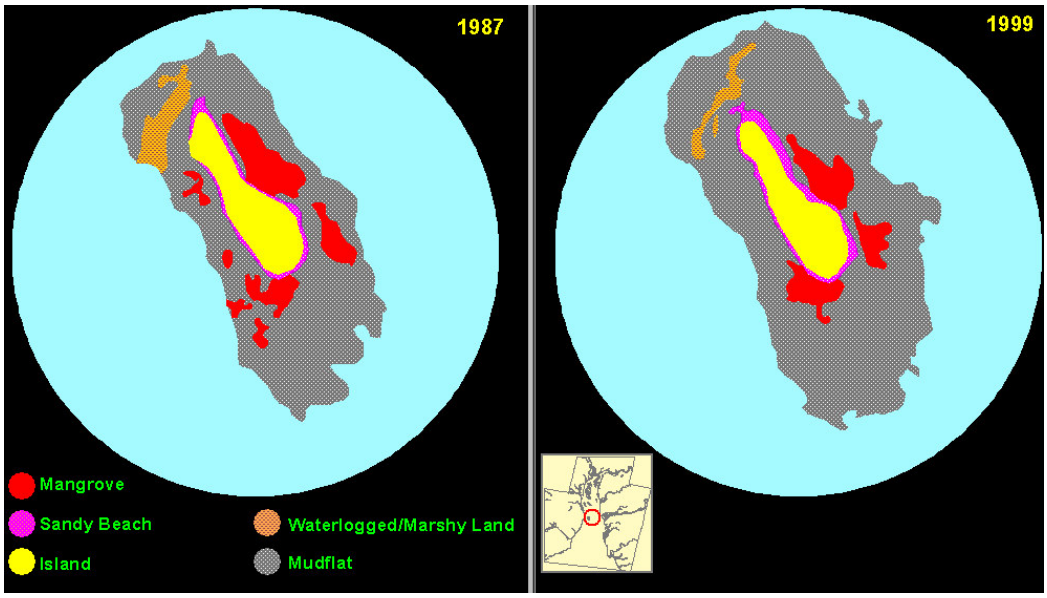


Fig. 8 - Area changes at Piram Bet during 1987-99

The estuarine area of Tapi constituted a unique ecosystem with dense forest of pure patches of *Sonneratia apetala* (Fig.9), *Avicennia marina* and *Acanthus ilicifolius*. *Avicennia marina* is evenly distributed. *S. apetala* formed dense forest and had close canopy, their height varied from 4 to 7m and girth from 20 to 55 cm.

Fig. 9 - *Sonneratia apetala* in Tapi estuary (critically endangered)

4.2.1.2.1 Degradation of mangroves

Mangrove in the Gulf of Khambhat has suffered severe degradation over a span of 20-30 years (GSEAP, 2000; Table 3). Mangroves which were present 30 years ago at Sigam, Zamdi and Malpore villages of Khambhat district are not available now. Mangroves in the area

are heavily exploited and reduced to open scrubby forms with very simplified zonation. A major reduction of mangroves to the extent of 50% occurred between 1960 and 1970 and continued to degrade further to 13 km^2 in 1993 which is roughly 10% of the mangroves in 1970 (Table 3). However, between 1993 and 1998 mangrove area increased to four fold due to afforestation measures taken by State Government and others.

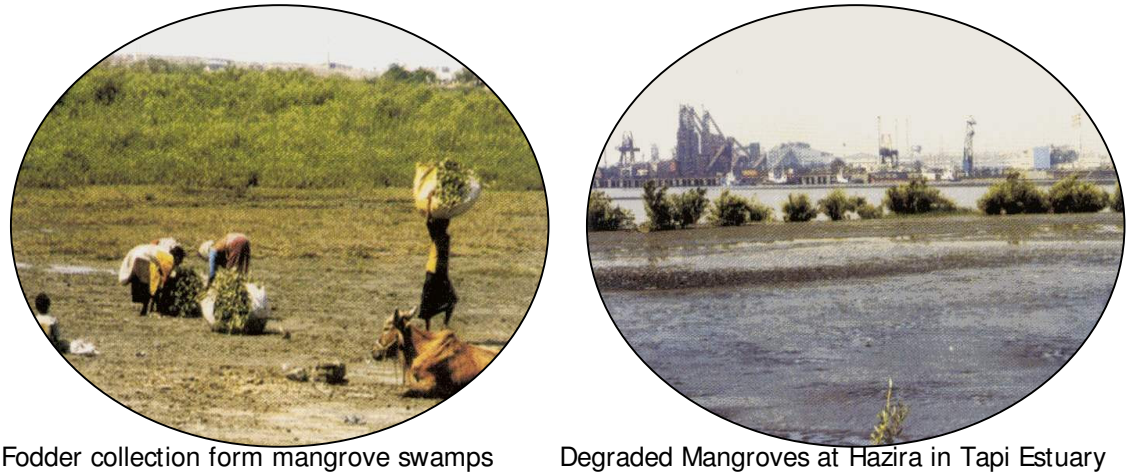
Table 3 - Changes in area under mangrove over the years

Year	Source	Area (km^2)
1870	Survey of India	338
1960	FIP	325
1970	Survey of India	160
1980	Untawale	100
1987	Survey of India	105
1990	Fishery Survey of India	56
1993	Gujarat Environment and Ecology Research Institute	13
1998	Integrated Coastal and Marine Area Management – Project Directorate (ICMAM-PD)	54

The various causes for degradation of mangroves are as follows:

- Illicit cutting for firewood.
- Use as fodder to cattle and camel.
- Hypersalinity of the soil – 7.45% of the whole area of the Gulf has been salt affected during 1960, which rose to 54% in 1984, 57.6% in 1986 and 64% in 1993 (Ashwani Kumar, 1996).
- Destruction for salt works, construction of jetties, gas drilling plants and other structures in mangrove swamps.
- Damage caused by crab that cut the radicals of young seedling and thick mat of algae driven ashore by tides
- Damage from oil pollution (accidental spills, ship breaking yard at Alang), discharge of chemicals and other pollutants.

Figure 10 depicts the degraded mangroves in the region.



Fodder collection form mangrove swamps

Degraded Mangroves at Hazira in Tapi Estuary (ESSAR industry in the background)

Fig. 10 - Degraded mangroves of Gulf of Khambhat

4.2.1.2.2 Afforestation of Mangroves

The Gujarat State Forest Department has initiated the afforestation measures for regeneration of mangroves in Gulf of Khambhat. Good coverage of *Avicennia* was recorded in some parts of Bharuch and Surat districts, in the recent years.

4.2.2 Water Quality

4.2.2.1 Ground Water

This region has diverse hydro-meteorological condition and similarly the topography making run-off rate higher in certain parts. Most of the coastal taluks are declared as 'white' category region on the basis of water balance except Jambusar and Amod in Bharuch district (Table 4).

Table 4. Talukwise soil salinity along the Gulf of Khambhat (as on 1980)

District	Taluk	Area (km^2)	Salt affected area	
			Km^2 (apporox)	%
Bhavnargar	Bhavnagar	1462.40	1387.82	95
	Vallabhipur	594.00	302.94	51
	Ghogha	426	426	100
Kheda	Khambhat	1194.80	1194.80	100
Bharuch	Bharuch	665.50	5.27	0.8
	Vagra	883.56	588.15	67
	Amod	464.90	176.84	38
	Jambusar	1097.40	634.84	58

Source : GEC,1997

In Gulf of Khambhat, 8 coastal taluks of 5 districts are affected by ground water pollution. Low levels of dissolved oxygen (<4 mg/l), high COD (>50 mg/l) and total coliforms were observed in most of the taluks. In places like Ankleshwar, Chorasi and Olpad, the TDS levels are very high (3000-7000 mg/l) and are not potable. Heavy metal concentrations are also higher than the permissible limits in these taluks.

4.2.2.2 Sea Water

The COMAPS data on water quality of the Gulf for the periods December 1998 and February 1999 were considered for the offshore stations of Mahuva, Alang and Piram Bet on western coast and Aliya Bet on the east coast of the Gulf. The data on sea water quality are depicted in Figure 11.

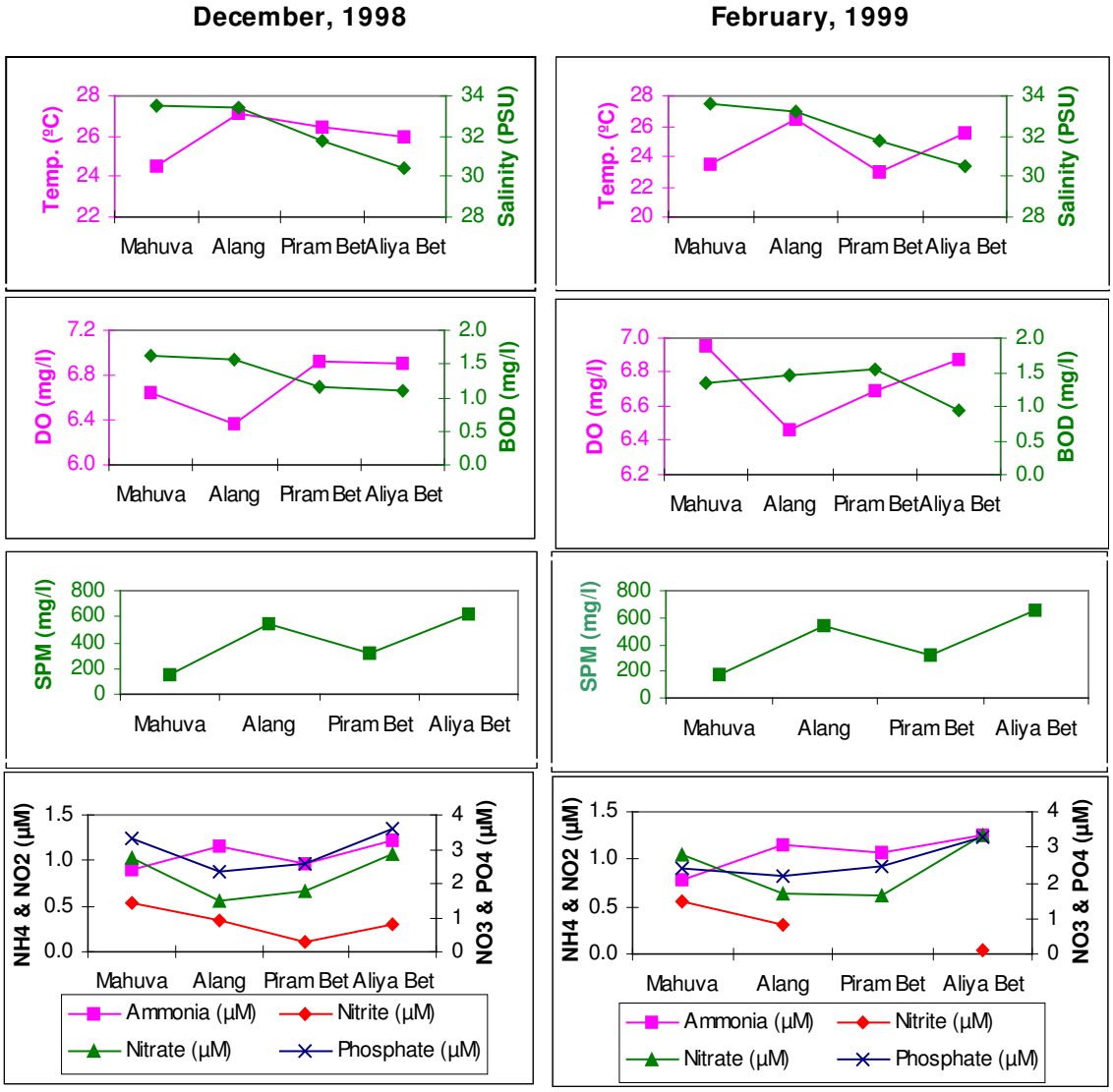


Fig. 11 - Sea Water quality of Gulf of Khambhat

Temperature varied between 23.0 and 27.1°C and did not show any significant temporal and spatial variation but followed that of atmospheric temperature. The Gulf displays estuarine condition around the river mouth and upstream with the influence of tides and river runoff. Aliya Bet being located at the mouth of Narmada river, influenced by the freshwater influx recorded the lowest salinity (~30.4 PSU). Piram Bet also recorded a lower salinity (~31.7 PSU) due to the influence of freshwater from Narmada and other rivers of northern Gulf.

The analysis of satellite data revealed that the turbidity of the Gulf water is highly variable and patchy (Fig.12). The northern Gulf waters are highly turbid as these areas are subjected to high tidal inundation. The shallow regions and areas close to mudflats and rivers also show high levels of turbidity. The rivers engulfing the area have a huge annual freshwater discharge of 38 km^3 carrying 74 million tons of sediments into the Gulf. Also, the tidal currents are fairly strong and bimodal in nature, the oscillatory motion churns the bottom sediments due to which the waters are heavily loaded with suspended matter. For example, the areas close to river runoff like Aliya Bet exhibited high suspended particulate matter (~600 $mg.l^{-1}$). The SPM load in the northern Gulf waters, where large intertidal mudflats prevailed, recorded a maximum value of 4000 $mg.l^{-1}$. The deeper regions and areas away from the river influence like Mahuva are relatively clear. High SPM values at Alang are due to the ship breaking activities.

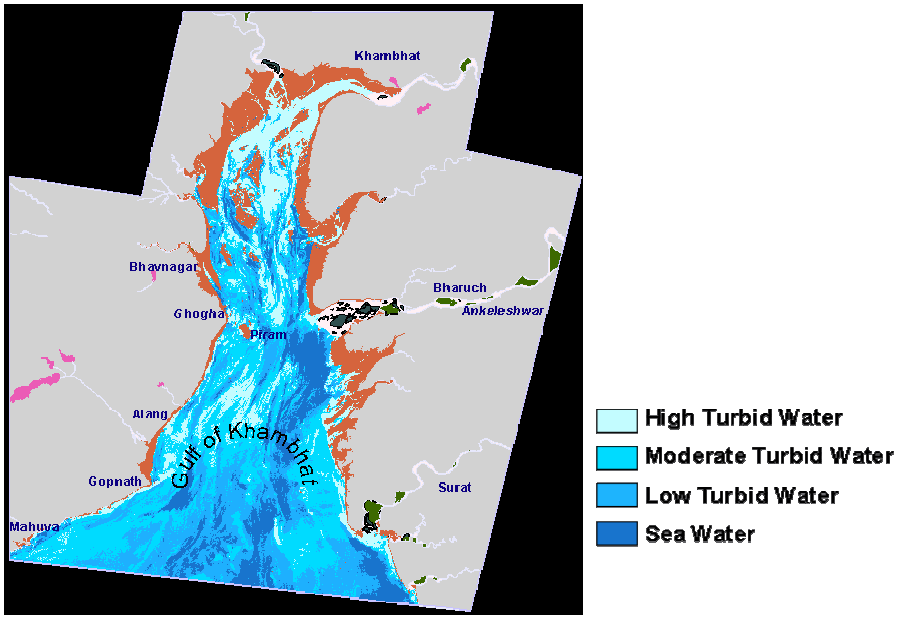


Fig. 12 - Turbidity Map of the Gulf

The waters are well oxygenated and DO levels exceed 6.0 $mg.l^{-1}$ at all the stations. High DO and low BOD values (2 $mg.l^{-1}$) at all the stations indicated the effective oxidation of organic matter. The distribution of DO and BOD also did not show any significant temporal and

spatial variations. Though nutrient concentrations are within the acceptable limits, levels of nitrate and phosphate are relatively high at Aliya Bet due to terrigenous input from the rivers.

4.2.3 Biodiversity

Data on phytoplankton and zooplankton were also extracted from COMAPS reports for the periods December 1998 and February 1999 for the offshore stations of Mahuva, Alang, Piram Bet and Aliya Bet. Subtidal benthos data were collected for March 1999 and the data on Intertidal benthic fauna and seaweeds were collected for June 1998, October '98 and March '99 by GEC, Vadodara.

4.2.3.1 Phytoplankton

The overall diversity of phytoplankton in the coastal regions of the Gulf during December 1998 and February 1999 indicated the presence of 26 and 35 genera, respectively. Bacillariophyceae dominated in both the seasons (15 and 22 genera respectively during 1998 and 1999) followed by Dinophyceae (7 and 10 respectively). Cyanophyceae was represented by only one genus in both the periods. The spatial distribution of phytoplankton (Table 5) revealed that Aliya Bet recorded the highest diversity with 16 genera followed by Mahuva (13), Alang (9) and Piram Bet (8) during December 1998, while the diversity was almost uniform at Mahuva (20), Piram Bet (19) and Aliya Bet (19) during February 1999.

Table 5. Spatial and temporal distribution of Phytoplankton

Location	Bacillariophyceae		Dinophyceae		Cyanophyceae		Total	
	Di*	De#	Di*	De#	Di*	De#	Di*	De#
	DECEMBER 1998							
Mahuva	9	168	4	44	-	-	13	212
Alang	6	146	3	22	-	-	9	168
Piram Bet	6	144	1	24	1	8	7	175
Aliya Bet	10	372	6	142	-	-	16	514
	FEBRUARY 1999							
Mahuva	15	586	4	172	1	4	20	758
Alang	10	408	3	14	-	-	13	422
Piram Bet	11	394	8	204	-	-	19	598
Aliya Bet	12	580	7	126	-	-	19	706

* Di: Generic Diversity; # De: Density (nos.l^{-1})

The genus *Coscinodiscus, Biddulphia, Surirella, Navicula, Peridinium, Nitzschia*, etc., were widely recorded and their dominance was more towards open Gulf near Mahuva and Aliya Bet. Aliya Bet recorded the highest density during December 1998. During February 1999, the density was the highest at Mahuva followed by Aliya Bet during February 1999. The relatively high nutrient availability at these stations (Table 6) have resulted in high abundance of phytoplankton population.

4.2.3.2 Zooplankton

The occurrence of zooplankton revealed the dominance of copepods and eggs in most of the stations in both seasons studied (Table 6). However, their percentage contribution varied seasonally and stationwise. Density of larvae occupied third position after copepods and eggs. Hydrozoans, pyrosomids, and chaetognaths had good shares in most of the stations. Chaetognaths, cladocerans and foraminiferans occurred in moderate numbers.

Table 6 - Spatial and temporal distribution of Zooplankton density

(Units in nos.m^{-3})

Location	Mahuva		Alang		Piram Bet		Aliya Bet	
	1998	1999	1998	1999	1998	1999	1998	1999
Copepods	187500	7500	5000	20000	5000	17500	7500	17500
Hydrozoans	17500	5000	-	-	-	2500	2500	2500
Tintinnids	30000	12500	12500	12500	2500	-	7500	2500
Pyrosomids	2500	-	2500	12500	2500	-	2500	-
Foraminiferans	-	2500	-	-	-	-	-	-
Chaetognaths	-	-	-	5000	-	-	-	-
Cladocerans	-	-	-	-	-	-	2500	-
Fish eggs	87500	70000	12500	37500	2500	7500	12500	10000
Decapod larve	42500	17500	5000	50000	2500	17500	5000	12500
Echinoderm larve	7500	-	-	-	-	2500	-	-
Polychaete larvae	15000	2500	2500	-	-	-	5000	2500
Total	**390000**	**117500**	**60000**	**137500**	**15000**	**65000**	**45000**	**47500**

1998 – December 1998; 1999 – February 1999.

4.2.3.3 Subtidal Benthos

The subtidal benthos along the shallow regions of the Gulf during March 1999 consisted of 7 groups, the major group being bivalves. *Tellina sp.* dominated this group occurring at 2 stations. Polychaetes also occurred in 2 stations with lesser numbers. Gastropods, scaphopods, copepods and amphipods were also observed at a few stations, their

occurrence being very less (Table 7). Plant debris and broken shells (coarse and fine) were observed in most of the sampling stations. Mahuva recorded maximum density. Overall, the Gulf was observed to be poor in faunal diversity and total count. This might be due to the suspension and re-suspension of sediments by strong semi-diurnal currents at the bottom.

Table 7 - Details of marine benthic fauna in Gulf of Khambhat

Groups/ Species	Density (No/ m^2)		
	Bharuch	**Gopnath**	**Mahuva**
Gastropods			
Turbo sp	20	-	-
Juvenile Gastropod	-	-	70
Scaphopods			
Dentalium sp.	-	-	60
Bivalves			
Tellina sp.	-	40	90
Katelysia sp	-	-	10
Arca sp	-	-	40
Pholas sp	-	20	-
Oyster spat	-	-	20
Minute bivalve	-	-	20
Polychaetes	20	-	10
Copepods	20	-	-
Amphipods	-	-	20
Crab juvenile	10	-	-

4.2.3.4 Intertidal Benthos

As a whole, the diversity of intertidal benthic fauna was more during monsoon (17) and premonsoon (14) and low during post-monsoon (8). Gastropods have dominated at all the stations followed by crustaceans (Table 8). Gopnath and Mahuva recorded the highest density during monsoon, while Piram Bet was the highest during post-monsoon.

Among the gastropods, *Littorina scrabra* and *Nodilittorina sp.* were abundant in upper and mid-intertidal zones at Mahuva. Among bivalves, density *of Crassostrea* sp. was higher in mid inter-tidal region of Gopnath during pre-monsoon. *Crethium* sp. and minute gastropods (unidentified) were abundant in upper and mid-inter-tidal regions at Ghogha station.

Table 8. Spatial and temporal distribution of Intertidal Benthic Fauna

Location	Bivalves		Gastropods		Crustaceans		Others		Total	
	Di*	De#	Di*	De#	Di*	De#	Di*	De#	Di*	De#
	JUNE 1998									
Mahuva	-	-	4	520	3	96	-	70	7	686
Gopnath	1	31	4	131	2	34	1	433	8	598
Ghogha	1	114	1	31	2	89	1	-	5	234
Piram Bet	-	-	-	-	-	-	-	-	-	-
Aliya Bet	-	-	-	-	-	-	-	-	-	-
	OCTOBER 1998									
Mahuva	1	6	4	50	-	-	1	11	6	67
Gopnath	-	-	3	53	1	13	-	-	4	66
Ghogha	-	-	2	103	1	17	-	-	3	120
Piram Bet	-	-	-	-	1	556	-	-	1	556
Aliya Bet	-	-	-	-	-	-	-	-	-	-
	MARCH 1999									
Mahuva	-	-	4	8	-	-	-	-	4	8
Gopnath	-	-	1	19	2	143	-	-	3	162
Ghogha	-	-	2	253	-	-	-	-	2	253
Piram Bet	-	-	1	23	2	52	-	-	3	75
Aliya Bet	-	-	-	-	3	15	1	47	4	62

* Di: Species Diversity; # De: Density (nos.m^{-2})

4.2.3.5 Marine Algae

As a whole, 13 species of algae were recorded during post-monsoon followed by 12 species during pre-monsoon and 8 species during monsoon. Mahuva and Gopnath, having rocky intertidal shoreline, have recorded high diversity during October 1998 and March 1999. *Ulva lactuca, U. fasciata* and *Enteromorpha tubulosa* were the most common species in these areas. At Piram Bet, only blue green algal filaments were recorded from the mid-littoral zone and a green alga and one red alga (*Enteromorpha, Ulva* and *Gracilaria*) were observed during pre-monsoon. The spatial distribution of marine algae in the Gulf is depicted in Table 9.

As far as the seasonal variation is concerned, it is negligible during the monsoon season where as, optimum growth of algae had been observed during the pre-monsoon season. Mahuva displayed maximum species in pre - monsoon and post – monsoon seasons, whereas Ghogha did not show much variation in all the seasons. The poor diversity of marine algae at Gulf of Khambhat may be due to high siltation rate and strong currents which are not conducive for marine algal growth.

Table 9 - Qualitative distribution of Marine Algae in the Gulf

Location	Chlorophyceae	Cyanophyceae	Rhodophyceae	Bacillariophyceae
	JUNE 1998			
Mahuva	-	-	-	-
Gopnath	8	2	-	1
Piram Bet	-	-	-	-
Ghogha	-	-	3	-
	OCTOBER 1998			
Mahuva	3	2	2	-
Gopnath	4	1	5	-
Piram Bet	1	2	-	-
Ghogha	2	2	-	-
	MARCH 1999			
Mahuva	3	2	4	-
Gopnath	4	1	3	-
Piram Bet	1	2	1	-
Ghogha	2	2	-	-

4.2.3.6 Fishery

Fishing activity is well established in Bhavnagar, Bharuch and Surat districts. A total of 6115 fishermen from 3017 families are involved in fishing in the region and about 16,280 tons of fish was landed (1999-2000) at 41 landing centres in the Gulf of Khambhat. With less number of active fishermen (28.83% of total population) and minimum number of mechanised boats (only 10), Surat district got the maximum share which may be due to high productivity in the region and easy accessibility for exploitation. Details of marine fish landing in the Gulf of Khambhat region are presented in Table 10.

Major commercial fishery is constituted by Bombay duck with 24.91% of the total fish catch followed by shrimp with 22.39%. Groupwise marine fish production in the Gulf is depicted in Figure 13 and the common fishes in Figure 14.

Table 10 - Marine Fish production in the Gulf of Khambhat during 1999-2000

District / Taluk	No. of landing centres	Active fisher Men	Fishing boats	Fish landings (tons)	% of share
Bhavnagar Dist					
Bhavnagar	2	833	24	414	2.54
Ghogha	2	691	43	1316	8.08
Talaja	3	439	52	1444	8.87
Mahuva	2	265	28	668	4.10

District / Taluk	No. of landing centres	Active fisher Men	Fishing boats	Fish landings (tons)	% of share
Kheda Dist					
Khambhat	1	369	0	1454	8.93
Bharuch Dist					
Hansot	1	173	0	160	0.98
Vagra	4	406	2	265	1.63
Jambusar	13	1190	22	1757	10.79
Surat Dist					
Choryasi	7	1405	44	5819	35.73
Olpad	6	1128	0	2986	18.34
Total	***41***	***6899***	***215***	***16283***	***100.00***

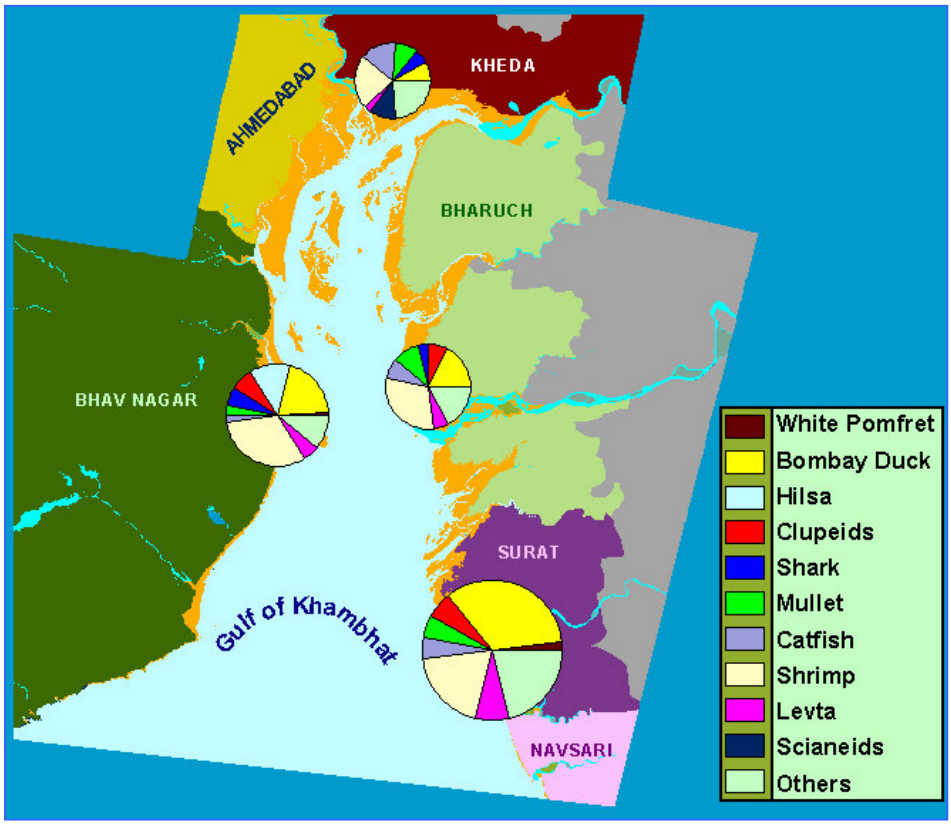


Fig. 13 – Group-wise marine fish production in the Gulf during 1999-2000

Mudskipper, clupeids, mullets and catfish combinedly contributed to 21.88% of total fish catch of the Gulf. Mudskippers *(Boleopthalmus dussumieri*) form an important fishery in the intertidal mudflats all over the coast. The dominance of Bombay duck depends mainly on the prevalence of optimum tidal amplitude and ideal nursery grounds like mangrove zones in the Gulf.

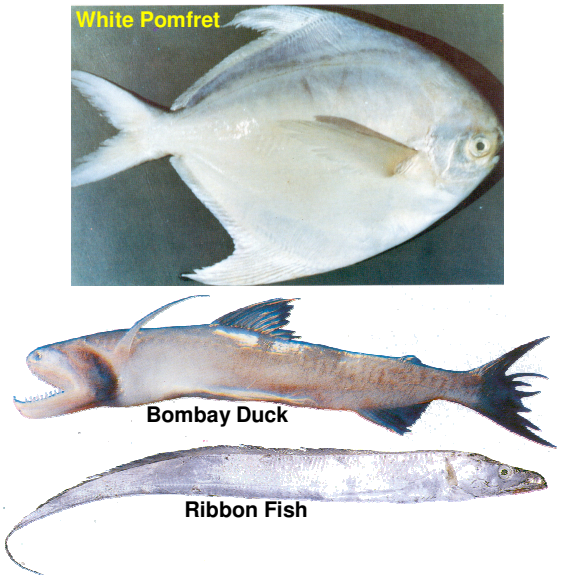


Fig. 14 - Common Fishes of the Gulf

Year-wise fish catch for the past decade showed that the minimum catch was recorded during 1993-94 and the maximum during 1995-96 (Fig.15). However, the fish production in the region remained at >15,000 tons in the past six years except during 1998-99. Landings of scianeids decreased during the last few years and their percentage contribution varied considerably. *Otolithus cuvieri, Johneieops macrorhymus, J.vogleri, J.sina, Johnius glaucus* and *Protonibea diacanthus* dominated in the catch. Surat district recorded the maximum fish catch, while Kheda district recorded the minimum in all the years.

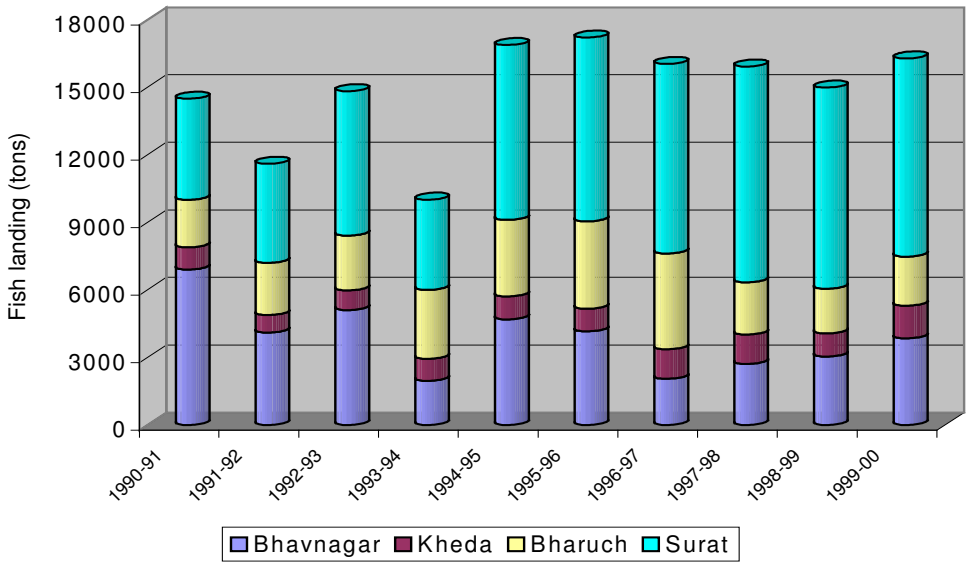


Fig. 15 - Yearwise fish landing in the coastal districts of the Gulf

4.3 Economic Activities

4.3.1 Ports

All weather ports of adequate size and facilities help to strengthen trade and industrialization process and also relieve congestion of the existing ports easing environmental problems. Gujarat State is strategically positioned on the west coast to serve the vast north and central Indian hinterland. The State as of 1995 has one major, 11 intermediate and 7 minor ports. Out of this, one intermediate (Bhavnagar) and five minor (Mogdalla, Dahej, Ghogha, Talaja and Mahuva) ports lie in the Gulf. Commodities such as fertilizer, rock phosphate, food grain, sulphur, Iron/iron scrap, coal, machinery, fuel oil, cement, clinker, lime stone, propylene, naphtha, paraxylene, butene, ethylene, etc., are the major imports, while food grains, cement, clinker, oil cakes, lime stones, soda ash, soyabean, other seeds, mollasses, machinery, etc., are the major items exported through these ports.

The ports in Gujarat handled 25.7 MT cargo during 1997-98, accounting for over 80% of the traffic handled by all ports in India. In order to cater to the needs of increasing cargo traffic without creating resource crunch, Gujarat Government announced a new port policy in 1995 permitting private investment. Dahej will be developed as a chemical port by Gujarat Chemical Port Terminal Co. Ltd., as a joint venture by IPCL, GNFC, GIIC and GMB. Mithivirdi and Dholera of Bharuch district are being developed as all-weather ports for general cargo and for steel and automobiles, respectively. Dahej and Hazira of Surat district are being developed for general and industrial cargo.

4.3.2 Ship Breaking

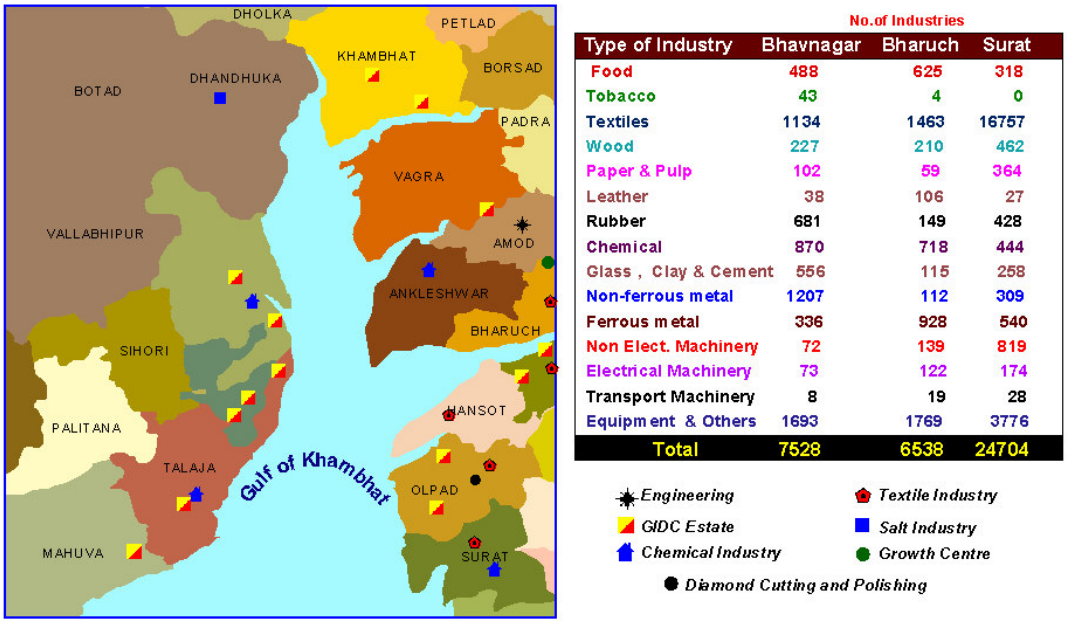
The world's largest ship breaking yard is located at Alang-Sosiya complex, Bhavanagar district. Availability of high tidal amplitude (up to 12 m), silt free beach, quick drying of seabed during the ebb tide, labour at less cost and ready market for the iron scrap have made Alang a highly suitable site for ship breaking. The breaking yard comprises 183 plots of different sizes and till now a total of 2453 ships mainly tankers, cargo carriers and bulk carriers were broken, providing a total of over 17 million tons of steel to the rerolling industries (GSEAP, 2000). The yard has reinforced growth of downstream industries like re-rolling, oxygen-producing and LPG bottling plants within Alang-Bhavnagar-Sihor triangle.

The ship breaking yard generates about 7500 MT of industrial solid waste per year, of which 32.37% is hazardous (GSEAP, 2000). The operation of the ship breaking yard of Alang has led to compaction and contamination of sediments in the littoral zone, the

dispersal of petroleum hydrocarbons, solid wastes, heavy metals and other toxic materials released in the off-shore and intertidal zones during ship breaking process, the bio-accumulation and bio-magnification of pollutants in the tissue of marine biota, which could damage the ecosystem irreversibly. People working are exposed to free asbestos fibre and vapours and dusts which contain heavy metals, tributyl tin, polycyclic, aromatic hydrocarbons and dioxins.

4.3.3 Industries

Liberalisation of Industrial Policy by the State/Central Government and the prevalence of vast coastline attracted many entrepreneurs for setting up of major and minor industries around the Gulf. The Govt. of Gujarat has established a corporate body viz. Gujarat Industrial Development Corporation (GIDC) to develop industrial estates with provisions for supply of water, electricity, roads, drainage system for effluents, communication system, etc., at suitable places all over the State. This, along with tax benefits offered by the State and other facilities such as availability of raw materials and good market for finished products has attracted many industrialists, through which Gujarat has emerged as a major industrial state. The GIDC has already developed 8 industrial estates around the Gulf; 3 in Bhavnagar, 1 in Kheda, 2 in



Type of Industry	Bhavnagar	Bharuch	Surat
Food	488	625	318
Tobacco	43	4	0
Textiles	1134	1463	16757
Wood	227	210	462
Paper & Pulp	102	59	364
Leather	38	106	27
Rubber	681	149	428
Chemical	870	718	444
Glass , Clay & Cement	556	115	258
Non-ferrous metal	1207	112	309
Ferrous metal	336	928	540
Non Elect. Machinery	72	139	819
Electrical Machinery	73	122	174
Transport Machinery	8	19	28
Equipment & Others	1693	1769	3776
Total	7528	6538	24704

Fig. 16 - Industries in the Gulf of Khambhat

Bharuch and 2 in Surat districts (Fig.16), out of which, the major one is situated in Ankleshwar, Bharuch district accomodating around 2000 units mostly of chemical and pharmaceuticals industries. Majority of the large-scale industries around the Gulf are located in Surat and

Bharuch districts (iNDEXTb,1999). An estimated quantity of around 5000 million m^3 of waste water is being discharged annually from these industries into the Gulf.

4.3.3.1 Small-Scale Industries

The cumulative registration of SSI units in the coastal taluks in 1996 (GSEAP, 2000) reveals that the coastal districts around the Gulf account for 79% of the total SSI units, Ahmedabad being the highest with 44570 (47%) units (Fig.17). This is due to the declaration of Dhandhuka taluk as eligible for incentives for industrial backwardness. Surat district has 26715 units (28%) Chorasi taluk having an overwhelming share of 90%. Bhavnagar district has most of the SSI units concentrated in Bhavnagar taluk and the rest of the coastal taluks are industrially backward. In the coastal taluks of Bharuch district, Ankleshwar (44%) has the highest concentration of coastal SSI units, followed by Bharuch (34%). Other coastal taluks of the districts like Vagra, Jambusar, Amod and Hansot are also classified under categories eligible for incentives. Industries that contribute significantly towards water pollution such as chemicals and pharmaceuticals, dye and dye intermediates, petro-products and fertilisers are all concentrated around the Narmada estuary in Bharuch district.

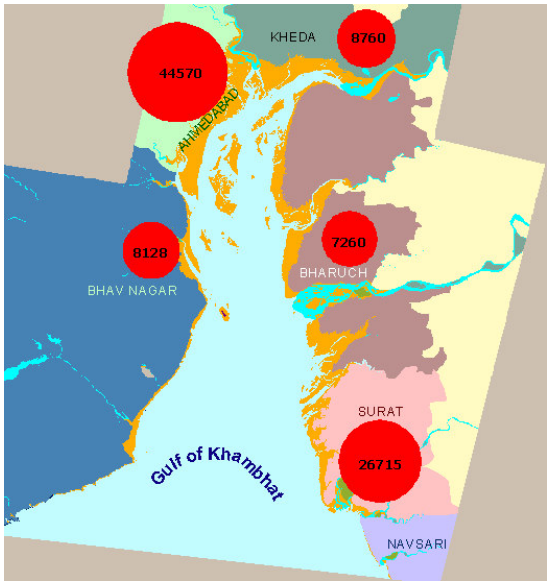


Fig. 17 - Districtwise status of SSI units in the Gulf

4.3.4 Salt industry

Out of the total 10.4 million tons of salt produced in Gujarat in the year 1997, Gulf of Khambhat area accounted for about 8,53,900 tons (8.2%). Salt industry is well established in Mahuva, Talaja, Bhavnagar and Ghogha taluks of Bhavnagar district, Jambusar, Vagra, Hansot taluks of Bharuch district, Khambhat of Kheda district and Olpad taluk of Surat district. The annual income of an agaria (traditional salt harvester) on an average is reported as Rs.6000 to Rs.8000. As per the directory of salt manufacturing units in Gujarat as of 1997, licence for

218 km^2 of area in the Gulf of Khambhat was given for salt production. However, the area under salt farming as calculated from 1999 Remote Sensing data is about 132 km^2 (Table 11) only. The difference in area may be because some of the licensed areas for salt production are either abandoned or farming is yet to start.

Table 11 - Details of Salt Pans in the Gulf

Name of District	Area (km^2)
Bhavnagar	36.11
Ahmedabad	1.72
Kheda	5.60
Bharuch	70.36
Surat	18.01
Navsari	0.12
Other	0.60
Total	***132.52***

4.3.5 Mineral Resources

Gulf of Khambhat is rich in natural reserves such as dolomite and limestone. Appreciable concentration of mineral placers in the intertidal zone of Hazira has also been reported (Vora *et al.,* 1992). Minerals available in the coastal districts are illustrated in Figure 18. The availability of these minerals have been the main criteria for locating specific industries at particular locations.

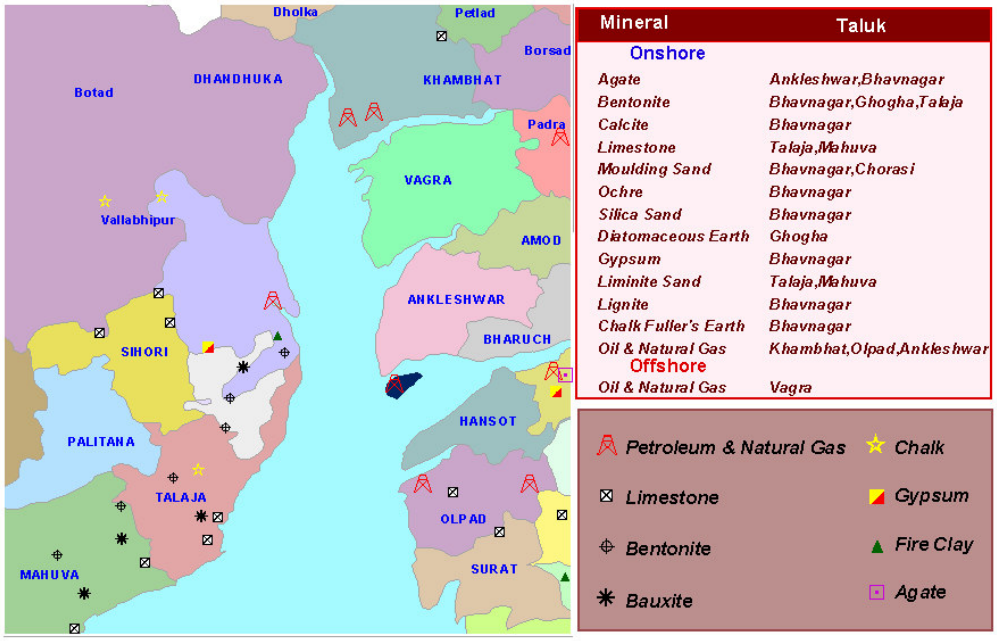


Fig. 18 - Mineral resources of Gulf of Khambhat

4.3.6 Aquaculture

Gulf of Khambhat has a vast brackishwater area of 1,17,000 ha, which has potential for shrimp farming. Out of this, about 36,000 ha has been initially identified for immediate development. However, coastal aquaculture is being practiced in 147 ha only which is hardly

0.1% of the potential area for culture. The details of aquaculture acting in the Gulf are illustrated in Table 12.

Table 12 - Brackishwater Aquaculture along Gulf of Khambhat as in 2000

S. No	Name of District	Potential Area (ha)	Area Sur-veyed (ha)	Area Alloted (ha)	No of farmers	Area under culture (ha)	Production (tons)
1	Bhavnagar	15,200	2,725	46	10	14	26
2	Kheda	20,253	16,326	-	-	3	-
3	Bharuch	57,500	16,155	725	199	76	118
4	Surat	24,300	1,583	221	96	54	60
	Total	**1,17,253**	**36,789**	**922**	**305**	**147**	**204**

Source :MPEDA,2001

5. Environmental Problems

The coastal environment of Gulf of Khambhat is under constant pressure due to the rapid industrialisation accompanied with increase in population. Developmental activities like ports, jetties, industries and other associated subsistence activities have led to environmental problems both in the Gulf as well as in the coastal regions. The carrying capacity of the Gulf and the coastal regions seems to be exceeding the limit, causing resource conflicts due to rapid industrialisation/ developmental activities associated with population increase, the major ones being:

- Oil and Natural Gas Exploration (inshore/offshore) releases a considerable volume of liquids, gaseous and solid wastes to the environment, major portion of which reaches the estuarine and / or marine environments due to their proximity to aquatic recipients. As a requirement and spin off of these industries, urbanization of adjacent areas takes place along with ancillary industries aggravating environmental pollution.
- Encroachment of the Gulf by way of reclamation/leveling of forest/mangrove areas and rocky coastline due to industrialisation, agricultural activities, population increase, etc, can cause not only irreversible impact to the coastal zone, but also alarming hazards due to disposal of domestic wastes to aquatic environment.
- Destruction of mangroves due to illicit cutting for firewood and fodder, construction of jetties, salt works, etc., and degradation due to pollution and dumping of wastes.

- Over-exploitation of ground water for drinking and irrigation will result in saline water ingress.

In addition to that, the Gulf is experiencing natural geomorphological (shoreline) changes mainly due to tidal currents leaving vast intertidal mudflats and high sediment influx from various rivers. The important changes which the Gulf has witnessed in the past two decades are as follows:

- The channel of Sabarmati shifted westward and narrowed compared to earlier days. The narrowing of the channel and the presence of new shoal at its mouth indicate the dominance of depositional activity, while its westward shift has resulted in erosion.

- The Mahi river has also changed its course and shifted southward to carve out two islands from the main land and numerous shoals are now visible at the mouth region. The northern shore of its estuary is under active erosion.

- Narrowing of Narmada river downstream of Bharuch, presence of new shoals in the estuary and extension of the Aliya Bet island towards east due to accretion, while the eroding southern bank below Aliya Bet indicates erosion.

- Many new shoals are observed in Tapi estuary and siltation noticed west of Surat.

- The shoreline west of Khambhat has advanced due to depositional activity, whereas the high water line between Dhuwaran and Khambhat has shifted due to erosion (Nayak and Sahai, 1985; Nayak *et al.,* 1985 and Shaikh *et al.,* 1989).

- Sedimentation around Dholera and the new shoal south of Dholera indicate dominance of depositional process.

- Erosion in the southern bank of Dhadhar river and west of Vagra. New shoals are observed at the mouth of the Dhadhar river.

- A large island present between Sonari creek and Kalubhar river has now joined the mainland.

6. Socio-Economic Activities

The coastal areas around Gulf of Khambhat have fishermen population to the tune of 18,779 from 3502 families. Surat district hosts the major share of 45% of the population, while Bhavnagar and Bharuch districts shared 26% and 24.8%, respectively. Kheda district hosted the remaining 4.2% of the fishermen population. Eventhough the fishermen population in the study area is reasonably higher, the overall share of active fishermen is observed to be less (36.8%). Hansot taluk of Bharuch district had the highest number of active fishermen (81.2%) followed by Ghogha and Talaja taluks (~56% each) of Bhavnagar district (Table 13). The reduction in number of active fishermen may be due to option of other jobs in industries adjacent to the towns.

Table 13 - Demographic details around Gulf of Khambhat as on 1999-2000

District / Taluk	Coastal area (km^2)	No. of villages	No. of towns	No. of fishing centers	No. of Families	Total Population	Active Fishermen	% w.r.t total population
Bhavnagar Dist	2892							
Bhavnagar		59	2	2	416	2299	833	36.23
Ghogha		44	1	2	266	1201	691	57.54
Talaja		111	1	3	118	766	439	57.31
Mahuva		93	2	2	105	618	265	42.88
Kheda Dist	1467							
Khambhat		82	2	1	147	798	369	46.77
Bharuch Dist	2976							
Hansot		44	1	1	63	213	173	81.22
Vagra		58	-	4	266	1292	406	31.42
Jambusar		58	-	13	643	3139	1190	37.91
Surat Dist	1211							
Choryasi		78	1	7	850	5149	1405	27.29
Olpad		89	1	6	628	3284	1128	34.35
Total	***10580***	***7716***	***11***	***41***	***3502***	***18759***	***6899***	***36.78***

Source: Gujarat Fisheries Department, 2000

About 99% of fishing is being carried out using non-mechanised crafts (fiberglass boats, dugout canoes and plank built boats) and the rest with mechanised boats (trawlers and Gill netters) probably due to the unfavourable conditions for operation of mechanised boats. Fishing gears consist mainly of trawl net, gill net, drag net and cast net.

The overall revenue from fisheries sector in the Gulf ranged between Rs. 233 lakh during 1997-98 and Rs. 284 lakh during 1999-2000 and the per head income of fishermen varied from Rs. 3579 to 4122 (Table 14), which is much less compared to per capita income in Gujarat (Rs.16,251) and national average of Rs.9660 during 1997-99 (DES, 1999). However, majority of fishermen working as crew earn between Rs.12,000 and Rs.24,000 annually and Rs.5000/- to 3000/- in case of women doing the shore labour (DES, 1999).

Table 14 - Revenue from Fisheries in Gulf of Khambhat

Year	Fish Production (tons)*			Average price / kg (Rs)*	Revenue (Rs)	* No. of active fishermen	Per capita income (Rs)
	Gujarat	GoKh	% Share				
1997-98	702355	15921	2.27	14.61	23,260,581	6499	3579
1998-99	551660	14984	2.72	16.50	24,723,600	6815	3627
1999-2000	670951	16283	2.43	17.47	28,442,907	6899	4122

* Source*: Gujarat Fisheries Department,2000*

7. Management Solutions

Gulf of Khambhat has the fastest growing industrial establishments concentrated along the coastal region. The consequences of these developments on the environment have to be properly managed for the sustainable development of the region. Implementation of following management solutions is required to protect the environment.

- The developmental activities in this region should be constantly monitored using remote sensing for geomorphological changes and the physico-chemical and biological status of the environment need to be assessed from time to time.
- Measures initiated by Central and the State governments for coastal zone management needs to be tightened.
- Regularisation of the commercial ventures along the industrial belts is the need of the hour in order to protect / conserve the sensitive ecosystem. Statutory requirement of conducting Regional Environmental Assessment (REA) enabling assessment of carrying capacity of the region need to be stressed for taking decision on the type and the extent of development.

- High loading of organic matter in the coastal waters has to be checked by development of proper sanitation facilities and/or, appropriate sewerage system and treatment mechanism.

- In order to reduce the stress on mangroves due to cattle grazing, fodder cultivation can be strengthened in suitable hinterlands of the gulf to augment fodder requirements.

- The waters of the Gulf and hinterland are under the jurisdiction of various departments such as Forests, Fisheries, Light House, Customs and Maritime Board and hence implementation of legal frame work to control various activities in the area is very difficult. It is suggested that an inter-departmental coordination among the stakeholders headed by Gujarat Government be set up to avoid conflicts in implementation of measures to protect the Gulf environment.

- Formulation of zoning atlas for Gulf of Khambhat based on hydrodynamic conditions and ecologically sensitive areas.

- A suitable organisation or body consisting of experts from various disciplines be set-up to look after various developmental activities that have already taken place and also the proposed activities in Gulf of Khambhat. The body may be sufficiently empowered for checking the statutory requirements including Environmental Management Plans (EMP) of all these activities and if required, to amend the rules and regulations as and when required, by which the marine environment and its ecosystem could be protected.

8. Conclusion

Considering the prevalence of multivarious activities which are thickly inter-woven, management of these activities in an integrated manner to ensure rational use of environment needs development of appropriate Resource Information System for attaining sustainable economic growth. The GIS based Information System is very useful to achieve this goal through monitoring of the spatial features of various ecosystems over the years. Also, the information system could serve as a baseline database for the decision makers to monitor these areas and to draw suitable management plans. The information system can also pave way for preparation of zoning atlas by updating the database with suitable information, which is essential for Gulf of Khambhat in view of increased developmental activities.

9. Bibliography

Ashwani Kumar (1996) Environmental issues in integrated coastal zone zone Management for Jambusar, Bharuch, Gujarat. School of Planning CEPT, Ahmedabad.

COMAPS (Coastal Ocean Monitoring and Prediction System), Department of Ocean Development 1999. Environmental quality from Kandla to Porbandar and Mahuva to Aliyabet sectors during 1998-1999.

Deputy Salt Commissioner, Ahmedabad 1997. Directory of salt manufacturing units in Gujarat as on 30th September 1997

DES (Directorate of Economics and Statistics) 1999. Socio-economic Review, Gujarat State 1998-1999.

GEC, 1997. NBSS & LUP, Nagpur and all India Soil & Land Use Survey Organization, AIS & IARI. *A status Report*

GSEAP (Gujarat State Environmental Action Programme), 2000. Coastal and Marine Environment Phase-I report, March, 2000. Gujarat Ecolgy Commission, Phase 1 Report.

Gujarat Fisheries Statistics, 1999-2000. Office of the Commissioner of Fisheries, Government of Gujarat, Gandhinagar.

iNDEXTb, 1999. Gujarat, the land of Opportunities. Industrial Extension Bureau, Ahmedabad, 1999.

IUCN Report, 1976. Management and Conservation of renewable marine resources, No.65: pp.86.

MPEDA (Marine Products Export Development Authority), Cochin. Status Report-2001.

Nayak, S. R. and Sahai Baldev 1985. Coastal Morphology: A case study of the Gulf of Khambhat (Cambay). *International Journal of Remote Sensing, 6 (3 and 4): 559-567*

Patel, P. P. (1996), Geo-Environmental Dimensions of The Ecosystem Regions of Gujarat (Department of geology, MSU, Baroda, 1996)

Shaikh, M. G. *et. al.,* 1989. Coastal landform mapping around the Gulf of Khambhat using Landsat TM data, Photonirvachak: *Journal of the Indian Society of Remote Sensing, 17 (1): 41-48*

Singh, H. S., 2000. Mangroves in Gujarat: Current status and strategy for conservation. *Gujarat Ecological Education and Research (GEER) Foundation, Gandhinagar.*

Unnikrishnan, A. S., S. R. Shetye and G.S. Michael, 1999. Tidal propogation in the Gulf of Khambhat, Bombay High and surrounding areas. Proc. *Indian Acad. Sci. (Earth Planet Sci.), 3: 155-177.*

Vora, K. H. *et. al.,* 1992. Heavy mineral occurrence off Hazira, West coast of India*. Indian Journal of Earth Sciences 9 (4): 189-197*