

2. GULF OF KACHCHH

2.1 Gulf environment

The Gulf (Figure 2.1.1) is an east – west oriented indentation north of Saurashtra Peninsula. It is about 170 km long and 75 km wide at the mouth, narrowing down abruptly with a distinct constriction at 70°20'E at Satsaida Bet, and dividing into a creek system often called the Little Gulf of Kachchh. The Gulf has an area of 7300 km² and a volume of 220,000 Mm³. Depth varies from 20 m at the head (Kandla-Navlakhi) to 60 m in the outer region. The average depth is 30m, the minimum 3 m above chart datum in the inner creeks. The actual fairway however is obstructed due to the presence of several shoals, needing periodic dredging in some areas, to facilitate navigation to the ports. Studies indicate that the Gulf region is rising at the rate of 1.3 cm per year as a result of Holocene transgression of the seas. The residence/ turnover time of the Gulf ranges from 8-51 days, decreasing upstream. The tidal scour, which follows the axis of the Gulf, has steep slopes and rugged surfaces. A number of scraps with relative elevation of 6 to 32 m also occur on the sediment-free bed of the Central Gulf.

The western extremity of the Gulf consists of a vast complex of marshland criss-crossed by innumerable creeks. Kandla, Nakti and Hanstal creeks are the major tributaries of the inner Gulf and drain into the Little Gulf of Kachchh. The Little Rann of Kachchh gets flooded during the south west monsoon establishing short term connection with the creeks at the head of the Gulf. Navlakhi port is located on the Hansthal creek. The vast mudflats that get inundated during high tide, consist of thick deposits of very soft marine clay upto a depth of 12-15m underlain by calcareous sand and highly weathered, weak sedimentary rock formations comprising of compact sand, siltstone, claystone and sandstone.

The coastal configuration is very irregular with numerous Islands, creeks and bays. Besides, there are a number of eroded shallow banks like Pirotan, Dide, Dhani, Bet Shankodar, Paga, Adatra and Boria reefs, many of which harbour living corals. The intertidal region is sandy and muddy or rocky. The raised coral reefs near Okha - Mithapur and clays and foraminiferans limestone of Oligocens - Pliocene period near Dwarka give a clear indication of a relative change in the sea level in the past. The Gulf and the surrounding region is active seismically with a number of recorded earthquakes.

The coastal area of the Gulf (within 20 km from the shoreline) fall under the Kachchh (6749.77 km²), Jamnagar (4863.53 km²) and Rajkot (576.71 km²) districts.

The Census of 1991 indicates that barely 5% of the land other than forest is irrigated in the Kachchh district. Cotton is the dominant crop in the Kachchh district while it is oil seeds in Jamnagar and Rajkot districts. Bajra, pulses, wheat, sugarcane etc. are the other common crops in the region. The general vegetation in the area is sparse and scattered and of tropical dry mixed deciduous scrub and desert thorn type belonging to the xerophytic group.

As per 1991 census the human population within the 20 km coastal belt around the Gulf is about 17 lakhs. The population density is low in the Kachchh district and is about 54 persons/km². About 50% of the coastal population is in urban areas. Out of the total working population, agricultural workers constitute the majority.

Due to extreme unreliability of rainfall in the Kachchh district, ground water is a more reliable source of water for domestic as well as agricultural needs. However, uncontrolled and

indiscriminate withdrawal of ground water has resulted in a sharp decline in water table in the coastal belt causing ingress of salinity.

The Gulf area is generally termed as semi arid region. The weak monsoonal rains and high rate of evaporation not only make the land area arid but also influence the seawater salinity to increase. Long-term mean rainfall on the surrounding area is 42 cm/y leading to a rainfall volume of 3087 Mm³/y. Thus the Gulf is an area of negative water balance. The region experiences four main seasons namely winter, summer, southwest monsoon and postmonsoon seasons. During winter season (December to February) winds are N-NE and rough sea conditions may prevail because of western disturbances characterized by chilly winds from the N-NE due to high pressure zone in the north of Himalayan ranges. Summer season (March to mid June) is characterized by high temperature and high humidity with the maximum air temperatures often reaching 40-45°C. Southwest monsoon (mid June to mid September) has weak monsoon mainly due to monsoon low centred around Kachchh district making it a rain shadow zone; but strong winds with S-SW directions are often experienced. Postmonsoon season (mid September to November) is a transition period between monsoon and winter when the climate is pleasant with relatively calm periods.

Throughout the year, the winds are light to moderate in the Gulf except during late summer and southwest monsoon periods. Stronger winds are also encountered with the disturbances such as depressions and cyclones. Tropical cyclones originating in the Bay of Bengal and the Arabian Sea cross the area in the later part of their tracks. The storms occurring in June-July have severe influence in this region with devastating effects on coastal areas.

Generally in June, the storms are confined to the area north of 15°N and east of 65°E. In August in the initial stages, they move along northwesterly course and show a large latitudinal scatter. West of 80°E, the tracks tend to curve towards north. In October the direction of movement of a storm is westerly in the Arabian Sea. However, east of 70°E, some of the storms move north-northwestwards and later recurve northeast to strike Gujarat-north Mekran coast.

The air temperature of the region vary from 10°C to > 36°C over the year. January is the coldest month with night temperatures falling below 10°C and May and June are the hottest months with mean maximum temperature of 36°C during day and mean minimum of 26°C during night.

The relative humidity is generally high during monsoon months and range from 70 to 80%. Rest of the year, humidity ranges between 55 and 70%.

The sky is clear or lightly clouded except during monsoon period. Visibility is good throughout the year. However, the average visibility of less than 1 km can be expected for a few days in winter months.

The Gulf has been hydrographically surveyed several times due to navigational interests and a hazardous southern shoreline. Within the Gulf, though water depths of 25 m exists in broad central portion upto a longitude 70°E, the actual fairway in the outer Gulf is obstructed by the presence of several shoals. The high tidal influx covers the low-lying areas of about 1500 km² comprising a network of creeks and alluvial marshy tidal flats in the interior region. All along the coast, very few rivers drain into the Gulf and they carry only a small quantity of freshwater, except during monsoon. They are broad-valleyed and the riverbeds are mostly composed of coarse sand and gravel.

The Gulf is characterized by numerous hydrographic irregularities like pinnacles, as much as 10 m high. The topography of the outer Gulf is more rugged as compared to the inner Gulf. The southern shore has numerous Islands and inlets covered with mangroves and surrounded by coral reefs. The northern shore is predominantly sandy or muddy confronted by numerous shoals. The sediments transported into the Gulf alongwith those denuded from the shores and wind borne sands give rise to poly-modal character to the sediment. The proportion of sediment derived from hinterland is considered to be small because of low run-off and the streams discharging in the Gulf are short with dams constructed across many of them. From the distribution of sand and clay sizes of the sediments, it has been considered that the tidal streams at the mouth of the Gulf act as dynamic barrier inhibiting sediment transport across the mouth. Based on the estimated sedimentation of 2 mm per year in the Little Gulf of Kachchh, it has been suggested that the area was less than 4 m deep water as late as 2,000 years ago.

There are three new ports, under various stages of planning and development around the Gulf. These are: Positra (near Okha), Bedi (Jamnagar) under the Gujarat Maritime Board on the Saurashtra coast; and the Adani port near Mundra, on the Kachchh coast. The two on the Saurashtra coast are planned ostensibly because of the shelter offered by the coral reefs.

The present scenario in the Gulf consists of several industries like 21 salt work units along the coast, Tata Chemicals and Associated Cement Company at Mithapur, Digvijay Cement Factory and Unit of Gujarat State Fertilizer Corporation at Sikka, Salaya-Mathura oil pipeline, Crude oil terminal of Indian Oil Corporation at Vadinar, Reliance Petroleum and ESSAR Oil Refineries at Moti Khavdi and Jam-Khambhaliya respectively, and the proposed Vadinar-Bina Pipeline of Bharat Petroleum on the Saurashtra coast, the sub-sea pipeline of Bharat-Oman Petroleum near Narara Bet, the proposed Kandla-Karnali oil pipeline, the Vadinar-Kandla undersea pipeline and Sanghi Cement Company on the Kachchh coast. The Gulf area is being aggressively developed as oil importing bases because of its proximity to the oil exporting countries of the Middle East. To facilitate unloading of oil from Very Large Crude Carrier (VLCC), seven Single Buoy Moorings (SBM) have been planned to be anchored along the southern shore of the Gulf of which four are already in place – one off Narara Bet, two off Vadinar, one off Sikka and two more under planning. All these activities are either close to or inside the 411 km² area of the Marine National Park, which has been established to protect and preserve the fragile ecosystem, particularly the coral reefs of the Gulf of Kachchh.

As of now, import of 40 Million Ton Per Annum (MTPA) of crude oil through the SBMs in the Gulf, has been cleared which will be gradually raised to 80-110 MTPA. Each SBM can be expected to release a maximum of 300 barrels (41 Tonnes) of oil to the sea per year during operation. This would mean that the Gulf will receive around 300 tonnes of oil per year during the operation of the 7 SBMs. This small amount can be expected to be taken care of by natural processes prevailing in the Gulf.

2.2 Physical processes

Tides in the Gulf are of mixed, predominantly semidiurnal type with a large diurnal inequality. The tidal front enters the Gulf from the west and due to shallow inner regions and narrowing cross-section, the tidal amplitude increases considerably, upstream of Vadinar.

The phase lag between Okha and Kandla is 2 h to 25 min while between Okha and Navlakhi it is 3 h to 20 min. Due to high tidal ranges in the inner regions, the vast mudflats and coastal low lands, which get submerged during high tide, are fully exposed during low tide.

The Tidal elevations (m) along the Gulf are as follows:

	MHWS	MHWN	MLWN	MLWS	MSL
Okha	3.47	2.96	1.20	0.41	2.00
Vadinar	5.30	4.30	1.70	0.70	3.00
Sikka	5.38	4.35	1.74	0.71	3.04
Mundra	5.50	5.00	2.00	1.20	3.40
Rozi	5.87	5.40	1.89	1.00	3.60
Kandla	6.66	5.17	1.81	0.78	3.90
Navlakhi	7.21	6.16	2.14	0.78	4.20

The tidal front enters the Gulf from westerly direction and due to shallow inner regions and narrowing cross-section the tidal amplitude increases upstream. The mean high-water spring of 3.47 m at Okha increases to 5.38 m at Sikka and further to 7.21 m at Navlakhi. The high tidal influx covers the low-lying areas over 1500 km² comprising intricate network of creeks, alluvial marshy tidal flats and rock outcrops. Commensurate with the increasing tidal amplitude, the inter-tidal expanse along the shores of the Gulf increases upstream. It increases from 0.5 to 2 km from Jakhau to Kandla and from around 1 km at Okha to over 5 km at Jodia. The associated tidal currents are fairly strong and bimodal in nature having two dominant directions – upstream during flood and downstream during ebb- in all encompassing oscillatory motions. Such motions cannot flush the Gulf completely, leaving behind parcels of perennially undulating water. Any substance released in such a water body will always have a fraction of it left behind, however small that might be, whose residence time will continuously increase with increasing number of oscillations.

Circulation in the Gulf is mainly controlled by tidal flows and bathymetry though wind effect also prevails to some extent. The surface currents are moderate (0.7-1.2 m/s) but increase considerably (2.0-2.5 m/s) in the central portion of the Gulf. The spring currents are 60 to 65% stronger than the neap currents. The bottom currents are also periodic with a velocity normally 70% of the surface currents.

With high tidal range, negligible land run-off and irregular topography, the waters are vertically homogeneous in terms of salinity and temperature.

Silt-size materials are found at the mouth with fine silt and medium silt occurring at the southern side at its head. Sediment sources are the wave erosion of the coastal rocks and those derived from River Indus – whose mouth is located at about 100 km northwest of the Gulf. Prograding sediments of the Indus delta accumulate on the northern shores of the Gulf while the southern shores remain deprived of sediments because of the existence of a dynamic barrier caused by the high velocity tidal stream flowing through the central channel of the Gulf.

Many of the wave cut, eroded Islands and shallow banks on the southern shores of the Gulf have coral reefs on their northern and western sides extending from inter-tidal to sub-tidal zones. These are mostly fringing reefs, which protect the coast, increase its stability and help to establish sheltered harbours. Storm and high tidal waves undergo numerous reflections against these reefs reducing their energies by orders of magnitude before breaking against the northern shores of Saurashtra. In fact the coral reefs offer natural protection to this coastal area.

2.3 Water quality

Typical water quality of the Gulf derived from the database of NIO is given in Tables 2.3.1 and 2.3.2. Hydrochemically, the Gulf shows properties typical of a shallow semi-enclosed sea in an arid region with the little or no freshwater input. The annual variation of water temperature is between 24 and 30°C though localised higher temperatures upto 35°C can result in isolated water pools formed in shallow intertidal depressions during low tide.

SS are highly variable (12 – 698 mg/l), spatially as well as temporally, and largely result from the dispersion of fine sediment from the bed and the intertidal mudflat, by tidal movements. Evidently, nearshore shallow regions between Okha and Sikka has low SS varying within a narrow range (15-40 mg/l) whereas the inner Gulf areas sustain markedly higher SS, often in excess of 100 mg/l.

Average pH of the Gulf water is remarkably constant (7.9-8.2) and is within the range expected for the coastal tropical seas.

The evaporation exceeds precipitation leading to salinities markedly higher than that of the typical seawater. This is particularly evident in the inner Gulf where salinities as high as 40 ppt commonly occur off Kandla and Navlakhi. Seepage of high saline waters from salt pans and exposed vast intertidal area coupled with high rate of evaporation result in high salinities at or near the head of the Gulf and in the creeks. Although the salinities decrease considerably for a brief period in some creeks of the Little Gulf of Kachchh under the influence of monsoonal runoff, the impact of this decrease in the Gulf proper is small and salinities exceed 36 ppt off Sikka and Salaya during normal monsoon periods.

DO is fairly high (4-6 ml/l) and BOD is low (0.84-1.75 ml/l) indicating good oxidizing conditions. Hence, the organic load in the water column is expected to be effectively oxidized aerobically. Near homogeneity, absence of stratification and large tidal amplitudes coupled with turbulence render the Gulf vertically well-mixed resulting in high dissolved oxygen at or over its saturation point.

The nutrients ($\text{NO}_3\text{-N}$, $\text{NO}_2\text{-N}$, $\text{NH}_4^+\text{-N}$, $\text{PO}_4^{3-}\text{-P}$) are more or less uniformly distributed in Okha - Sikka segment and their concentrations indicate healthy natural waters. Their levels however are marginally high in the Kandla-Navlakshi segment. In fact, the network of creeks of the Little Gulf of Kachchh sustains high natural concentrations of nutrients perhaps due to high regeneration rates. As expected for an unpolluted coastal environment, the concentrations of PHC and phenols are low.

The Gulf in general, has excellent water quality quite close to the characteristics of a pristine water body. Marginal degradation in water quality in localized areas around industrial and urban center is possible. But such changes can only be ephemeral because of semi – diurnal tidal flushings associated with moderate to strong tidal currents.

2.4 Sediment quality

Central portion of the Gulf extending from the mouth to upstream of Sikka is rocky with sediments confined only to the margins. The nearshore sediment which consists of light gray silt and clay with patches of fine to coarse sand in-between, are poorly sorted with highly variable skewness. The major source of this sediment is considered to be the shore material and the load transported by the Indus River. The portion of sediment derived from the hinterland is considered to be small because of the low run-off. Moreover, the streams discharging in the Gulf (during brief monsoon season) are short with dams constructed on many of them.

The concentrations of heavy metals such as chromium, manganese, cobalt, nickel, copper, zinc and lead though variable, indicate natural background levels and there is no evidence of gross sediment contamination (Table 2.4.1). The concentrations of PHC are also low though large quantities of petroleum crude and its products are off-loaded at Vadinar, Sikka and Kandla.

2.5. Types of ecosystems

The Gulf abounds in marine wealth and is considered as one of the biologically richest marine habitat along the west coast of India. It is endowed with a great diversity of natural ecosystems, of which the major systems are salt pans, intertidal zones, marine algae (seaweeds), sea grass and sand dunes, mangroves, coral reefs, creeks and open ocean.

Salt pans

Salt pans are unique tide water impounded enclosed system adjacent to creek environment. They are characteristically exposed to a wide range of environmental stress and perturbation which manifest mainly through salinity changes. The distinct feature of the brine ecosystem is its biotic simplicity and stability. However, salt pans are immature ecosystem as compared with a typical marine system and harbour a high proportion of opportunistic and fugitive species. The ecosystem is simplified, as the number of species in each trophic level is low. Species diversity is directly linked with salinity. Hence the higher the salinity, the lower the species diversity and simpler the structure of the ecosystem. Energy influx to the salt pan ecosystem is usually large and algal production may therefore, be high, but food chain nevertheless is usually simple and often restricted to a few producers and low number of consumers.

In the Gulf there are about 21 salt work units. These salt pans serve as feeding grounds for a variety of resident as well as migrant birds.

Intertidal zone

The intertidal area is the transitional region between land and sea. In general, it is covered and exposed by the tidal waters each day. The intertidal zone can be either rocky or particulate shore. Rocky shores are solid substrates and particulate shores consist of sediment particles ranging in size from clay through cobbles. Particulate shores may be either well or poorly sorted. The rocky shore provides a firm substratum while the others are unstable. The rocky intertidal area consists mostly of epibenthic organisms attached to the rock surface. The communities of the intertidal fauna can be divided into epifauna, which live at the surface of the rocks, shore and sediment, and infauna consisting of all animals that burrow and live in the sediment.

The intertidal expanse of the Gulf increases towards upstream. The increase is from 0.5 to 2 km from Jakhau to Kandla and from around 1 km at Okha to over 10 km at Navlakhi.

The intertidal habitat of Gulf covers a wide range of ecosystems; sandy beaches, mud and sand flats, rocky foreshore and rock pools, sea grass beds, salt marshes and mangroves. The continuous wave action and associated littoral sediment transport make intertidal stretch a unique environment for biogenic activities of organisms. The physico-chemical, geomorphological and biological features play an important role in determining the distribution and abundance of benthic fauna of the intertidal habitats. Gulf sustains a rich and highly biodiversified intertidal flora and fauna.

Mangroves

Mangroves are salt tolerant plants found mainly in tropical and subtropical intertidal regions. Where conditions are sheltered and suitable, mangroves form extensive and productive forests. These plants have peculiar adaptations such as support roots, viviparous germination, salt excreting leaves, breathing roots, knee roots etc. by which they are well adapted to the water logged, anaerobic saline soil of coastal area. Mangroves are an extremely important component of the coastal marine environment, both in an ecological sense as well as in economical terms. Mangrove plants contribute to the marine food web through the production of detritus by litter fall. They prevent soil erosion and act as a buffer for the mainland from storms to protect the coast from erosion. Mangroves are one of the most productive natural systems and support a rich and diverse flora and fauna. Mangroves act as dynamic benthic environment with detritus system. Small-scale fisheries in the waters of mangrove produce substantial quantity of crustaceans and finfishes.

Vegetation of mangrove ecosystem can be divided into the following broad categories (i) mangroves (ii) salt marshes (iii) sand strands and (iv) inland shrubs.

The area covered by mangroves along the Gujarat coast is the second largest in India, next only to the Sundarbans area. Majority of the area covered by mangroves of Gujarat is confined to the Gulf. Of the 991 km² for the state, Gulf with 954 km² covered with mangrove forms 96% of the total. Due to high salinity, grazing and cutting pressure the Kachchh mangroves have stunted growth and are only 1-2 m tall. However, trees in some untouched patches gain a height upto 5 m. The best-conserved mangroves of Gujarat are those which lie along the Kori creek. This is because they are located in sparsely populated area near the international border with Pakistan and have a relatively difficult accessibility.

The coastal wetland of the Kachchh district with numerous creeks and channels associated with shoals and vast tidal flats have one of the richest mangroves along the west coast of India. Hence, a portion of the mangroves of the Kachchh region is classified under the "West Mangrove Reserve Forest". The area covered by mangroves (km²) at Kachchh area is estimated based on satellite data to be about 938 km² in 1998 which has considerably increased from 1992 to 1998 as per the details given below for the Gujarat State.

District	1992	1998
Kachchh	601.8	938.0
Jamnagar	131.2	98.3
Junagarh	0.8	0.3
Bhavnagar	14.5	6.2
Bharuch	10.9	17.1
Surat	7.8	2.0
Valsad	-	5.0
Total	767.0	1066.9

The main mangrove species found in the Gujarat region are as follows:

Common species	Status
<i>Avicennia marina</i>	Dominant
<i>A. officianalis</i>	Common
<i>A. alba</i>	Common
<i>Rhizophora mucronata</i>	Vulnerable
<i>Ceriops tagal</i>	Vulnerable
<i>Bruguiera gymnorhiza</i>	Vulnerable
<i>Sonneratia apetala</i>	Vulnerable
<i>Aegiceros corniculatum</i>	Endangered

Marine algae (sea weeds), sea grasses and sand dunes

Seaweeds which are known as a source of food, fodder and manure are widely distributed along the west coast of India, mostly found attached to substratum of coral or rock. Some of the green seaweeds are edible while red algae are the important source of agar; some of the brown algae are used for manufacturing algin and alginic acid. They play a significant role in enriching nearshore sea by adding dissolved organic matter, nutrients and detritus besides serving as nursery areas for the larvae and juveniles of several marine animals.

Sea grasses are flowering plants of the seas. They are completely adapted to life in intertidal and shallow coastal marine areas. Sea grasses have successfully colonized the sea because of their ability to function and reproduce even when they are submerged in saline medium. Sea grass meadows are widespread in the shallow marine environments and contribute to higher amount of organic production and serve as a good substrate for a variety of epiphytic algae including diatoms and sessile fauna. Numerous adult shell and fin fishes live here atleast during a part of their life cycle. Photosynthetic production of oxygen in the sea grass beds also supports high densities of various marine organisms. Sea grass habitats though categorized under ecologically sensitive coastal areas, are largely ignored.

The Gulf contributes to the maximum species and biomass of seaweeds for the west coast of India. The southern coast of Gulf supports luxuriant growth of marine algae because shoreline has gradual slope with high tidal amplitude, moderate wave action and low turbidity. The northern shore of the Gulf has very poor algal biodiversity, as the sandy/ muddy substratum associated with relatively high turbidity does not support algal growth. Sea grass species exist in the subtropical regions of a few Islands.

Ridges of loose sand drifted by the wind often support vegetation known as sand dunes. The dominant species of sand flora are *Euphorbia caudicifolia*, *E. nerifolia*, *Aloevera* sp., *Ephedra foliata* and *Urochodra setulosa*.

Corals and coral reefs

The coral reef ecosystems are unique in their diversity, intricate inter-relationships and spectacular in beauty. The term coral refers to coelenterates secreting a massive calcareous skeleton, particularly of the Order Scleractinia (Class Anthozoa). The scleractinian corals fall under two groups namely ahermatypic or non-reef building and the hermatypic or reef building corals. The former are widely distributed at all latitudes down to several thousand meters depth, and the hermatypic corals are limited to warm saline waters where temperature never falls below 20°C and salinity is not lower than 30 ppt. The depth distribution of reef building, corals is restricted to the illuminated layers of the sea, a condition clearly associated with the endo-symbiotic zooxanthellae of the coral polyps which require light for photosynthesis.

A coral reef is a ridge or mound of limestone predominantly composed of calcium carbonate secreted by the organisms, of which the most important are corals. Corals are regarded as slow growing with measured rates of colony growth varying from < 1 to 10 cm/y, the net upward growth rate varying from a few mm to around 3 cm/y. Under favourable conditions optimal growth occurs at a temperature of 23– 25°C and a salinity of 32-42 ppt.

Coral reefs are shallow water, tropical marine ecosystems known for high biological productivity. The reef biodiversity is enormous. It houses various species of benthic algae, sea weed, sea grasses, other coelenterates, annelids, lobsters, sponges, echinoderms, fin fishes, crabs, bivalves, gastropods and cephalopods maintaining unique symbiosis among all these life forms. The high rate of productivity at the coral reefs is due to the efficient retention and recycling of nutrients within the reef system. Reefs are sites of rich living and non living

resources. The fish yield from coral reefs is comparable to most other productive marine ecosystems.

The Gulf is the only area in Gujarat where corals exist with high diversity and density. The coral formations of the Gulf are found exclusively between 22° 20' N and 22° 40' N latitudes and 69° and 70° E longitudes along the coast of Jamnagar district. The age of these corals as dated from the raised beaches, vary from 5240 years at Salaya to 45,000 + 105 years before present at Okha. Based on the existing classifications these reefs are classified into fringing reefs (north of Okha, north of Bet Shankodar fringing the mainland from Dhani Bet to Sikka, Jindra and Chad, Pirotan, near Valsura), platform reefs (Paga reefs, Bural Chank, Karumbhar, Munde reef etc.), patch reefs (Goose and Ajad) and several coral pinnacles (eg. Chandri, etc). The most northerly reefs are coral patches found at Munde reef and Pirotan Island, but solitary corals are found as far as Jakhau in the east and Dwarka on the Saurashtra coast. Recently live corals with associated flora and fauna have been observed off Mundra for the first time.

Creek system

Creeks are special habitats, the speciality being the mixing of fresh water and salt water and periodic stirring up by tides. The hydrographic conditions are peculiar and these influence the flora and fauna of such environments. Often a marked gradient of decreasing salinity is evident from the mouth (sea) towards the head (upper reaches) especially during monsoon. Depending on the salinity regime typical estuarine and oceanic communities prevail in the creek system. In some regions evaporation and lack of fresh water flow extend the brackish range upward into hyper saline conditions. This state is invariably experienced by the Gulf creek system especially during non-monsoon periods. In such situations exceptionally hardy forms with special adaptations alone are likely to survive.

There is a network of creeks and alluvial marshy tidal flats in the interior part of the Gulf. The creek system consists of three main creeks namely Nakti, Kandla and Hansthal, and the little Gulf of Kachchh is inter connected through many other big and small creeks. The three desert rivers, Banas, Rupen and Saraswati, carry annually 140 Mm³ water to the Little Rann of Kachchh that gets flooded during the southwest monsoon period establishing short term connection with the creeks at the head of the Gulf.

The creek receives negligible freshwater inflow during the dry season. Hence, the evaporation exceeds precipitation leading to salinities higher than that of typical seawater (35-36 ppt). The higher salinities may also result due to the drainage of brine from salt pans and higher evaporation rates in the adjoining creeks. Thus salinities upto 50 ppt have been recorded in the Little Gulf of Kachchh. These higher salinities lead to lateral gradient in the Gulf with salinity decreasing from 40 ppt in the Kandla-Navlakhi segment to 37 ppt at Salaya. The fresh water run off during monsoon considerably dilutes the seawater in creeks such as Chach, feeding the Little Gulf of Kachchh and salinities of < 10 ppt may occur. The Phang, Kandla and Nakti creeks however retain high salinities (> 35 ppt) even during monsoon.

Open ocean

The open sea has very specific characters. Most evident are its uniformity and stability in environmental conditions, its three – dimensional space and its vastness. In the pelagic realm there are no boundaries or barriers to distribution of organisms and all environmental changes are gradient. This part of the sea harbours two types of communities namely the nekton or good swimmers and the plankton, with feeble powers of movement. The bottom fauna or benthos is constituted by epifauna and infauna. Typical sea fauna, in general, exhibits a rather high diversity and this is clearly seen in the zonation of organisms.

2.6. Marine Sanctuary and Marine National Park

The southern Gulf between Okha to Navlakhi of Jamnagar district is declared as Marine National Park and Sanctuary (MNP & S) to protect and conserve the fragile ecosystem particularly the live intertidal and subtidal coral reefs and mangrove habitats of the Gulf. Major part of the MNP & S consists mainly of intertidal zones and intricate network of Islands with coral reefs and mangrove forests. Intertidal zones of Dwarka, Kalyanpur, Khambhalia, Lalpur, Jamnagar and Jodia Talukas along with 42 Islands in the district have been included in the marine protected area. As per the State Government notification in 1980 & 1982 an area of 457.92 km² of MNP&S includes 148.92 km² of 42 small and big Islands and 309 km² of intertidal zone along the coast. Area of the MNP is 162.89 km² whereas the remaining protected areas have the status of Marine Sanctuary. The MNP&S as per the notification of 1983 includes three categories of areas namely 11.82 km² Reserve Forests, 347.90 km² unclassified forests and 98.20 km² territorial waters of India. 162.89 km² area of the MNP is distributed amongst 37 Islands and coasts whereas the remaining 295.03 km² area of the sanctuary covers 5 Islands and intertidal zone from Navlakhi to Okha.

However, as per satellite-based wetland map of SAC the total area of 42 Islands during low tides is 410.6 km². The area of the Islands varies from 27 ha of Lafa Marudi and Man Marudi to 5972 ha of the Kalubhar (Karumbhar) Island. Only 148.9 km² area of the Islands have been notified as MNP & S because accurate maps and extent of area of the Islands were not available at the time of declaration of the sanctuary. Hence, major parts of the Islands (261.7 km²) covering healthy coral reefs are out of the legal boundary of the MNP&S, but for practical purpose, they are considered as part of management boundary.

The Gulf of Kachchh MNP & S is the first of its kind to be established along the Indian coast. The notification is based on a few theoretical surmises, reasoning and some anticipated threat perceptions supported by scanty data. The reasonings behind the demarcation of the area is nowhere to be found on record. Also there is huge overlap of areas (87%) of MNP&S and GMB for port developments. However the basic necessity is the biogeographical importance of the Gulf and its rich marine wealth.