Summary

CORAL REEFS are the most ancient and one of the fascinating ecosystems on the earth. They are the largest structures ever created by millions of tiny animals over thousands of years. In a coral reef environment many a species coexist; symbiosis and prey-predator relations are common phenomenon everywhere in reef environment (Dave and Mankodi, 2009a; Dave and Mankodi, 2010). During mid Ordovician period, first time tabulate and rugose reef corals appeared around the tropical world and achieved optimum development in the Devonian Period. The modern corals – Scleractinians evolved 245 million years ago in Mesozoic era. Even though considerable variations took place during evolution of coral reefs, the survived coral families were further diversified into various reef building corals in the beginning of the tertiary period of the Cenozoic era. Thus, the modern known corals came in to existence in the world's reefs (Stanley, 2003; Veron, 2000). Coral reefs are mainly categorized into three types originally suggested by (Darwin, 1842), Fringing reefs, Barrier reefs and Atoll reefs. Apart from the main 3 types, reefs are further classified in to platform reefs, patchy reefs, coral pinnacles, knolls etc.

The scleractinians are the unique examples of plant-animal symbiosis. In many hard corals photosynthetic dinoflagellates (genus: *Symbiodinium*) commonly known as Zooxanthellae are present inside the polyp's endodermis, especially in tentacles and oral disc (Trench, 1987). Reefs are found throughout the world's ocean. Hard substratum, least turbid waters, water temperature between 20°C to 30°C and 36‰ salinity are the most essential requirements for coral to thrive at their optimum. Most of the scleractinian's distribution remained restricted to the tropical shallow waters between 30°N and 30°S latitudinal limits. The Indian reefs are divided into four major reef regions viz. Andaman and Nicobar Islands, Gulf of Mannar and Palk Bay, Lakshadweep and Gulf of Kachchh (Venkataraman et al., 2003). Gulf of Kachchh (GoK), an indent of Arabian Sea into mainland of Gujarat, is the fourth major coral reef region of India. Fringing, platform and patchy types of reefs are found along the southern coast of the Gulf. Earlier studies reported 36 species of hard corals occurring in GoK,

the list was then updated to 45 species recently (Dixit et al., 2010; Pillai and Patel, 1988).

A very fragile equilibrium amongst various biotic and abiotic factors is maintained in a very unique way. A slighter imbalance in the equilibrium may collapse the entire ecology and lead to the degradation of the coral reefs. Further, being the nearest to the ocean surface and shores the reefs undergo tremendous threats of anthropogenic and natural origin as well. These situations have raised great concern of conservation and sustainable management of reefs and reef resources. Scientific community has taken up extensive reef research to document effects of globally changing environment with help of thousands of volunteers and non government organizations. To answer the issues of anthropogenic pressures on the fragile coastal/marine ecosystems, a concept of declaring coastal/marine areas reserved to provide legislative cover has become popular for effective protection of vulnerable coastal/marine ecosystems like coral reefs.

The GoK reefs are less studied compared to other Indian reefs in all manner. The studies conducted so far were mainly limited to the biodiversity assessment, impact of industries, effect of natural disasters, and a few EIA studies. Studies on the economic valuation of GoK reefs has attempted to focus on the revenue generated by eco-tourism and fish resource harvesting from this region (Dixit et al., 2010). But still no systematic efforts have been taken up to understand the effects of all such activities on the ecology of the reef area.

Therefore, present study was planned to understand the basics of a popular reef area of Marine National Park and Sanctuary, Gulf of Kachchh - **the Narara reef**. This aim is achieved by studying Scleractinian diversity and distribution of the reef area, coral reef associated fauna and flora, physico-chemical nature of water of study area and the anthropogenic activities and its impacts.

The Narara reef (Latitude 22°25.8'N to 22°28.3'N and Longitude 69°42.1'E to 69°40.7'E), an integral part of India's first Marine Protected Area the Marine National Park, is situated in Gulf of Kachchh on the coast running along Jamnagar district of

Gujarat state. The Narara reef intertidal area was divided in to five sub-sites i.e. S1, S2, S3, S4 and S5 for habitat characterization study, biodiversity assessment and seawater sample collection to assess prevailing physico-chemical environment on the basis of its geo-morphology.

Physico-chemical environment has a very critical role to play in the dynamics of any ecosystems. Like many of the GoK reefs, Narara reef gets partial/fully exposed during low tide rendering the corals prone to desiccation stress due to increased solar radiation. Depressions on the intertidal area get converted into shallow tide-pools when tide recedes, the only place for the organisms which require water as medium to sustain their lives. The values of parameters for lower intertidal areas were only considered for detailed analysis. The parameters were represented as monthly variations. The marine water quality did not change much during the study period. The average water temperature of intertidal area ranged between 17 to 30°C. The pH values were ranging from 7 to 9.7. The average water salinity values for year 2007-08 and 2008-09 ranged from 34 - 39.48‰. The highest average value - 39.48‰ was recorded for the month of June from sub-site S3, the lowest average value 34‰ was recorded for the month of November from sub-site S4. The average Total Solids values ranged from 32-47.45 g/l. Sub-site S3 has maximum TS while, minimum TS values were recorded from sub-site S2. The maximum and the minimum values of Total hardness were recorded in October and March respectively in S3.

During present study total 26 scleractinian species belonging to 18 genera and 09 families were recorded from Narara reef. Out of these, 25 species were of hermatypic corals and 01 was ahermatypic coral. However, this figure differs from that of the reported by previous workers, the highest 33 species were reported by (Singh et al., 2004) followed by 28 (Dixit et al., 2010) and 08 (Pillai and Patel, 1988). Family Faviidae emerged as the most diverse taxon represented by 06 genera and 09 species. *Favia* and *Porites* were the commonly occurring genera whereas *Mycedium* was recorded only once in live condition. No *Acropora* genus was recorded alive, but large quantities of eroded dead remains of *Acropora spp.* skeletons were common all around on the reef area. The scleractinian diversity of Narara reef accounted for 12% of total

scleractinian species reported from all Indian reef regions and 58% of scleractinians reported from GoK reefs. Two species e.g. *S. savignyana* and *A. hillae,* recorded in present study are restricted to GoK reefs only in Indian subcontinent. *P. pini* reported here in this study have not been reported previously from this locality.

During the field visits stony corals were found to occur in all the sub-sites with varied diversity and abundance. The nearest to shore hard coral formation was found in sub-site S4 in upper intertidal area. The interesting observation was that all the colonies there in the lagoon were of *C. serailia,* massive and large, forming 100% mono-species assemblage. Otherwise, the upper intertidal area of Narara mainly consists of mudflat with no coral formation was recorded. Small colonies of *S. savignyana* and *F. favus* were across intertidal area from HTL to LTL.

The highest number of hard coral species were recorded from sub-site S4 followed by S2, S3, S1 and S5. *S. savignyana, S. radians* and *F. favus* were the commonly occurring species in all the sub-sites. Three species *viz. P. tayami, C. monile* and *M. elephantotus* were found occurring only at sub-site S4. The sub-site S1 is dominated by encrusting coral *G. stutchburyi* and massive coral *P. compressa* equally, S2 is dominated by massive coral *P. lutea,* S3 and S4 are dominated by massive life forms of *P. compressa* and *F. favus* respectively.

A few forms of abnormal condition of hard corals were observed at Narara reef. These were bleaching, sedimentation, coral diseases and polychaete infestation (Dave and Mankodi, 2009b). Generally sporadic, very small scale, partial bleaching was seen during summers in *Siderastrea, Hydnophora, Favia, Favites* and *Goniastrea.* Large patches of *Montipora* and heterogenic assemblage chiefly comprising of *S. radians, T. reniformis* were found victimized by smothering due to sedimentation in sub-sites S1, while at sub-site S4 *S. radians* colony were having similar problem of sedimentation effect. No apparent changes in sediment cover were observed in sub-sites S2, S3 and S5 during the study period. Two genera, *Montipora* and *Porites* were common to be observed with burrowing polychaetes' infestation in sub-sites S2 and S3. Generally more number of polychaete infestations per unit area are indicative of pollution load in

the reef ecosystem (Brock and Brock, 1977). *Leptastrea purpurea* and *Symphyllia radians* were also observed infested with polychaetes rarely in sub-site S4. Two kind of hard coral disease prevalence was recorded in *Porites lutea* during the study period, viz. whit plaque and pink line syndrome (PLS).

The coral reefs are the most cryptic habitat providing suitable shelter to thousands of animals and plants. The life forms inhabiting reefs are part of a complex food web. In the reef environment prey-predatory relationships are common and more complex than any other ecosystems. Alteration in diversity at varied trophic level leads to serious alterations in food web of the ecosystem (Bruno and O'Connor, 2005). All together 11 animal phyla were represented in this study area namely Porifera, Cnidaria, Annelida, Platyhelminthus, Nemertea, Arthropoda, Mollusca, Echinodermata, Echiura and Chordata covering total 132 species of associated fauna. The sponges are among the prime competitors of the scleractinians for the space. The burrowing sponges can overgrow the live coral colonies and can significantly damage the hosts. In Narara, majority of the sponges observed were of encrusting forms growing under the rocks in all the sub-sites except S5. During present study it was revealed that sponges dominate (84%) the biotic communities found underside of rocks and boulders. In Narara reef, except jellyfishes and *Porpita sp.* all the cnidarians were sessile forms; 4 species of Zoantherians, 4 species of Actiniarians, 1 species of Ceriantherians, 1 species of Coralimorpharians and 2 species of Alcyonarian were recorded. A new record of distribution range of *Rhodactis sp.* (Class: Anthozoa, Order: Corallimorpharia) from Gulf of Kachchh is reported for the first time here in this study. In this study site 04 species of zoanthus were recorded 03 belonging to genus *Zoanthus* and 01 of *Palythoa.* The *Zoanthus spp.* were recorded from all the sub-sites, with predominating sub-site S5. The *Palythoa tuberculosa* was only recorded from sub-sites S1, S2 and S4. Their distribution was sparse but covering large patch of substratum in sub-site S4. The soft coral *Lobophytm pauciflorum* was found in sub-sites S1, S2 and S4. Few species of Saballid and serpulid worms were recorded from various sub-sites. Variety of a sand worm (Nereis sp.) and a leech were also observed.

Molluscans form a highly diverse group among the reef associated fauna. They are present in the beach sand, under the rocks, moving over the sediments and pelagic ones. During this study total 42 molluscan species were recorded out of which 09 were bivalves, 32 gastropods and 01 of cephalopods and scaphopods each. The distribution of the some of the molluscan fauna was observed to be restricted. *Octopus vulgaris* is one of the tourist attractions in MNP & S because of its mysterious morphology and its ability to camouflage. Being pelagic in nature they were recorded from sub-sites S1, S2, S3 and S4 during low tides where they can swim freely in sufficiently deep tide-pools. All together 17 species of crustaceans (11 species of brachyuran crabs, 02 of anomuran crabs, 03 species of shrimps and 01 species of barnacle) were recorded from Narara reef area. The echiurans, popularly known as "spoon worms" or "innkeeper worms", were represented by genus *Acanthobonellia* in Narara reef, the genus is represented by a few species worldwide. During present study the *A. pirotanensis* was found to occur on Narara reef, first time from mainland attached coral reef in GoK (Dave and Mankodi, 2008). Total 07 echinoderms were recorded; all these species of echinoderms were recorded living cryptic life underneath rocks except *L. depressum* which inhabited sandy bottoms in mid intertidal area.

Total 04 fishes namely *Tetradon lineatus* (puffer fish), *Plotosus lineatus* (cat fish) and *Periopthalmus sp.* (mud skipper) were recorded. Out of them, puffer fishes are of great tourist attraction among the visitors. It was common in all sub-sites except S5 due to shallower tide-pools. Mudflats in sub-site S5 were inhabited by mud skippers. Apart from above listed fauna 1 species of flatworm - *Pseudoceros indicus* (phylum: Platyhelminthes), Nemertine worm (phylum: Nemertea) and ascidian (Order: Ascidiacea, Phylum: Urochordata) each were recorded.

The main vegetation on reef is formed by seaweed/macro algae. The algae not only serve as the main primary producers, but they are also effective indicator to assess any change in the biotic community or environment as a whole (Lefèvre and Bellwood, 2010; Mumby et al., 2007; O'Connor and Bruno, 2007). In Narara, algae start dominating from January and remain dominated till late of April, then gradually start diminishing. During the dominating months they cover entire intertidal area. It was

observed that the distribution of seaweeds on the reef flat was not in uniform manner and was found to follow specific patter from one sub-site to another. Total 65 species of intertidal vegetation is reported from Narara reef covering 62 species of marine algae and 03 species of sea grasses (Nair, 2002). Moving from upper to lower intertidal area, a gradual shift in dominance pattern was seen shifting from *Ulva* dominated community to *Sargassum* dominated community, this was common to all sub-sites except S5 where *Ulva* was found dominating all across the intertidal area.

During study total 03 apparent interrelationships between animals were observed on Narara reef. Out of the 03 interrelationships two were commensalism and one was predatory relationship. A pair of *Periclimenes brevicarpalis,* anemone shrimp, was invariably observed dwelling between tentacles of *Stichodactyla spp.* of sea anemones. In another case, a species specific relationship was observed between *Paraiptasia radiata,* a tiny sea anemone and a snail, *Nassarius olivaceus.* Here *P. radiata* lives an epibiont life on the snail and enjoys commensalism (Dave and Mankodi, 2009a). The predatory relationship was found to exist between *Porites lutea* and Puffer fish, *Tetradon lineatus.* The predation of *P. lutea*'s polyps was evident by scrap marks made by puffer fish exclusively on the coral's colonies. The empty shells of *Pinna bicolor* and *Cardium flavum* were often seen with fish egg masses.

The anthropogenic activities on Narara reef were categorized into two broad categories i.e. exploitation of biodiversity and habitat degradation (Dave, 2010). Activities falling under both the categories have direct and/or indirect adverse effects on reef environment. The fishermen explore the intertidal area during low tides on feet to collect crabs and octopuses. Here in GoK, the octopuses are exploited for fish baits and not for food. The area near to LTL was preferred by fishermen to erect fishing net with help of metal rod/bamboo involving digging into the coralline areas. During the study sub-site S1 was found to be affected severely by direct anchoring of barges and other vessels on the reef area. Close observations revealed presence of live coral colonies entangled with and uprooted by the anchor. Fishermen in groups of 15-20 people were observed to visit Narara reef in boats. Generally they land their

mechanized fishing boats on the outer reef flat, reef edge or inner reef flat, which was found to crush coral colonies present under the landed boat.

The Narara reef as attached with main land and easily approachable, it is susceptible to all possible anthropogenic and climate changes. In last two decade extensive industrialization has taken place near this area. Also previously due to lack of awareness of conservation this area has been highly exploited for coralline sand and rocks. There was a necessity to generate comprehensive baseline database of this reef for future exploitation of the area and also contribute to academic and research segment of corals and coral reefs of the Gulf of Kachchh. This study was planned with the aim to fulfill the requirements of such database. Strategic observations were made through appropriate methodology for diversity and distribution of corals, environmental status of coral reef, associated fauna and flora in this reef and anthropogenic impacts with natural threats to coral and entire reef area. Overall study reveals that even though there are several activities taking place within the vicinity of this area, the notable diversity of corals are sustained, also habitat characteristics do not mark significant change during study period; comparatively associated fauna and flora of the reef have been recorded in good conditions. The interactions between animals indicate healthy state of ecosystem. Through awareness program the proper utilization and conservation of this reef is required. This information is envisaged to contribute to academics, researchers and planners.

Credentials earned by the candidate during present study

PUBLICATIONS

1. Dave, CS and Mankodi, PC. 2008. Occurrence and distribution of *Acanthobonellia pirotanensis* on the Narara reef, Gulf of Kachchh, Gujarat. J. Curr. Sci., **12**: 517-520.
2. Chandresh S. Dave and Pradeep C. Mankodi. 2009. Species specific association of sea anemones. Curr. Sci., **97**: 1522.

CONFERENCE PRESENTATIONS

1. 2006, Chandresh S. Dave: ***Wetlands and its management*** at Workshop on Basic work in Biosciences, Visnagar.
2. 2008, Chandresh S. Dave, Pradeep C. Mankodi: ***Preliminary survey of anthozoan diversity and distribution on Narara reef*** at Science Excellence - 2008, Ahmedabad. *Adjudged 2nd for best oral paper presentation.*
3. 2009, Chandresh S. Dave, Pradeep C. Mankodi: ***On abnormalities in Scleractinians from Narara reef, Gulf of Kachchh*** at 20th All India Congress of Zoology, Mumbai.
4. 2010, Chandresh S. Dave: ***Anthropogenic activities involving habitat exploitation on Narara reef, Gulf of Kachchh, India*** at Student Conference on Conservation Science (SCCS), Bangalore.
5. 2010, Chandresh S. Dave, Pradeep C. Mankodi: ***Animal inter-relationships on Narara reef, Gulf of Kachchh*** at National Conference on Interdisciplinary approaches in Environmental Science, The M. S. University of Baroda, Vadodara. *Adjudged 2nd for Young Scientist Award.*

ACTIVE SCIENTIFIC INTERACTIONS AT CONFERENCES/SYMPOSIA: 16