DIVERSITY AND ECOLOGY OF FAMILY FAVIIDAE (GREGORY, 1900) IN GUJARAT

A Thesis Submitted to

The Maharaja Sayajirao University of Baroda

For the Award of

Doctor of Philosophy in Zoology

by

Mirza Ruzbeh Tehmurasp

Department of Zoology,

Faculty of Science,

The Maharaja Sayajirao University of Baroda,

Vadodara, India. 390002

December 2020

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INTRODUCTION

Coral reefs all over the world cover an estimated area of 2,84,399 km^2 (Venkatraman et al., 2003) which is less than 0.2 % of the global ocean area and about 15 % of the shallow sea areas within 0-30 mts depth (Lalli and Parsons, 1997). Around 54 % of the coral reefs lie in the Asiatic Mediterranean and the Indian Ocean. The remaining Pacific reefs account for 25 %, Caribbean reefs for 9 %, Atlantic for 6%, Red sea for 4 % and Persian Gulf for 2% (Smith, 1978). Majority of corals are concentrated on western side (Fig. 1) of the three oceans (Scheer, 1985).

They are the largest structures ever created by millions of tiny animals over thousands of years. They are refuge to many thousands of flora and fauna in comparatively nutrient rich marine realm (Spalding et al., 2001). Corals are tiny invertebrate life forms, exclusively marine and sedentary animals. They belong to Phylum Cnidaria. In ancient time the word "Coral" was used for precious red corals - *Corallium rubrum* (Sreekumaron and Gogate, 1972). The scleractinians or Hard corals, evolved 245 million years ago in Mesozoic era. Generally, they adopt asexual mode to grow in colony size. Majority of hard coral colonies are hermaphrodite, however a few percent of total population may be unisexual possessing only male or female sex organs (Veron, 2000).

Looking at the coral reefs, the Indian reef regions fall into Indo-Pacific reef zone. The Indian reefs can be divided roughly into four major reef regions viz. Andaman and Nicobar Islands, Gulf of Mannar and Palk Bay, Lakshadweep Archipelago and Gulf of Kachchh (Venkatraman 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. The geographic isolation from other coral reef areas of India and extreme environmental conditions are the main factors for the least coral diversity of this reef region among the major Indian coral reef regions (Pillai and Patel, 1988). Early studies have 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).

The new sights of coral formations have been reported along the Kachchh district in the northern part of GoK and along the Saurashtra coast also (Deshmukhe et al., 2000; Raghunathan et al., 2004. Parasharya and Padate, 2014). Joshi (2016) documented impact assessment of coral reef ecosystem with special reference to climate change. As adapted to wider range of seasonal temperature fluctuations, the GoK reefs were not found much affected by 1997-98 El-Nino southern oscillation events (Arthur, 2000). However, the region is facing heavy industrial developments in the form of major petroleum-based refineries and related industries and crude transport through the gulf water. Hence, it becomes important to monitor the status of Flora and Fauna in the Gulf of Kachchh. So, the present study was aimed to find out coral diversity with main emphasis on Faviids, fauna associated with the Faviids, physicochemical properties of sea water and the substrate characteristic of the reef. This can help in finding out if there is any change in the ecology of coral reef ecosystem in GoK and help in planning management and conservation of the area as it also includes India's first Marine National Park.

AIMS AND OBJECTIVES

To assess the diversity of the family Faviidae in Gok

To study fauna associated with family Faviidae in Gok

To study the ecology of two reefs in Gok

MATERIALS AND METHODS

Study area

Gujarat: The study was conducted in the southern Gulf of Kachchh (Fig. 1) Marine National Park and Sanctuary (MNP&S), Jamnagar. The MNP&S contributes its major role in harbouring the major macrobenthic flora and fauna. The Protected area was established for the conservation of its

abundant and rich reef ecosystems. The two coastal reefs Narara and Poshitra were studied for the Faviid diversity and ecology.

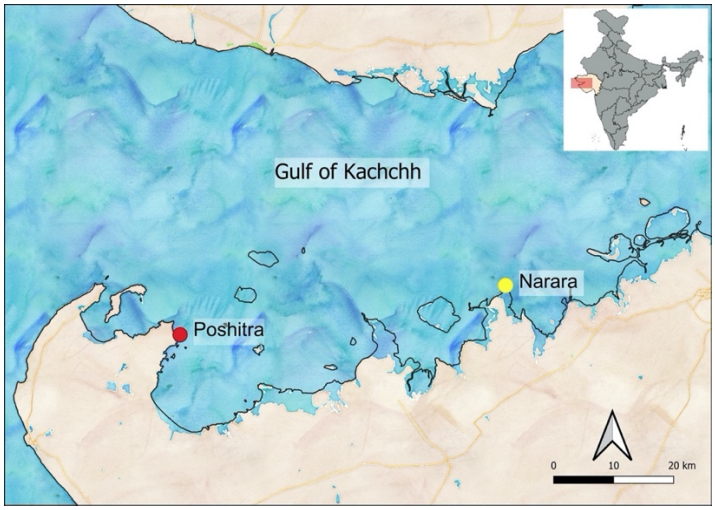


Fig. 1 Location of Narara and Poshitra coastal reefs.

Diversity and Distribution:

For the diversity and distribution of Faviids and associated microbenthic fauna reconnaissance survey was conducted. Based on the reconnaissance survey, Random Quadrate Sampling, Line Intercept and Point Intercept Transect were conducted at both the study reefs. The characteristics of substratum was measured using grids in the quadrat.

Physicochemical parameters:

The Sea Surface Temperature, pH, DO, Salinity, Nitrate, Nitrite and Phosphate were measured for gulf water using appropriate instruments and kits.

Statistical Analysis:

The post sampling statistical analysis was carried out using PAST, MS-excel and R-programme. The frequency distribution, single factor-ANOVA, species diversity index, and correlation were performed.

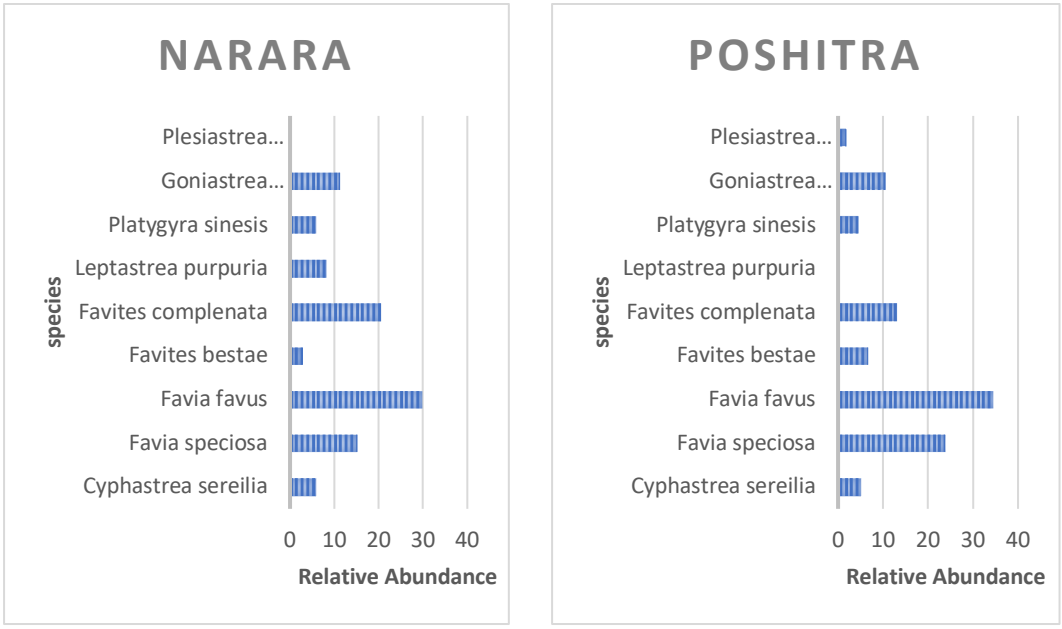


Fig. 2 Relative abundance of Faviids at Narara and Poshitra coastal reef

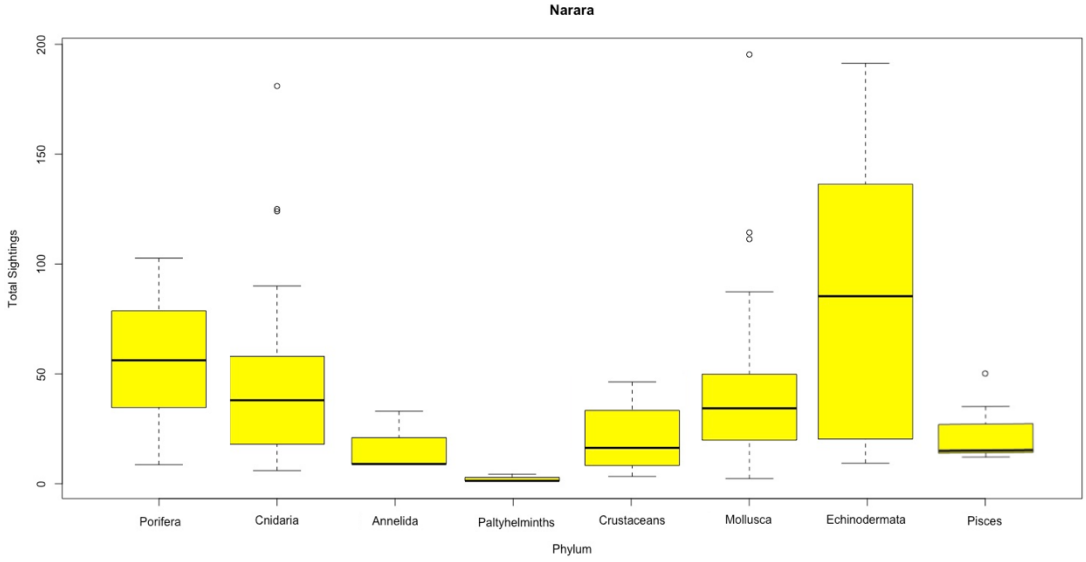


Fig.3 Phylum wise mean representation of individuals observed in Narara reef

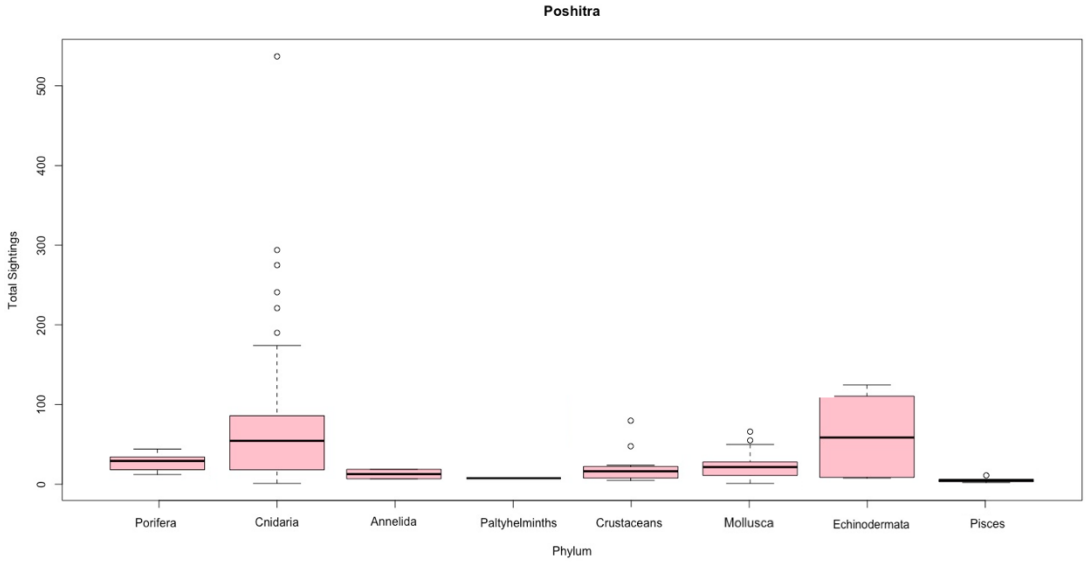


Fig. 4 Phylum wise mean representation of individuals observed in Poshitra reef

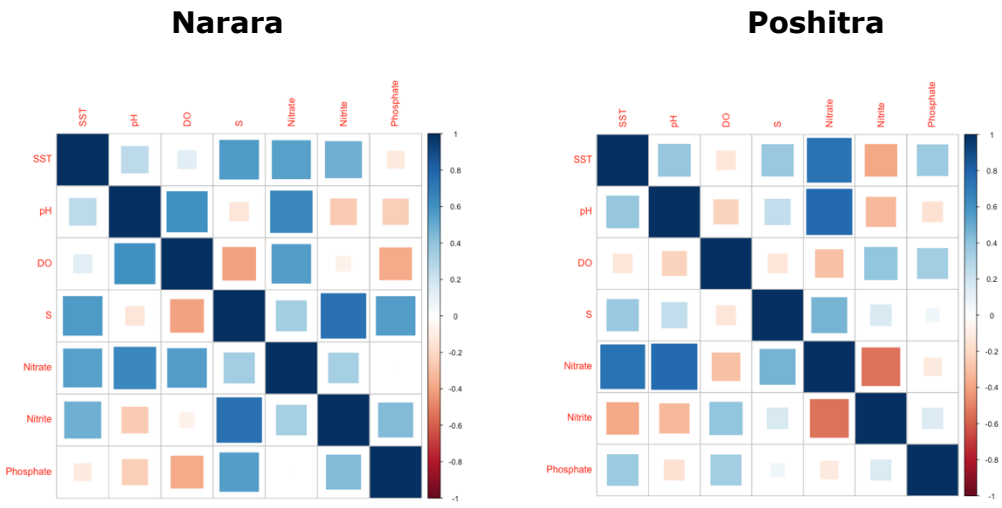
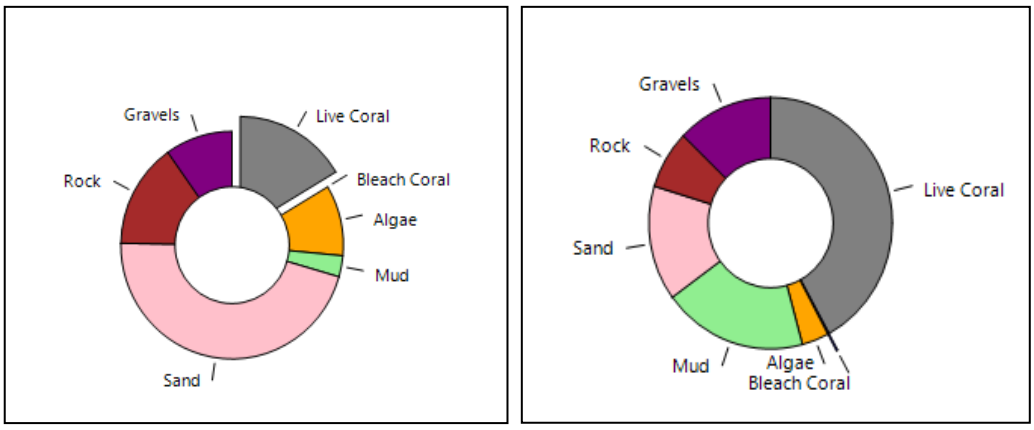


Fig. 5 Correlation matrix of physicochemical parameters of Narara and Poshitra coastal reefs.



Narara **Poshitra**

Fig.6 Substratum characteristics

The survey on the current distribution of Faviids was an approach to assess the sustenance of faviids since the past studies at Narara and Poshitra coastal reefs.

Assessing the status of Faviidae in Gulf of Kachchh was challenging as the corals were sparsely located in Narara and closely located in Poshitra coastal reef. At Poshitra reef transect surveys were testing as the concentration of coral patches were high and care was needed to avoid stamping as well walking over them. The Narara and Poshitra reefs being in the same gulf, former in the centre and other near the mouth of Gulf and at about 54 kms. apart, basically had most species common to them except difference in one species each. In past, studies on coral reef biodiversity of Gulf of Kachchh have been carried out by Pillai and Patel (1988), Singh (2001), Singh et al (2004), NIO (2009) Dixit (2010) Dave (2011), Parasharya (2013) Srinath (2014). In gulf of Kachchh Narara reef is highly popular as a tourist spot and easily accessible. Whereas Poshitra is an isolated reef hence less visited by tourists. However, it does have low tourist inflow.

The descriptive statistics of Narara and Poshitra reefs with reference to faviid diversity is given in Table 3. The Narara reef had counts in the range between minimum 0 and maximum 90 with Mean 33.55. Whereas, the

Poshitra reef also had minimum zero but maximum 275 counts with Mean 89. The sum of the total individuals found at Narara reef was 302 and Poshitra reef 801. The standard deviation of the both the reefs differed in terms population because the number of individuals found on both the sites varied remarkably giving an account of SD $\pm$ 28.32 for Narara and SD $\pm$ 89.93 for Poshitra. Both the reefs showed positive skewness in terms of individuals encountered with Narara at +1.01 and Poshitra +1.33 skewness. Both the reefs showed platykurtic distribution having no outliers in the population.

Phylum wise representation of individuals of the various phyla studied is plotted as boxplots to understand the differences in status of these phyla (Fig. 3 Narara, Fig. 4 Poshitra). In Narara coastal reef, the majority of counts that go away from the average number of individuals were of Echinoderm and has greater differences in numbers of individuals observed per visit by having high median value. Similarly, in Cnidaria and Porifera the differences in numbers sited are higher but the medians varied in comparison to Echinoderm. However, their medians fall in the normal central tendencies of the total sightings of the individuals at Narara. Annelida, Crustaceans, Platyhelminthes and Pisces showed occurrence skewed to the right. The least encountered group of individuals belonged to the Platyhelminthes. The outliers were spotted in Cnidaria, Mollusca and Pisces showing the contrast of sightings with regard to each phylum. Figure 4 shows variations in the sightings status in regard of individuals encountered for different phyla at the Poshitra coastal reef. The Annelida, Crustacea, Mollusca and Porifera were negatively skewed indicating that the sighting of the individuals was low contrary to the other phyla. However, the Cnidaria had higher number of outlier and also in highest number of *Heteractis malu* was encountered with maximum individuals (1140 Nos.) during one visit. The higher median values were found in Cnidaria and Echinodermata giving an understanding of varied number of sightings in both the categories. The Platyhelminthes and Pisces were found with low median values.

The Pearson correlation test was performed to find out if any relation exists between various physicochemical parameter studied in the Sea water

collected from Narara and Poshitra coastal reefs. At Narara (Fig. 5) there was positive correlation between SST and pH, DO, Salinity, Nitrate and Nitrite; whereas negative correlate to Phosphate. The pH was positively correlated with DO and Nitrate. Whereas it was negatively related with Salinity, Nitrite and Phosphate. The DO was positively correlated with Nitrate. Whereas it was negatively correlated with Salinity, Nitrite and Phosphate. The Salinity was Positively correlated with Nitrate, Nitrite and Phosphate. The Nitrate was positively corelated to Nitrite, whereas negatively correlated to Phosphate. None of the parameters studied showed any significant relation with each other.

At Poshitra, (Fig. 5) the SST was positively correlated to pH, Salinity, Nitrate and Phosphate and negatively correlating to DO and Nitrite. The pH was positively correlated to Salinity and Nitrate and negatively correlated to DO, Nitrite and Phosphate. The DO was positively correlate with Nitrite and Phosphate, whereas it was seen negatively correlated with Salinity and Nitrate. The salinity was positively correlated with Nitrate, Nitrite and Phosphate. The Nitrate was negatively correlated with Nitrite and Phosphate. The Nitrite was positively correlated with Phosphate. As noted for Narara, here also no significant correlations were obtained between various parameters studied.

The positively skewed graph for frequency of abundance showing mesokurtic trend obtained for Narara gives the probability of more species between 0 to 40% encountered rates. The Poshitra coastal reef too showed positively skewed graph but it showed platykurtic trend where the most of the encountered individuals gave probability between 0 to 100%. The probability of encounter rates was comparatively higher for Poshitra than the Narara coastal reef. The Faviids here were more congregated in the form than the Narara coastal reef giving higher encounter rates. It is less disturbed and less visited by the tourists as well, letting the reef grow and sustain more than the Narara reef. At Narara, the disturbance and pollution pressure on Faviids and other Scleractinians is likely to be higher due to the presence of ship gateway for mega oil industries linked to the near-by coast. In addition, Narara coastal reef encounters direct flow of tide water too. Whereas, Poshitra lies towards inner margin at the mouth of gulf that makes

the reef less prone to the disturbances and away from direct flow. But on the other side the crab catching activity disturbs the reef at much higher rates at Poshitra coastal reef. Both Narara and Poshitra coastal reefs deal with the fishing activity leading in upturning of bio-rocks and the corals.

The macrobenthic fauna associated with the Faviids plotted in histogram with respect to their abundance rates at Narara and Poshitra coastal reefs helped in evaluating the population status of associated fauna with Faviids

Species specific differences in distribution of fauna in a marine ecosystem are known to occur depending on the temperature of sea water (Murawski, 1993). The temperature is also known to influence breeding performance of various species (Orton, 1920). Thus, temperature as an environmental parameter is dependent on various other environmental factors including pollution, while temperature in turn also influences various environmental characteristics. Narara reef being closer to industrial belt of Gulf of Kachchh the higher SST is likely to occur compared to Poshitra reef which is seclusive. However, the difference in the temperature of sea water of two reefs is non-significant as the Gulf as a whole face highest of hightides in the world (Vethamony et al 2005) mixing water twice in a day.

The Narara and Poshitra coastal reefs were also evaluated on the basis of their substrate characteristics based on the benthic cover of live coral, bleached coral, algae, mud, sand, rock and gravels. The live coral composition at Narara was 16% (Fig. 6) and that at Poshitra was 42% (Fig. 6). The bleached coral cover was not recorded during the study in Narara reef, while at Poshitra reef 0.19% of bleached corals were encountered. The algal cover at the Narara reef was 10.06% and that of Poshitra reef was 3.57%. The aggregation of algal growth differed at both the reefs. The mud cover near the corals in both the reefs also differed. There was only 3% of mud encountered in the Narara coastal reef and 19.19% of mud cover at Poshitra reef. The sand was a major part in the Narara coastal reef along with the reef structure and the corals. The sand comprised the total 45.76% in the Narara and 14.8% in the Poshitra coastal reef. The rock composition at Narara was 14.93% towards the sea whereas; it was 7.5% in Poshitra.

The benthic cover of gravels were found to be 9.8% in Narara and 12.76%. at Poshitra reef.

DISCUSSION

The survey on the current distribution of Faviids was an approach to assess the sustenance of faviids since the past studies at Narara and Poshitra coastal reefs.

Assessing the status of Faviidae in Gulf of Kachchh was challenging as the corals were sparsely located in Narara and closely located in Poshitra coastal reef. At Poshitra reef transect surveys were testing as the concentration of coral patches were high and care was needed to avoid stamping as well walking over them. The Narara and Poshitra reefs being in the same gulf, former in the centre and other near the mouth of Gulf and at about 54 kms. apart, basically had most species common to them except difference in one species each. In past, studies on coral reef biodiversity of Gulf of Kachchh have been carried out by Pillai and Patel (1988), Singh (2001), Singh et al (2004), NIO (2009) Dixit (2010) Dave (2011), Parasharya (2013) Srinath (2014). In gulf of Kachchh Narara reef is highly popular as a tourist spot and easily accessible. Whereas Poshitra is an isolated reef hence less visited by tourists. However, it does have low tourist inflow.

The past studies of Pillai and Patel (1988) at Narara coastal reef reported four species of Faviids i.e. *Favia favus, Goniastrea pectinata, Leptastrea purpurea* and *Cyphastrea serailia*. This study was followed by Singh et al (2004) who reported eight species of which only two were reported earlier. The additional six species encountered were *Favia speciosa, Favia maxima, Favites complanata, Favites flexulosa, Platygyra sinenses,* and *Plesiastrea versipora*, while *Goniastrea pectinata* and *Cyphastrea serailia* were not recorded by them. In NIO study (2009) seven species reported were all recorded earlier. Dixit et al (2010) reported eight species of Faviidae i.e. *Favia favus, Favia speciosa, Favites complanata, Favites bestae, Goniastrea pectinata, Platygyra sinenses, Leptastrea purpurea* and *Cyphastrea serailia*. While Dave (2011) could report 9 species with one new record *Platygyra pini*. Parasharya (2013) reported eight species, with *Favites complanata*

and *Favites bestae* with status as "might be possible". In Current study carried out at Narara encountered total eight species all recorded earlier, however *Platygyra pini, Favites flexulosa* and *Plesiastrea versipora* could not be spotted. *Favia maxima, Favites flexulosa* and *Plesiastrea versipora* reported by Singh et al (2004) are not reported in any of other studies. At Narara reef vast area is exposed during low tide and the surveyor must complete the survey in short exposure time and if the size of coral is small it is very much likely that some species are missed. Further the species encountered during the surveys by the individual /groups might by due to species complexes made by the members of the family Faviidae. The species reported in all the studies is *Favia favus* which is the most common species of the reef as is recorded in the present study too with maximum relative abundance.

The Poshitra coastal reef near Laku point has also been studied by Patel and Pillai (1988), Singh (2001), Pandey et al., (2010), Parasharya, (2013), Kamboj (2014) and Joshi (2016), in the past. Kamboj (2014) reported maximum eleven species of Faviids i.e. *Cyphastrea serailia, Favia favus, Favia Maxima, Favia speciosa, Favites bestae, Favites flexulosa, Favites complanata, Goniastrea pectinata, Leptastrea purpurea, Platygyra sinenses* and *Pleseastrea versipora.* The current study finds eight of these species. At Poshitra fishermen and crab catchers' upturn or thump the corals for searching crab for their lively hood in intertidal pools. The said phenomenon results in expulsion of zooxanthellae, disturbing the symbiotic relation and ultimately bleaching of corals. This is likely to lead to the death of Faviids and other scleractinian corals (Parasharya, 2013). Though very low in percentage, coral bleaching was observed at Poshitra coastal reef among the two reefs surveyed.

When compared with studies of Parasharya (2013) the relative frequency of *Cyphastrea serailia, Favia speciosa and Favia favus* showed decline in relative frequencies whereas *Leptastrea purpurea, Platygyra sinenses*, *Goniastrea pectinata* showed increase in relative frequency. In present study *Plesiastrea versipora* was not encountered at Narara, however, Singh (2004) have reported this species from the Narara coastal reef. This Faviid is often mistaken with *Favia stelligera* and *Cyphastrea sp.* (Veron, 2000).

Looking further with the sustainance of coral species at Poshitra coastal reef the *Cyphastrea serailia, Favites besate, Favites complanata, Platygyra sinensis, Goniastrea pectinata* and *Plesiastrea versipora* recorded in this study were not reported earlier by Parasharya (2013). At Poshitra the corals are densely packed forming massive structures and very likely to be missed. During the current study the relative abundance of *Favia speciosa* and *Favia favus* showed an increase when compared to Parasharya (2013). *Leptastrea purpurea* was not found at Poshitra coastal reef. Here, *Favia favus* was the most abundant species.

The positively skewed graph for frequency of abundance showing mesokurtic trend obtained for Narara gives the probability of more species between 0 to 40% encountered rates. The Poshitra coastal reef too showed positively skewed graph but it showed platykurtic trend where the most of the encountered individuals gave probability between 0 to 100%. The probability of encounter rates was comparatively higher for Poshitra than the Narara coastal reef. The Faviids here were more congregated in the form than the Narara coastal reef giving higher encounter rates. It is less disturbed and less visited by the tourists as well, letting the reef grow and sustain more than the Narara reef. At Narara, the disturbance and pollution pressure on Faviids and other Scleractinians is likely to be higher due to the presence of ship gateway for mega oil industries linked to the near-by coast. In addition, Narara coastal reef encounters direct flow of tide water too. Whereas, Poshitra lies towards inner margin at the mouth of gulf that makes the reef less prone to the disturbances and away from direct flow. But on the other side the crab catching activity disturbs the reef at much higher rates at Poshitra coastal reef. Both Narara and Poshitra coastal reefs deal with the fishing activity leading in upturning of bio-rocks and the corals.

The Bray curtis similarity indices showed the similarity of the population on both the costal reefs. Only two species *Plesiatrea versipora* at Narara and *Leptastrea purpurea* at Poshitra coastal reefs were missing at the respective reefs.

The need to find out the number of individuals was to evaluate the population status of the species at both the respective sites. The individuals

of cnidarians and molluscans encountered at both the sites were always higher. If we look at the global and Indian cnidarian species status of its diversity is high with 9924 Cnidarian reported globally including 1042+ from India (Venkatarman and Raghunathan, 2015). This group dominated Narara as well as Poshitra reefs with Poshitra giving higher encountered rate in the compactly packed coral reef system. As mentioned earlier*, H. malu* influenced the total number of cnidarians because of their presence in huge number.

Similarly, when one looks at status of marine molluscs, about 3400 have been recorded from Indian waters that make a part of 52525 species globally (Venkatarman and Raghunathan, 2015). The comparatively smaller reef areas of Narara and Poshitra also recorded higher species as well as individuals that is 23 species at Narara and 28 at Poshitra compared to other groups of associated fauna.

The representation of Crustaceans seems to be moderate at the two reefs as only 11 (Narara) and 12 (Poshitra) species were recorded at the two reefs against global species diversity of 44950 and Indian species 2394 (Venkataraman and Raghunathan, 2015). The encounter rate of the same group was also moderate at the two reefs.

SUMMARY

Coral reefs are considered the rain forest of the ocean. A network of commercial and medicinal purposes are derived from the ocean. The reefs play an important role in providing the complete web of life from producers to primary consumers to the quaternary consumers. The marine biodiversity is dependent on the reef ecosystem in various ways in which the diverse and abundant fauna of corals are surviving.

Looking into current aspects it was felt necessary to study the diversity of corals of family Faviidae and assess the ecology regarding the fauna associated. Narara and Poshitra coastal reefs were selected for the same.

There are total 24 genera of Family Faviidae of which 13 genera are present in the Indian subcontinent. Gujarat, Southern Gulf of Kachchh has 14 species of family Faviidae till date. During the current study 8 species were encountered at Narara and Poshitra coastal reefs. The density of the Faviids were comparatively moderate in terms of the geographic area and the reef locations. Poshitra reef had more density of faviids than Narara reef. Also, the frequency of sighting was higher in Poshitra coastal reef. The disturbances are likely to be higher at Narara due to vessel movements to and from crude based industries that might release waste in the gulf. Poshitra is towards the inner side of GoK and away from major vessel movements and major industries. The population status of the Faviids was found to be low on the Narara coastal reef while the Poshitra reef was found to stand at the better condition with reference of Faviidae and other Scleractinian diversity apart from anthropogenic pressures.

However, the diversity of macrobenthic associates was near to the normal distributional curve on both the study sites. The major phylum and subphylum ie. Viz. Porifera, Cnidaria, Annelida, Platyhelminthes, Crustacea, Mollusca, Echinodermata and Pisces taken into consideration for the ecological studies gave interesting findings in the species presence and population status. Both the reefs had almost same species of Porifera but the populations differed with reference to respective reef. The annelid and crustacean diversity as well as population were higher at Narara reef. Many past studies have reported that the diversity in the Narara coastal reef is

declining, however in present study good diversity of poriferans, annelids and crustaceans were encountered at Narara. The Cnidarian diversity apart from Faviids at both the sites were comparatively high. The Actiniarians were diverse at Poshitra and population of *H. malu* was higher than the Narara coastal reef. Association of nudibranchs were higher at Poshitra than Narara coastal reef. The encounter of nudibranchs was mainly during the evening tides.

The physicochemical parameter analysed using the correlation plots with SST as independent factor gave positive correlation with DO, pH, salinity, nitrate, nitrite at Narara whereas, it showed negative correlation with phosphate. For Poshitra coastal reef positive correlation were obtained with pH, salinity, nitrate and phosphate whereas, negative with DO and nitrite. The difference in the correlations of physcochmical parameters may be attributed to high mixing of Gulf water twice in a day.

The substrate characteristic of Narara costal reef dominated with sand and live corals while at Poshitra live coral dominated with mud patches. The coral bleaching was negligible at Poshitra and not recorded at Narara whereas algal cover was more at Narara. The overall study indicates that both the reefs have their own characteristic substratum as well as the microbenthic fauna they support. Additionally, these reefs are adapted to extreme environmental conditions as the fluctuation in tidal water is high, turbidity/ sedimentation in the area is also high, the ambient temperature also show extreme fluctuations and the gulf currents are also strong. Under such circumstances the reefs support good diversity of faviids and equally good diversity of fauna which is not likely to face threat due to climate change but if the industries around the gulf are not taking care and any crude is added to the gulf water in long term the reef may face a threat of destruction.

The authorities need to have stringent control of the policies to check the industrial effluent flow in the gulf. This study is expected to help policy makers and private agencies to build their strategies in conservation of species and transplantation of that are declining species in the coastal reefs. Marine tourism fetches enormous economy and cannot be halted due to any

such physical and anthropogenic pressures. Awareness programs should be organised frequently not only for locals and tourists but also for industries. Awareness amongst the fishermen community and the local schools is strongly needed to stop the ill practices of exploiting the reefs. This will help in capacity building in the villages that are adjoining the coastal reefs of Southern Gulf of Kachchh.

Arthur, R. 2000. Coral bleaching and mortality in three Indian reef regions during an El Nino southern oscillation event. *Current Science* 79 (12): 1723-1729.

Dave, C. 2011. *Ecological assessment of Narara reef with special reference to coral community*. Ph.D. Thesis, submitted to The M.S. University of Baroda, Vadodara, India.

Deshmukhe, G., Ramamoorthy, K. and Sen Gupta, R. 2000. On the Coral reefs of the Gulf of Kachchh, *Current Science* 79 (2): 160-162

Dixit, A.M., Kumar, P., Kumar, L., Pathak, K.D. and Patel, M.I. 2010. Economic valuation of coral reef systems in Gulf of Kachchh. Gujarat Ecology Commission, Gandhinagar 143 pp.

Joshi, D. 2016. impact assessment of coral reef ecosystem with special reference to climate change, Ph.D Thesis submitted to The Maharaja Sayajirao Univerisity of Baroda, Vadodara.

Lalli, C. M. and Parsons, T. R. 1997. *Biological Oceanography, An Introduction*. 2nd ed., Oxford. Buttersworth-Heinmann.

NIO (2009) Management of Marine Ecology and Conserivation of Corals off Vadinar. National Institute of Oceanography, Mumabi 176 pp.

Parasharya, D .2013. *Study of corals and associated fauna in Marine National Park, Jamnagar, Gujarat.* Ph.D. Thesis, submitted to The M.S. University of Baroda, Vadodara, India.

Parasharya, D. and Padate. G. 2014. Additional record of scleractinian corals on Porbandar coast, Gujarat, India. *Journal of Threatened Taxa* 6(6): 5900–5904.

Pillai, C. S. G. and Patel, M. I. 1988. Scleractinian corals from the Gulf of Kutch*. J.Marine Bio.l Asso. India*, **30** .1&2.: 54-74.

Raghunathan, C., Sen Gupta, R., Wangikar, U. and Lakhmapurkar, J. 2004. A record of live corals along the Saurashtra coast of Gujarat, Arabian Sea. *Current Science* 87:1131-1138.

Scheer, G. 1985. The distribution of reef corals in Indian Ocean with a historical review of its investigations. *Deep Sea Research* 31 (6-8):885-900.

Singh H.S., Panday C.N., Yennawar P., Asari R.J., Patel B.H., Tatu K. and Raval B.R. (2004) The Marine National Park and Sanctuary in the Gulf of Kachchh - a comprehensive study on biodiversity and management issues. GEER Foundation, Gandhinagar 370 pp.

Singh, H. S. 2001. *Marine Protected Areas of India*. Published by Gujarat Ecological Education and Research Foundation, Gandhinagar, India. pp: 140.

Smith, S. V. 1978. Coral reef area and the contribution of reefs to processes and resources of the World Oceans. *Nature*, 273:225–226.

Spalding, M. D., Ravillious, C. and Green, E. P. 2001. *World atlas of coral reefs.* Berkeley, CA: University of California Press. U. S. A.

Sreekumaron, C. and Gogate, S.S. 1972. Studies on mineral constituents of some species of corals. *Current Science* 41: 241-244.

Venkataraman, K., Satyanarayana, C., Alfred, J. R. B. and Wolstenholme, J. 2003. *Handbook on Hard corals of India*. Zoological Survey of India. Kolkata, India.

Venkataraman, K. and Raghunathan, C., 2015. Coastal and marine biodiversity of India. In *Marine faunal diversity in India*(pp. 303-348). Academic Press.

Veron, J. E. N. 2000. Corals of the world. Vol- I to III, Australian Institute of Marine Science, Townsville, Australia.