SYNOPSIS OF THE THESIS ENTITLED

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

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Ph. D Student

Mirza Ruzbeh Tehmurasp

Registration number: FoS/2038

Registration Date: 23-01-2017

Supervisor

Prof. Geeta Padate

Department of Zoology,

Faculty of Science,

The Maharaja Sayajirao University of Baroda,

Vadodara, Gujarat, India. 390002

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INTRODUCTION

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 and Gulf of Kachchh (Venkataraman et al., 2003). The Andaman and Nicobar Islands lies in southeastern direction in the Indian Ocean. The reef region represents the highest generic diversity of scleractinians from the Indian waters. The Andaman and Nicobar reefs are nearer to the Indonesian coasts therefore the coral diversity of this region is more similar to that of the Indonesian and the Southeast Asian reefs (Bahuguna et al., 2010). The islands have two Marine National Parks viz. Mahatma Gandhi Marine National Park and Rani Jhansi Marine National Park. All together 177 species of hard corals have been reported from Andaman and Nicobar Islands (Venkataraman et al., 2003).

Lakshadweep Archipelago, situated in Arabian Sea in the southwest direction of mainland about 200-470km off the Kerala coast (Bahuguna et al., 2010). Lakshadweep reefs harbors 91 species of hard corals and forms the second most diverse Indian reef region (Venkataraman et al., 2003).

Gulf of Mannar and Palk Bay, the third most important coral reef region of India, is located along the southern coast of Tamil Nadu state. These reefs had suffered large scale quarrying of coral blocks by construction industries before the declaration of the area as Gulf of Mannar Marine National Park in 1986. Subsequently in the year 1989 the Gulf of Mannar was declared as "Marine Biosphere Reserve" (Bahuguna et al, 2010; Patterson, 2007). Gulf of Mannar and Palk Bay reefs have been reported to have 82 species of corals, however recent surveys have reported all together 117 species of hard corals (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. Here, fringing, platform and patchy types of reefs are found along the southern coast of the Gulf. No barrier and atoll reefs are found in the GoK.

This reef region forms the northern reef formations of Indian Ocean. The GoK receives heavy load of sediments from the Indus River (Kunte et al., 2003). Further, 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).

Further, apart from the above-mentioned major reef regions, distribution of corals in form of patchy reefs and otherwise on rocky intertidal area have been reported along Vizhinjam, Mangalore, Gaveshani Bank, between Vengurla and Vijaydurg, Redi Port, Malwan, Bombay High (near Mumbai) on the west coast of India (Jasmine et al., 2009; Nair and Qasim, 1978; Qasim and Wafar, 1979; Sengupta and Deshmukhe, 2000).

The largest reef settlement on the globe is the Great Barrier Reef situated in the Coral Sea off Queensland in the Australian continent. The reef is composed of more than 2900 smaller reefs covering an area of 344400 km^2, with more than 400 coral species (Veron, 2000). Coral reefs are distributed in a circum tropical band mostly between the latitudes of 20^0 North and 20^0 South (Fig.1). The western Atlantic and the Indo-Pacific are the two main coral reef regions in the world (Wells, 1988). From the biodiversity point of view, the Indo-Pacific reef is roughly ten times more diverse than the western Atlantic reef with approximately 60 species of hermatypic corals reported from the coral reefs of the western Atlantic whereas 500-600 species are reported from the Indo-Pacific reefs. Approximately 800-1000 spp. of corals are found all over the world. More than 100 countries are endowed with coral reefs worldwide; most of these are developing countries (Venkatraman et al., 2003).

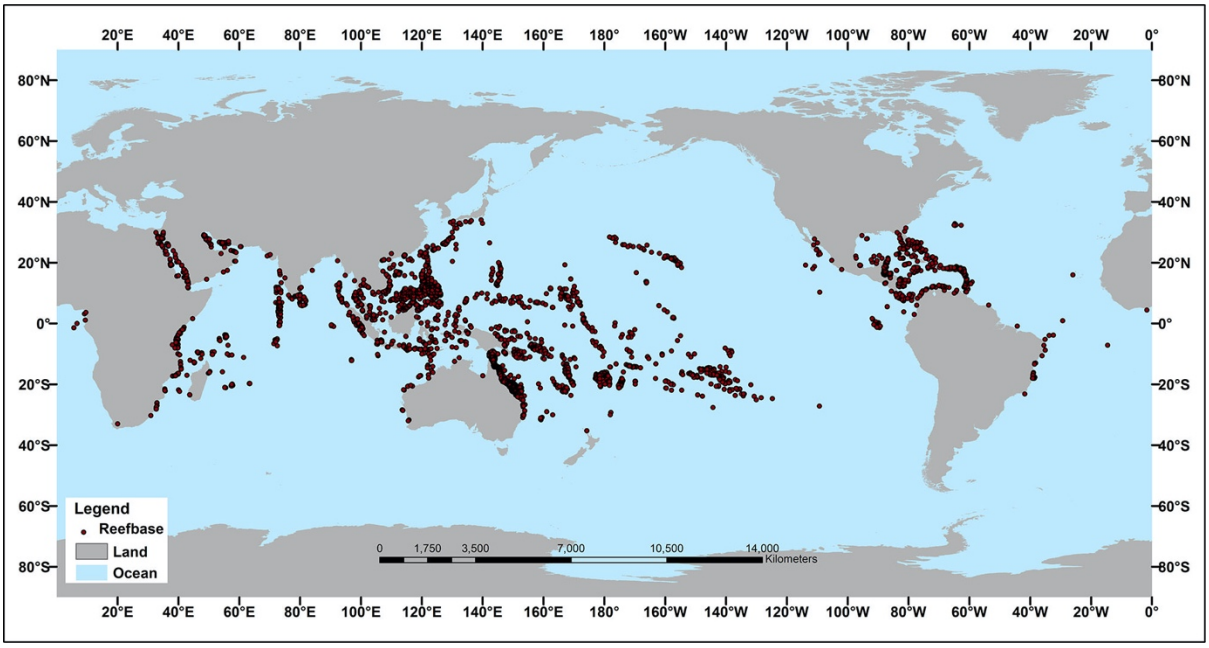


Fig.1: Major coral reefs regions of the world.(Source: National Oceanic and Atmospheric Administration).

The species diversity of corals varies at different regions. The maximum coral species are found in South East Asia at a region known as the Coral Triangle where 605 spp of the world's coral species have been reported. The Coral Triangle is a geographical term referring to the tropical marine waters of Indonesia, Malaysia, Papua New Guinea, Philippines, Solomon Islands and Timor-Leste. The highest coral diversity resides in the Bird's Head Peninsula of Indonesian Papua, which hosts 574 species, with individual reefs supporting up to 280 species per hectare. Within the Bird's Head Peninsula, reef of Raja Ampat is the World's best coral diversity spot with 553 species (Venkataraman et al., 2003). Coral reefs of the world cover an estimated area of 2,84,300 km ^{2} (Venkataraman, 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. Of the remaining, Pacific reefs account for 25%, Caribbean reefs for 9%, Atlantic for 6%, Red Sea reefs 4% and Persian Gulf reefs for 2% (Smith, 1978). A

majority of the coral reefs are concentrated on the western sides of the three oceans (Scheer, 1985) however the reason could be geomorphological conditions of these reefs.

The southernmost distribution of coral reef can be observed in the south of Australia and also in the Southern Africa whereas the northern most distribution of the coral reefs can be found in the northern Caribbean reefs. The coral reefs of GoK are also considered to be the northern most reef of the Asian continent.

The corals are classified into two groups on the basis of their symbiotic dependence on photosynthetic algae called Zooxanthellae. Corals with zooxanthellae in their tissues are called Zooxanthellates and those without zooxanthellae are called Azooxanthellates. These are further divided into reef building corals named Hermatypic and the ones which do not contribute to reef formations as Ahermatypic.

All extant Faviids are hermatypic and colonial. They may have Septa, paliform lobes, columellae and wall structures. Septal structures are simple, columellae are a simple tangle of elongate septal teeth, and walls are composed of thickened septa and cross-linkages. When all these structures are present, all species appear to be similar.

The reef ecosystems is considered to be the richest ecosystem, next to the rain forest. It harbors good species diversity, both in terms of flora and fauna thriving in close association and maintains diverse pattern of biotic assemblages including rare and endangered species (Sakkaravarthi et.al., 2012). Though found to be common in the ecosystem of reef habitats, faviids are having complex associations with the nearest species. Such scientific studies have been so far concentrated at Andaman and Nicobar Islands, Gulf of Munnar, and Lakshadweep islands (Satyanarayana and Ramakrishna 2009). The Gulf of Kachchh having varied diversity of coral species needs to be studied at ecological aspects through their interaction with microbenthic fauna. The first systematic reporting of 37 species of scleractinians from 15 localities across Gulf of Kachchh was made by Pillai and Patel (1988). Later on there was a

huge gap of information on the coral reefs of this region. In 2011 Dave conducted ecological assessment of Narara reef while Parasharya (2012) studied corals and some associates in Marine National Park. During same period GEER Foundation, Gandhinagar also conducted surveys as well as worked on coral implantation in the area. Several reports are now available on corals as well as various groups of invertebrates found in the area. However no detailed study has been carried out related to faviids, their ecology and the fauna associated with them.

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). Joshi (2016) documented impact assessment of coral reef ecosystem with special reference to climate change. New sights of coral formations were 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).

Hence, the present study deals with the current status and ecology of family Faviidae and the fauna associated with it at Narara and Poshitra coastal reefs, Jamnagar.

OBJECTIVE:

1. **To study the ecology:**
    - To assess physico-chemical parameters of water around family Faviidae
2. **To evaluate the status of the fauna associated with family Faviidae**
    - To estimate diversity an d density Faviids and their associated fauna

METHODOLOGY

***Instruments*:**Nikon Coolpix AW120 Camera, Compass Bearing : Sunto, 1x1 meter PVC pipe with nylon string fixed into the pipe on two opposite sides (For quadrat sampling), fiber-glass Tape 20 meters, 11-inch forceps, rubber gloves, Sechi disk, pH meter, Aquasol Digital-multiparameter AM-AL-01 [pH, TDS, Salinity, temperature], Aquasol water testing kit.

Reconnaissance Survey:

A reconnaissance survey was conducted on the study sites. On initiation of sampling, the probable areas on the digital map were plotted on the QGIS software. This plotting was further used on the study sites to conduct the transects, quadrats and sampling for water samples. The survey was based on the past secondary data that were carried out so far on both the reefs of Marine National Park, Southern Gulf of Kachchh. The data collection on the sites was carried out by walking on the reefs and not by the SCUBA. The intertidal reefs in the Gulf of Kachchh are muddy and becomes turbid immediately if walked upon the reef locations.

Table 1: Visits Abbreviations

Month	Visit Number
April 2015	V1
May 2015	V2
October 2015	V3
January 2016	V4
February 2016	V5
March 2016	V6
April 2016	V7
May 2016	V8
November 2016	V9
December 2016	V10
January 2017	V11

PHISICOCHEMICAL PARAMETERS:

The water samples of the study sites were assessed from random locations in the intertidal pools. The samples were collected during the high tide to evaluate the average of the water

physicochemical parameters. The water parameters were analysed by Integrated Coastal and Marine Area Management [ICMAM] protocol for Temperature, Dissolved Oxygen, pH, Salinity and using Aquasol water parameter testing kit for Nitrates, Nitrites, Ammonia and Phosphates

LIMITATIONS DURING STUDY:

During the study there were several limitations of visiting the sight and working on reef area. the study conducted so far was from the month of October to June only. This limitation was due to the Jamnagar Marine National Park that stays closed during July to September month of every year. This protocol of National Parks and Wildlife Sanctuaries are amended to stay closed during these following months in the Indian Sub-Continent.

DIVERSITY STUDY

Reconnaissance Survey:

A reconnaissance survey was conducted on the study sites. On initiation of sampling, the probable areas on the digital map were plotted on the QGIS software. This plotting was further used on the study sites to conduct the transects, quadrats and sampling for water samples. The survey was based on the past secondary data that were carried out so far on both the areas of Marine National Park, Southern Gulf of Kachchh. The data collection on the sites was done by walking on the reefs and not by the SCUBA. The intertidal reefs in the Gulf of Kachchh are muddy and becomes turbid immediately if walked upon the reef locations.

Data Collection:

The Gulf of Kachchh with its unique access to the intertidal zone gives access to visit on the reef sites by walking. During the tide-ebb duration, the reefs here as exposed to a vast extent and hence could be visited during the inter-tidal hours. Quadrats of 1x1 meter size was

developed. This was further divided by 100 small quadrats of 10 cms each. Such division of quadrat into 100 small boxes assisted in collecting the data from small coral cover tidal pools.

Diversity and Distribution:

Diversity of the species at the study sites was carried out by transects. The transect performed comprised of 20 meters length that helped in encounter of the fauna that were present in the respective study sites. A simple checklist-oriented data was collected initially to mark the presence of each Faviid species.

STUDY SITE:

Southern Gulf of Kachchh

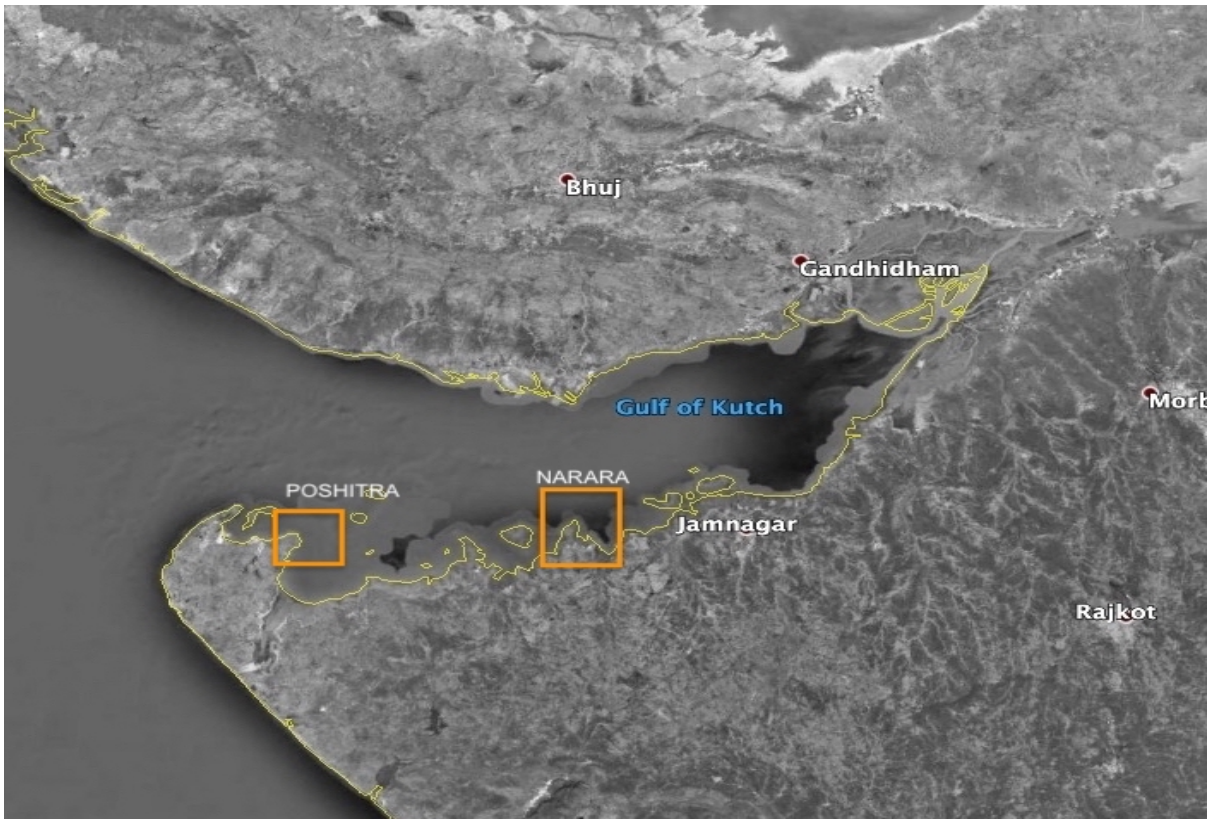


Fig.2: Southern Gulf of Kachchh, Gujarat. The two study sites marked, Narara and Poshitra

NARARA

The Narara reef or Narara Tapu or Narara Bet lies on 22°25.8'N to 22°28.3'N and 69°42.1’E to 69°40.7'E. It is part of India's first Marine Protected Area the Marine National Park and situated in the Southern Gulf of Kachchh (GoK), Jamnagar, Gujarat. The reef formation of Narara in GoK is joined to mainland because of land feeling and is accessible by walking or vehicle. This island has rich patches of mangroves and also harbours good corals.

Narara is one of the famous tourist attractions of MNP & S, the location is also popular for Nature Education Camps organized by MNP & S authorities annually to generate awareness on marine life among the locals of adjoining areas.

POSHITRA

It is the coastline with small embayment lying close to Poshitra (Laku point) and connected to the mainland. This area contains eulittoral fringing reefs about 100 meters wide each, which rarely get exposed directly to the sun and are with high coral diversity. Above them there were several rocky pools with rocks covered by barnacles and oysters giving a rugged appearance and needs care while treading through them because of the knife edged topography. These rocky pools harbour dense patches of corals with less diversity, attributable to high rate of evaporation. These rock pools are found in tiers clearly showing variation to coral distribution and diversity depending on the exposure to the tides. Tourists visit this place to see the corals and Educational camps are also being organised in this place to create awareness among the public. It is told that the fishermen visit this place occasionally to catch crabs and reef fishes.

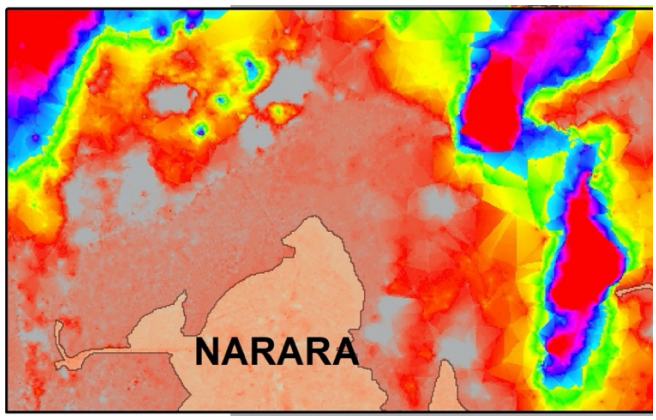


Fig.3:Cartosat-3 image of Narara coastal reef, Southern Gulf of Kachchh, Jamnagar, Gujarat.

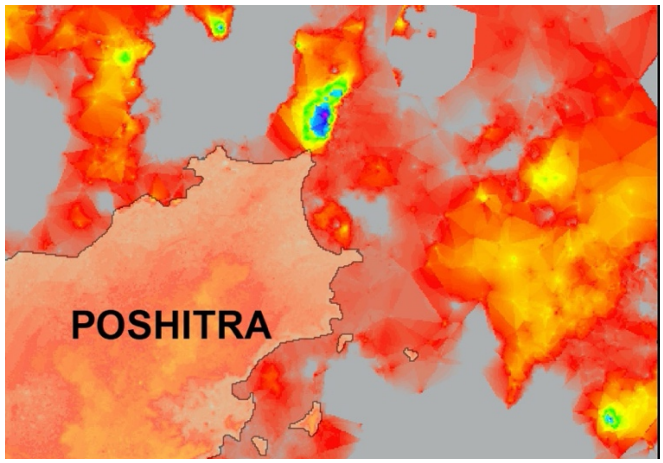


Fig.4: Cartosat-3 image of Poshitra coastal reef, Southern Gulf of Kachchh, Jamnagar, Gujarat

RESULTS

Physico-Chemical Parameters for Narara and Poshitra Coastal reef.

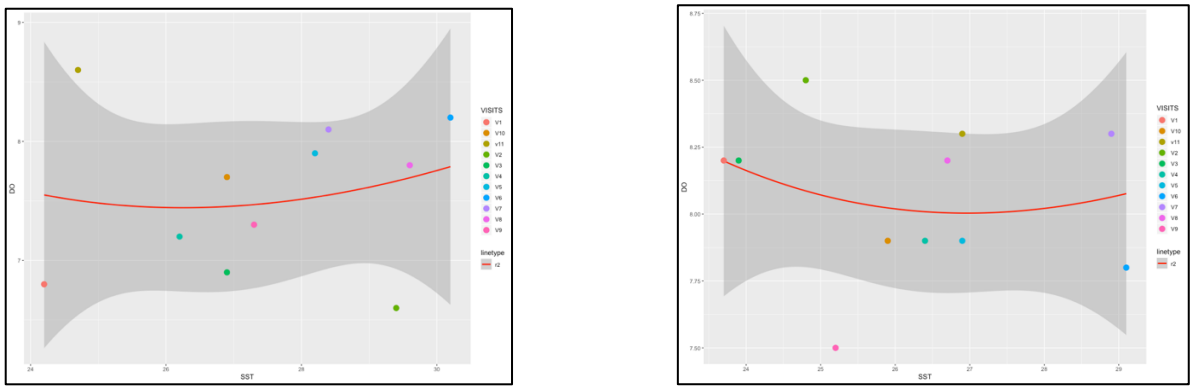
Table 2: Mean reading of physicochemical parameters of the two coastal reefs

Variables	Narara	Poshitra
SST °C	**27.45**	**26.22**
SDev	1.94	1.77
pH	**7.918**	**7.845**
SDev	0.0918	0.1139
DO mg/L	**7.555**	**8.064**
SDev	0.64	0.28
Salinity ppt	**37.55**	**38.08**
SDev	0.93	0.74
Nitrate ppm	**0.8173**	**0.8418**
SDev	0.089	0.026
Nitrite ppm	**2.424**	**1.635**
SDev	0.2666	0.119
Phosphate ppm	**1.481**	**1.965**
SDev	0.1267	0.1512

The mean sea surface temperature at Narara reef was found to be 27.45 $\pm$ 1.94 while the same at Poshitra reef was 26.22 $\pm$ 1.77. Similarly, the mean pH at Narara was 7.918 $\pm$ 0.0918 and at Poshitra reef was 7.845 $\pm$ 0.1139. The mean DO at Narara reef was 7.555 $\pm$ 0.64 and Poshitra reef was 8.064 $\pm$ 0.28. The salinity at Narara reef was 37.55 $\pm$ 0.93 and at Poshitra reef was 38.08 $\pm$ 0.74. The Nitrate at Narara was 0.9173 $\pm$ 0.089 and at Poshitra reef was

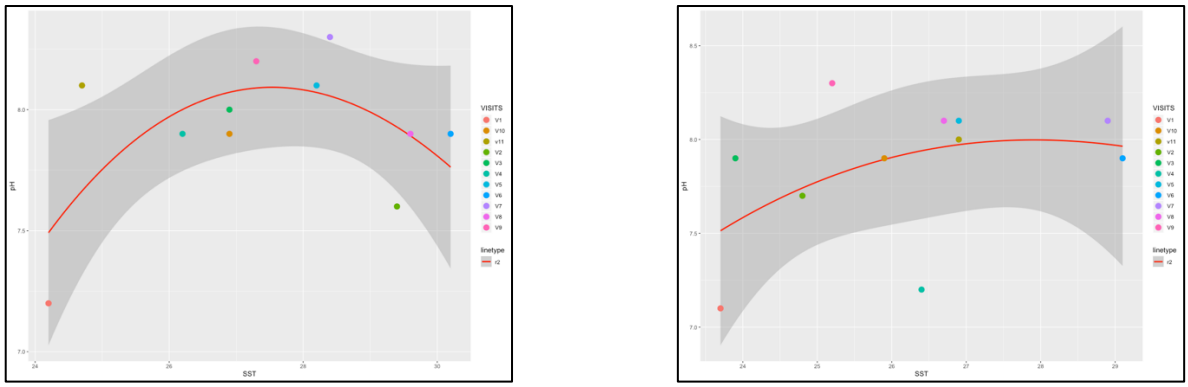
0.8418 ± 0.026. The Nitrite content at Narara was 2.424 ± 0.2666 and at Poshitra was 1.635 ± 0.119. The phosphate content at Narara was 1.481 ± 0.1267 and at Poshitra was 1.965 ± 0.1512.

An attempt is made to correlate various physicochemical parameters with Sea surface Temperature. The relationships are shown in Figures 5 to 10. For this sea water temperature is considered as an independent factor with the other water quality parameters such as Dissolved Oxygen (DO), pH, Salinity, Nitrate, Nitrite and Phosphate as dependent. The data has been arranged visit wise in the graph. The reference abbreviations of each visit are given in table 1.



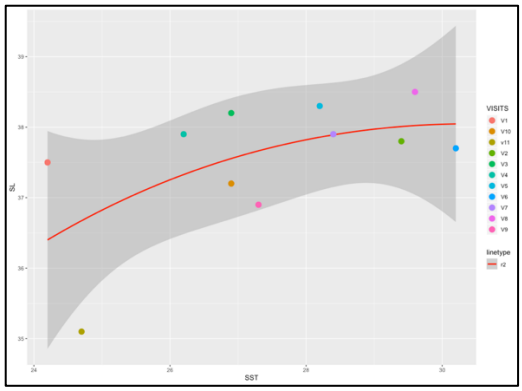
A B

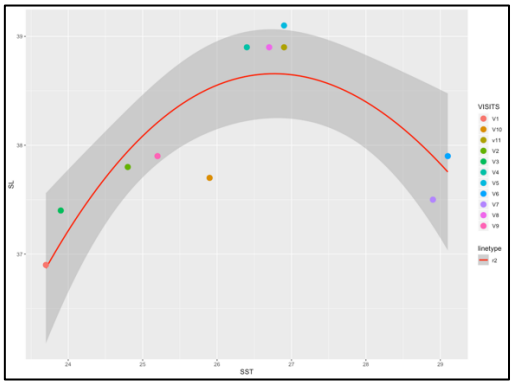
Fig.5: Correlation of Sea Surface Temperature with DO for Narara and Poshitra Costal reefs



A B

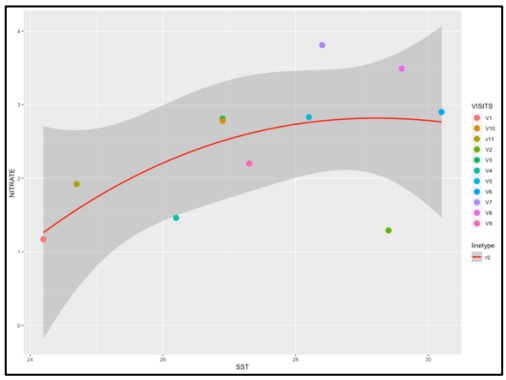
Fig.6: Correlation of Sea Surface Temperature with pH, for Narara and Poshitra coastal reefs

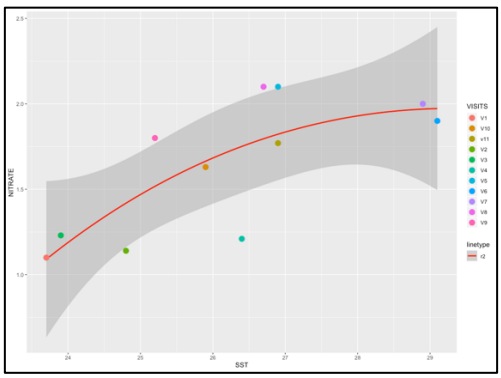




A B

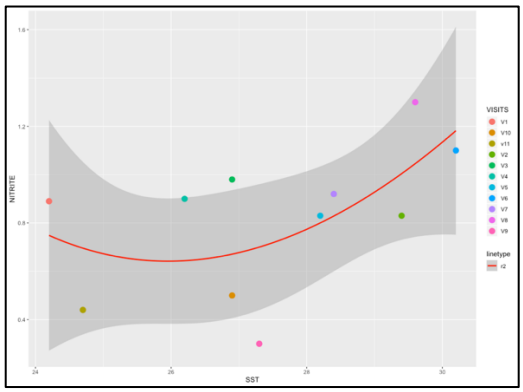
Fig.7: Correlation of Sea Surface Temperature with Salinity for Narara and Poshitra coastal reefs

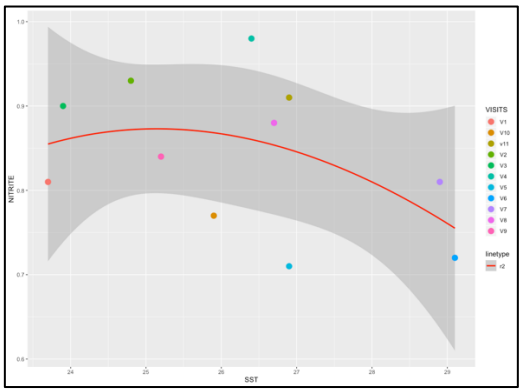




A B

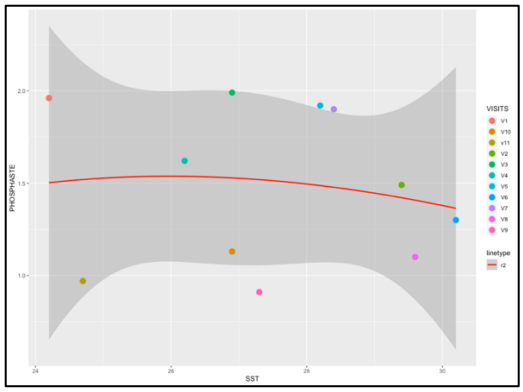
Fig.8: Correlation of Sea Surface Temperature with Nitrate for Narara and Poshitra coastal reefs



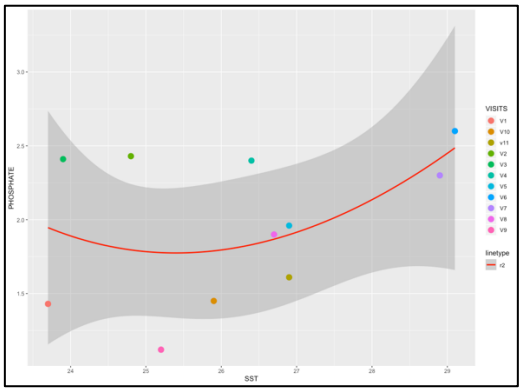


A B

Fig.9: Correlation of Sea Surface Temperature with Nitrite for Narara and Poshitra coastal reefs



A



B

Fig.10: Correlation of Sea Surface Temperature with Phosphates for Narara and Poshitra coastal reefs

Narara

The correlation of SST with DO (Fig.5a) shows that the point of dependent factors are closely lying to the trend line and few outliers are spotted. The visit 11 and visit 2 are outliers showing no correlation with the increasing temperatures. The Fig. 6a describes correlation of pH with SST. Almost all values were found to be correlating with the increasing SST. However, the trend line was curved at the higher SST levels. The salinity (Fig.7a) against SST was seen increasing linearly along with the trend line. The visit 7 was seen highly correlating in Salinity against SST. There was only one outlier seen in this result. The Nitrate (Fig.8a) correlated with SST showed moderate correlation at the increased SST. The points were found to be sparsely located along the trendline. Visit 10 and 3 were found to be almost near the same points of trend line. The correlation of Nitrite with SST (Fig.9a) showed downward curve of trend line. The plots were more often found towards SST between 26ºC to 28ºC. The Fig. 10a showed correlation of Phosphate with SST. The points were seen to be away from the trend line showing less significance with increase in temperature along the field site. However only three outliers were spotted.

Poshitra

In the (Fig.5b) correlation of SST with DO shows that the point of dependent factors were not so closely lying to the trend line and two outliers are spotted. The Fig. 6b describes correlation of pH with SST and maximum values were found to be correlating with the increasing SST. However, the trend line was not curved at the higher SST levels. The salinity (Fig.7b) against SST was seen having peak at temperatures between 25^{o} C and 28^{o} C along ...with the trend line. The visits were seen highly correlating at the peak in Salinity against SST. There were two outliers seen in the graph. The Nitrate (Fig.8b) correlated with SST showed less correlation at the increased SST levels. The points were found to be highly sparsely located along the trendline. The correlation of Nitrite with SST (Fig.9b) showed decreasing trend line at the higher temperatures. The points were found to be scattered away from the trend line. The Fig. 10b showed correlation of Phosphate with SST. Three points were seen to be away from the trend line showing less significance with increase in temperature along the field site. The trend line was seen bulging down towards the temperatures between 25^{o} C and 28^{o} C. The correlation of independent factor along with the dependent factors showed positive relation.

Faunal Diversity studies

Table : 3 Diversity of faviids recorded at the two costal reefs

No	Species	Narara	Poshitra
1	*Acanthastrea hillae*	13	41
2	*Cyphastrea serailia*	18	41
3	*Favia speciosa*	46	190
4	*Favites bestae*	9	54
5	*Favia favus*	90	275

6	*Favites complenata*	62	105
7	*Goniastrea pectinata*	34	84
8	*Leptastrea purpurea*	25	0
9	*Platygyra daedalea*	0	4
10	*Platygyra sinenses*	18	37

Diversity results of Faviidae in Narara and Poshitra coastal reefs.

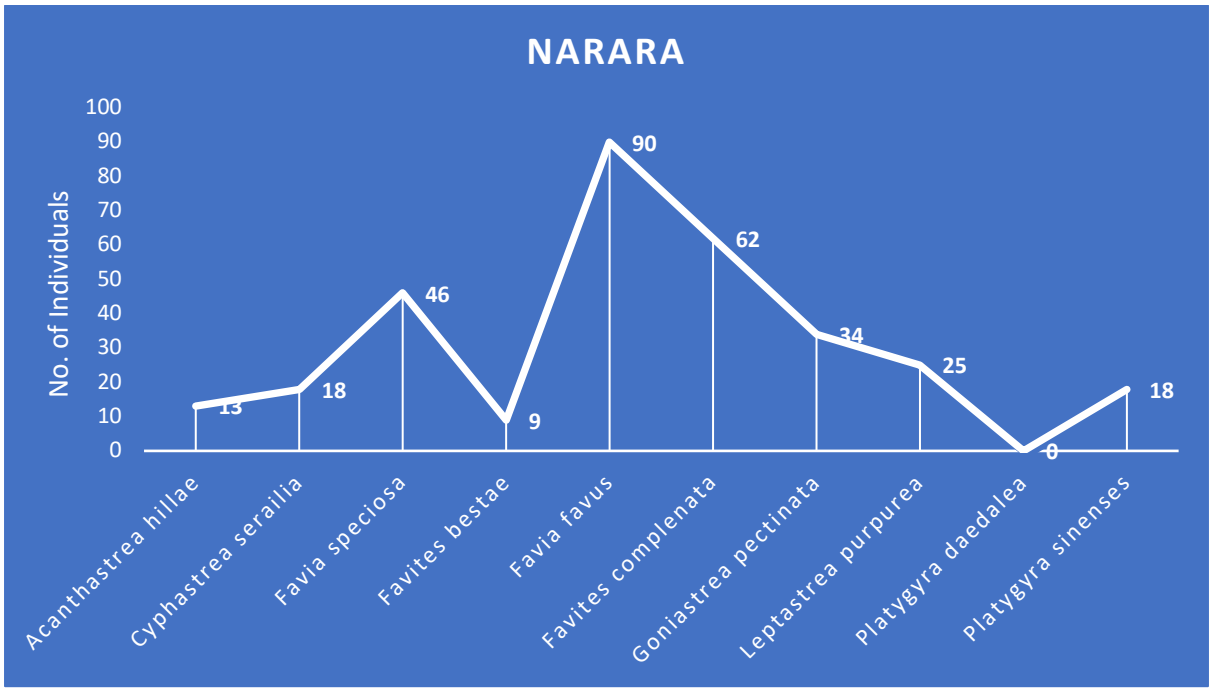


Fig.11. Total Species and number of individuals of Faviids in Narara.

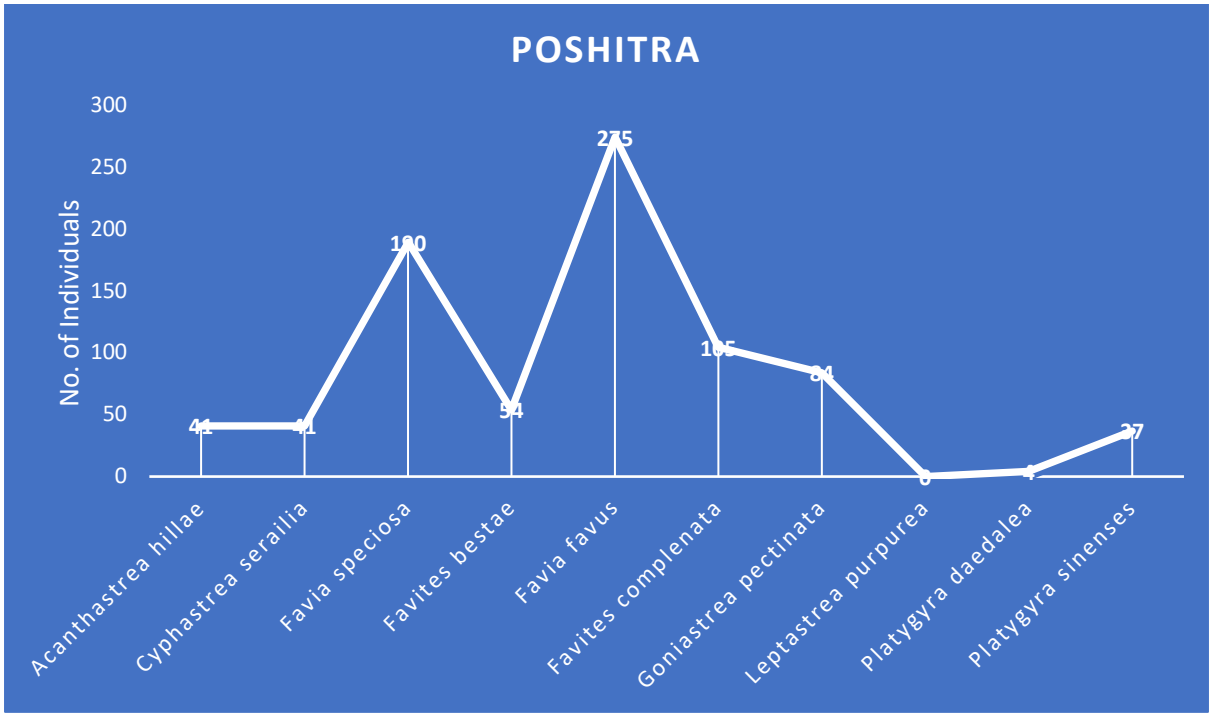


Fig.12. Total Species and number of individuals of Faviids in Poshitra.

Faviids being at the centre of study, their diversity and number of individuals recorded at the Narara and Poshitra coastal reefs during study period have been noted down (Table 3). Total 10 faviids are recorded with 9 species present at each site. However at Narara, the *Favia favus* was found to be the most abundant, followed by *Favites complenata* and *Favia speciosa*. The *Platygyra daedalea* was found to be absent at this study site. The faviid with lowest number of occurrence was *Favites bestae*. At Poshitra also the same species *Favia favus* was found to be the most abundant, but followed by *Favia speciosa* and then *Favites complenata*. The *Leptastrea purpurea* was found to be absent at this study site. The faviid with lowest number of occurrence was *Platygyra daedalea*.

Among other reef fauna total 81 species (associated fauna) have been recorded at Narara and 91 at Poshitra coastal reefs. The association of various faviid species with these fauna is being worked out. Further, correlation of faviids with various physicochemical parameters studied is also being be attempted.

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Ph.D Student

Mirza Ruzbeh Tehmurasp

Supervisor

Prof. Geeta Padate