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DARING TO RESTORE

Coral Reef Recovery in Mithapur

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FOREST DEPARTMENT GOVT. OF GUJARAT

TATA CHEMICALS LIMITED

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Wildlife Trust of India (WTI) is a non-profit conservation organisation, committed to help conserve nature, especially endangered species and threatened habitats, in partnership with communities and governments. Our principal objectives include managing or preventing wildlife crises and mitigating threats to individual wild animals, their populations and habitats through holistic strategies and practical interventions.

Established in 1939, Tata Chemicals Limited (TCL) is India's leading manufacturer of inorganic chemicals, fertilisers and food additives. Part of the US$-22-billion Tata group, the company owns and operates the largest and most integrated inorganic chemicals complex in the country at Mithapur, Gujarat. The company's state-of-the-art fertiliser complex at Babrala, Uttar Pradesh, is known for its world-class energy efficiency standards, and has won several awards in the fields of environmental conservation, community development and safety. TCL's phosphatic fertiliser complex at Haldia in West Bengal is currently the only manufacturing unit for DAP/NPK complexes in West Bengal. The acquisition of an equal partnership in Indo Maroc Phosphore S.A. (imacid) along with Chambal Fertilisers and the global phosphate major, OCP of Morocco recently, is the first step that TCL took towards globalisation. In early 2006, TCL acquired the UK based Brunner Mond Group (BM). This acquisition makes TCL one of the most diversified companies with manufacturing facilities in three continents and markets across the world. Tata Chemicals Society for Rural Development (TCSRD) was established by Tata Chemicals in 1980 for the benefit of the rural population in an around the company's plants and township. Over the years it has initiated a number of development, welfare and relief activities.

The Gujarat Forest Department is entrusted with the prime responsibility of protection, conservation and development of forests and wildlife of the state. They have extended support to the Whale Shark campaign even beyond the shores of the state.

Keywords: Conservation, Mithapur, Coral reef, Acropora, Gujarat, Agatti Island, Acclimatization, Lakshadweep, El-Nino, Transplantation, Coral spawning, Coral rescue, Artificial reef, Beach cleaning.

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Dr. C. N. Pandey, IFS,
Principal Chief Conservator of Forests (WL) and
Chief Wildlife Warden
Gujarat.

Message

I am happy to have seen the technical report brought out by the Wildlife Trust of India on their scientific work carried out for securing the coral reef of the Mithapur coast on the Gulf of Kachchh region in Gujarat. The coral reef science is relatively young in India and Coral restoration is much younger. In this context, the attempt by the Wildlife Trust of India marine research team is praiseworthy.

While the Gulf of Kachchh Marine National Park authority have been protecting and managing the coastal and marine biodiversity of this important marine area, it is gratifying to note that the corporate have also joined hands with Gujarat Forest Department and Non-Governmental Organization like Wildlife Trust of India to protect and restore the coral reefs closer to their area of operation- i.e. the Mithapur Salt works.

The Wildlife Trust of India have made detailed survey and inventorisation of the marine biodiversity of the Mithapur reef and have disseminated the information in beautifully produced series of posters targeted at the school and college students. They have also joined hands with the local fishing community, coast guard, navy and the general public to educate everybody about the coral reef and even have ventured successfully to initiate coral rescue and rehabilitation programme by creating artificial reef beds.

The most enterprising attempt by the WTI's marine team however, is the experiment to transplant *Acropora humilis* species in to the Mithapur and Laku reef of Gulf of Kachchh after bringing from lakshadweep waters. I am given to understand that this is the longest distance coral transportation, translocation and transplanting attempt in the world which was taken up to achieve some degree of success and deserves to be complimented.

Such public–private collaborative projects facilitated by scientific organizations are the much needed inclusive management practice in the coastal and marine environment which are in the Common Property Rescue Regime and requires innovative co-management approaches.

I wish Wildlife Trust of India to enhance their collaborations and continue to work in the future for a better and secured coast in India.

Date: 20th June, 2014

(Dr. C. N. Pandey)

FOREWORD

Coral reefs are an important ecosystem around the world. Also known as rainforests-of-the-sea, they harbour immense biological wealth.

Yet in India, very little seems to have been done to revive or even save this unique ecosystem historically.

The Gujarat Forest Department, the Wildlife Trust of India (WTI) and Tata Chemicals Limited (TCL) pioneered a crucial project to restore coral ecosystems in the state, after beginning and continuing collaboration through whale shark conservation.

The field of study was home itself for TCL in Mithapur town. Beginning with creating an inventory of the biodiversity in Mithapur reef, the project also evaluated threats, took actions to mitigate them and even worked at spreading awareness on this important ecosystem. The highlight of the project was the unprecedented attempt to transplant locally-extirpated coral species as well as to enrich reef health through restoration activities including placement of artificial substrates for the corals to extend their reach.

Despite being a new initiative, much has been achieved over the past five years that the project has been in existence. We continue our efforts to conserve the coral reef of Mithapur and also create a model for replication in coral reef restoration elsewhere.

This publication outlines the initiatives undertaken over the past five years by our collaborative project, its successes, difficulties, and the way forward.

R. Mukundan
Managing Director,
Tata Chemicals Limited

PREFACE

India has a history of 2500 years of terrestrial conservation. Arthashastra documents Gajavanas or elephant forests and ever since Ashokan inscripts and royal decrees abound on saving wild animals and their forests. The birds of Vedanthangal, the lion of Gir, the shikargahs of Kashmir, all have a long history of protection and so do sacred groves and community forests. What is completely missing out in this remarkable panoply of conservation in India is that of the marine nation. The sea and its creatures have always got the short shrift and the first fish (the whale shark) was protected only a few years ago. Corals likewise, tropical forests of the ocean, have never been under traditional protection systems and even the extension of the Wildlife (Protection) Act, 1972 to them and the Indian Forest Service to look at them (Are seas forests? some may argue) is relatively recent. The coral reefs around Mithapur are a case in point. They are within the Tata Chemicals arena of work for long and the company has wanted to protect them as also allow access and interpretation to local communities. WTI in collaboration with them and the Gujarat Forest Department has worked on this project to monitor, restore and interpret the corals of Mithapur. The first is routine work, the second path breaking and the third exhilarating. So let me concentrate on the latter two. Transplanting corals over a few kilometres have been done by scientists around the world but this project demonstrated that Acropora, a reef building coral that had gone extinct due to an El–Nino effect at Mithapur could be got from Lakshadweep, many hundreds of kilometres away and that they could survive for several months. The technique of creating artificial coral substrates that attract natural coral to grow has also been a great success as has the coral garden concept where most species of coral found in the area have been 'planted'. Finally the interpretative literature including posters that have been produced about the marine fauna of Mithapur are a great hit with local children.

In doing so, once again, WTI has broken new ground or in this case new tides. The idea of conservation has been taken from secure terrestrial scenarios to the Gulf of Kachchh and there using a combination of good old fashioned marine science and interpretation is proving to be a path breaking project. This report documents 5 years of this project and therefore the founding principles of this novel conservation effort.

Vivek Menon
Executive Director & CEO
Wildlife Trust of India

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We would like to thank Mr. Vivek Menon, Dr. N.V.K. Ashraf, Ms Rupa Gandhi Chaudhary and Dr. Sandeep Kumar Tiwari for their support through out this project.

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Plate 1: Flower coral (*Goniopora sp.,*) Mithapur reef

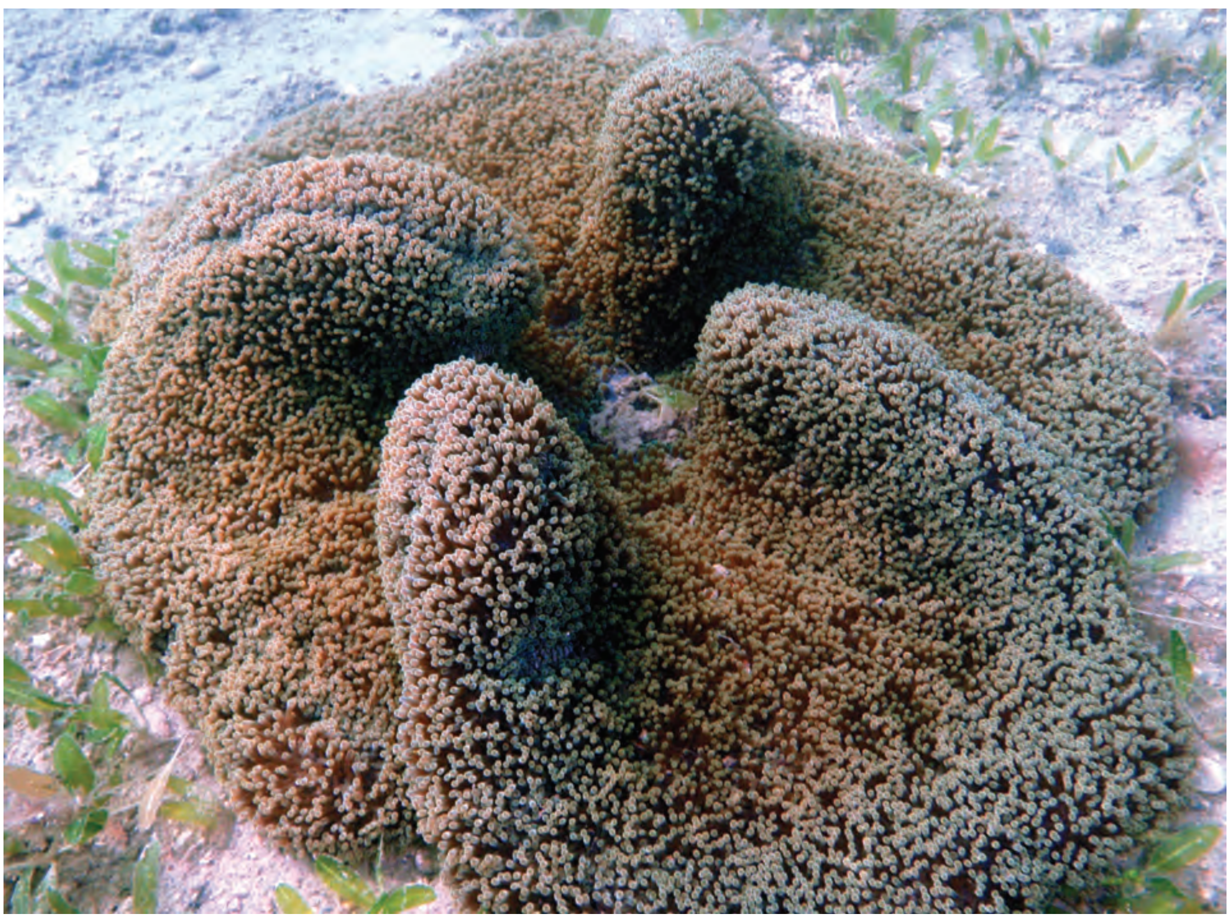


Plate 2: Carpet sea anemone (*Stichodactyla haddoni*), Mithapur reef

EXECUTIVE SUMMARY

The Gulf of Kachchh harbours one of India's four major coral reefs, the others being in the Andaman and Nicobar Islands, Lakshadweep and Gulf of Mannar. Worldwide, coral reefs are declining due various anthropogenic factors and natural climatic changes. The coral reefs of the Gulf of Kachchh (GoK) too were in a relatively healthy state until rapid development intensified along the southern coast of GoK. Dredging of limestone and coralline sands and the impacts of onshore development activities were considered responsible for the rapid degradation of the coral reef of GoK. Another cause for the loss of coral cover was extensive deforestation of mangroves along the coast. Fluvial deposits in the form of silts, which washed onto the reefs, have killed a large portion of leftover intertidal corals. To add to this, estimates of the impact of 1998 coral bleaching suggest that it affected 50–70% of GoK's corals too (Muley *et al.* 2000). Alarmed at the plight of corals in the GoK and their habitats, Tata Chemicals Ltd (TCL) supported the Wildlife Trust of India (WTI) in initiating a project to restore the coral reefs of Mithapur. The Mithapur Reef Recovery Project was a collaborative project of the Gujarat Forest Department (GFD), Tata Chemicals and WTI.

A habitat survey of the Mithapur reef in the early phase of the project found the presence of less than 12% of live hard corals, highlighting the need to focus on its recovery and restoration. Mithapur is a small town in Jamnagar district in the Indian state of Gujarat. The coral reef of Mithapur is located on the western outer fringe of the GoK facing the Arabian Sea, along the west coast of India. The reef stretches across about 10 km of the coast line, between Arambada (northern side) and Shivarajpur village (southern side). Approximately 0.56 km^2 of the total reef area falls under the Marine National Park (MNP) as per the GoKMNP management plan. Initially, an area of around 2.5 sq km of the Mithapur reef was selected by WTI, GFD and TCL (located at the beach head of Mithapur Township) for the first phase experimentation of recovery and restoration activities.

An effort to restore lost glory

Acropora humilis coral, once believed to be part of the coral reefs of GoK, is now locally extinct and only dead skeletons are observed. *Acropora* is one of the major corals responsible for building an immense calcium carbonate sub-structure that supports the thin living skin of a reef. The sub-structure also provides a habitat to many other life forms, thereby contributing to the reef's rich biodiversity. Hence, the first priority action was to revive *A. humilis,* the lost glory of Gujarat's coral reefs. To test the feasibility and viability of restoration, a small-scale experimental transplantation activity was initiated.

Transplantation as a viable tool for recovery

During coral transplantation, coral fragments from an identified donor colony are broken, and transported to the recipient site, by following a scientific protocol. Such transported fragments propagate into a new colony at the recipient site. Fragments are once again broken from the new colonies and allowed to develop into more new colonies. In course of time, the transplanted corals reproduce and repopulate the recipient reef. For re-introduction of *A.humilis* in GoK, the nearest possible site for donor colonies was located in Lakshadweep. Factoring in the distance and complex logistics of transportation, and after a thorough survey of scientific literature, translocation of the species from Lakshadweep was considered the best option for the re-introduction experiment.

Assess to understand

Corals are sensitive to environmental variables like suspended matter, excessive sediment accumulation, sea water dilution from surface drainage and groundwater discharge, temperature fluctuations, emersion on shallow reef during low tides, and pollution (Randall, 1990). These parameters were studied for the Mithapur reef to produce a benchmark range against which fluctuations could be assessed. The reasons were two-fold:

a) To ascertain if the ranges were within acceptable limits which corals could tolerate and

b) To provide information on when and where transplantation could be most effective.

Compare to correlate

The quality of sea water mostly depends on oceanographic parameters and the magnitude of various forms of pollutants. It was essential to monitor these parameters, as well as the water quality at both the donor and recipient sites to assess the similarities and suitability at the Lakshadweep and Mithapur sites.

Basic parameters monitored

a. **Temperature-** is one of the most important parameters affecting coral survival. All other parameters depend on temperature. Temperature can affect the solubility of chemical compounds; distribution and abundance of organisms; rate of growth of biological organisms; water density; mixing of different water densities and current movements; the amount of oxygen dissolved in water; salinity fluxes; pH and nutrients. As temperatures rise, the animal metabolic rate also rises, which in turn increases the growth rate and challenges for survival ability.

b. **pH -** of seawater plays an important role in the ocean's carbon cycles and indicates the acidity and alkalinity of water. The average pH value in seawater shared ranges between 7.5 and 8.4.

c. **Turbidity-** is the amount of suspended sediment and plankton in the water column. Normally, turbidity affects light penetration. If light penetration is reduced significantly, it may reduce photosynthesis, which in turn may lower the daytime release of oxygen into the water. Turbidity is measured by NTUs (Nephelo-metric Turbidity Units).

d. **Sedimentation-** sediments cause turbidity that in turn severely degrades coral reefs. Excessive sedimentation can adversely affect the structure and function of the coral reef ecosystem by altering both physical and biological processes. Sediment particles also reduce the light available for photosynthesis. Normal sedimentation rates in sea water are 1–10 mg cm^2/ dl.

e. **Nitrite-** nitrates are less toxic than nitrites. An increase in nitrate levels can potentially cause the death of organisms. High levels of nitrates and nitrites can inhibit growth, impair the immune system and cause stress in marine animals. The ambient nitrite value in seawater is 0.0001 ppm

f. **Phosphate-** is an important nutrient for coral reefs. The water around natural coral reefs contains very little phosphates, typically around 0.005 ppm. But if the concentration decreases, the coral tissue will regenerate. The production of the calcareous skeleton of a hard coral is significantly inhibited by high phosphate levels which stunt growth or cause general decay.

For the purpose of coral transplantation, the water quality was monitored simultaneously at Mithapur and Lakshadweep to figure out similarities in the water and environment, and confirm the suitability for a successful transplant.

The terrain, depth and position of the coral colonies were also recorded to choose a suitable nursery site which mimics the donor site.

A coral nursery site basically contains a fabricated steel table, on which the coral fragments are kept after harvesting for growth. Coral nursery tables were placed in Lakshadweep (to stabilise the coral after harvest) and Mithapur (to monitor the coral after transplantation). Water quality parameters, both physical (temperature, pH, visibility, salinity and sedimentation rate) and chemical (nitrites and phosphates) were measured for two years before initiating transplantation at the recipient project site. All these parameters suggest evenly distributed values across both the donor and recipient reefs; and water quality values within the accepted range.

Mithapur waters, safe waters

The water quality parameters, both physical (temperature, pH, visibility, salinity and sedimentation rate) and chemical (nitrites and phosphates) suggest evenly distributed values across both the donor and recipient reefs; and water quality values within the accepted range.

Coral spawning, a sign for natural recovery

A mass coral spawning in the Mithapur reef was identified for the first time in Gujarat waters in 2012. The spawning proves that the reef still has the capacity for natural recovery with aided habitat restoration.

Additional route to recovery

Additional coral reef restoration activities targeting the existing/local coral species were also experimented with.

- **Artificial reefs** have been deployed in sandy areas (devoid of corals) to help in natural recruitment of coral larvae which would later form into a reef.
- **Coral rescue operation:** A first of its kind coral rescue has been in operation with the help of Volunteers for TCL, Gujarat Forest Department and local fishermen to help restore damaged corals in the Mithapur reef.
- **Fish aggregating devices (FAD)** are being experimented with to help provide shelters for small fishes and other organisms in the barren area of the reef.

History made

Coral Transportation Protocols, with 80% survival of transplants were tested successfully as part of the project. Corals were transported over approximately 1500 km from Lakshadweep to Mithapur; a record in the history of coral transplantation anywhere in the world.

Success in artificial reef deployment

After a year of their deployment, the first signs of new coral recruits were noticed, encouraging the team to expand the artificial reef deployment activities. For the first time in Gujarat waters, coral spawning was identified and documented in May 2012.

Biological surveys on the reef over the last two years reveal that Mithapur still has some important life forms, and their presence indicates that conditions are favourable for improvement measures, if required. Through these surveys, the team was able to document 29 coral species, 55 species of fishes, 28 species of seaweeds, 13 species of crabs and lobsters, 26 species of sea shells, nine species of sea slugs, five species of flat worms and 12 species other associated animals. Reef habitat mapping helped identify key degraded areas. It also allowed in identification of the best area within the reef which could harbour nurseries for coral transplant.

New records in biological surveys; One sea slugs and one sea horse were also found for the first time in India in the Mithapur reef.

History planned to be written

Coral Garden: A garden refers to a variety of species in a single/particular area. Similarly, a 'coral garden' refers to various coral species present in a single identified area. 'Coral garden' is a fascinating concept and a recent trend in marine conservation across the globe.

Usually, a 'Marine National Park' area spreads across many kilometres and a Marine National Park (MNP) can be managed only by the Government. However, by virtue of being smaller in size, coral gardens can be managed by small communities (e.g. a small fishing village and its jurisdictions) or the private sector. They offer an excellent opportunity for public–private partnership in marine conservation.

The proposed 'coral garden' at Mithapur will be one of its kind, set up in a public-private partnership. The garden will house nearly all coral species found in GoK, including the transplanted *A. humilis*. As in a terrestrial botanical park or garden, the reef will be separated into various sections, based on accessibility. The tidal pools in the Mithapur reef have been primarily targeted for setting up of the Coral Garden. Each pool will contain a variety of corals, so that they can be used for educational as well as conservation purposes. It will be the first coral garden in India to be set up using a public–private partnership mode.

Project activity timeline

Project activities	**2008 (Oct – Dec)**	**2009**	**2010**	**2011**	**2012**	**2013**	**To be continued**
Setting up of field station and other infrastructure							
Ecological monitoring							
Acropora sp., coral transportation and transplantation							
Artificial reef building							
Coral rescue							
Coral rescue and rehabilitation*							
Community participation							
Coral spawning monitoring							
Coral reef interpretation facility planning							
Interpretation implementation**							
Coral garden development**							
Expanding the program for other marine species***							

*Subject to approval from the Gujarat Forest Department and GoKMNP Authorities.,

**Subject to TCL, GFD and GoKMNP approval and agreement.

***Subject to development of a justifiable proposal and funds raised

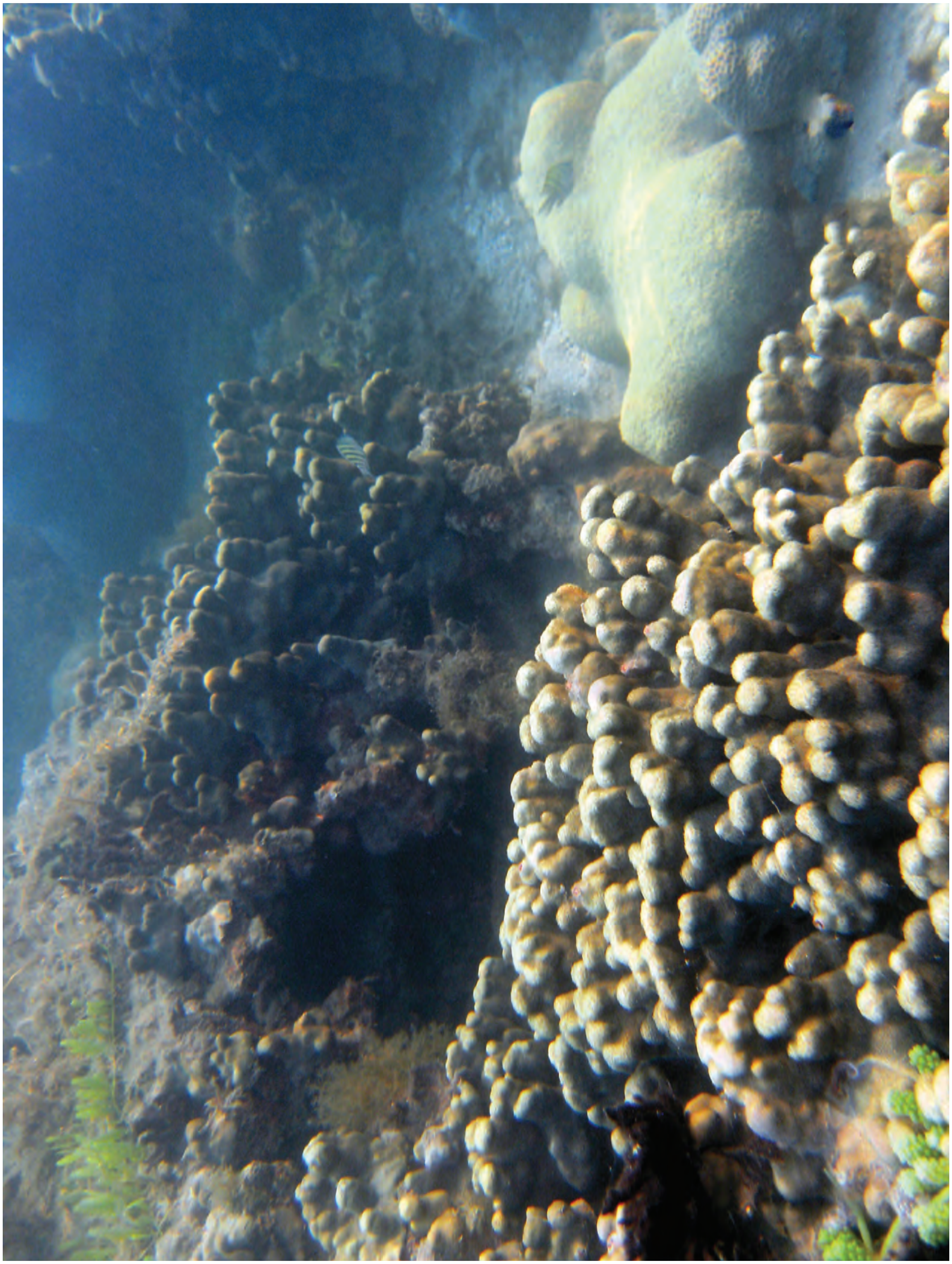


Plate 3: Mithapur Coral reef

CHAPTER 1

Mithapur Reef: An Introduction

Globally corals are under threat, due to development activities, climate change and storms. When damaged beyond any hope of natural recovery, reefs may need artificial assistance to revive

Coral reefs are vital components of ocean ecosystems, providing shelter to nearly a quarter of all marine life forms. Coral reef systems, along with the tropical rain forests, are the most mature ecosystems of our planet. They play an important role in global biogeochemical processes and in the production of food resources. They serve as breeding and nursery grounds for many fin and shellfishes. Coral reef also serve as atmospheric carbon dioxide sinks and act as historical climate recorders.

Corals are sessile invertebrates with potentially long life spans. They are the major reef builders that produce calcium carbonate skeletal frameworks of fringing reef environments (Sharma *et al.* 2008). Globally, corals are under threat from development activities carried out in their habitat and in the neighboring waters, especially activities that alter water temperatures, salinity, and nutrient levels. Climate change, stress, and storms also contribute to coral reef decline. When the reef are disturbed beyond regenerating ability, then their death is inevitable (Edward and Gomez, 2007). Therefore, the top priority should be to prevent or minimize disturbances and conserve the existing ecosystems, inducing their natural recovery (Randall, 1990). However, when natural recovery is not progressing well or too slowly without artificial assistance, rehabilitation measures to induce the recovery are needed; and those that are degraded need to be restored suitably (Edwards, 2007). In the Gulf of Kachchh, which is a 7300 km^2 east–west oriented indentation north of the Saurashtra Peninsula the coral formations occur between 22°20'N and 22°40'N latitudes, and 69° and 70°E longitude (Pillai *et al.* 1980). The coral growth in the GoK occurs in the form of fringing reef on the wave-cut sandstone banks around the 32 islands among the 42 that adjoin the southern flank of the Gulf. Due to the geographical isolation and extreme environmental variations, the diversity of corals in the GoK is relatively low among all Indian reef (Patel, (1985), Pillai and Patel, (1988), Dixit *et al.* 2010). However, heavy anthropogenic pressure and natural hurdles are also responsible for the reduction in the density of corals and reef around GoK (Pillai *et al.* 1980, Biswas, 2009).

Wildlife Trust of India surveyed the coral reef of Mithapur, the western most reef of GoK, Gujarat, in 2008. From the results, it was apparent that the coral communities in Mithapur were in a poor condition. Therefore, WTI and TCL initiated research and experimentation for restoration and recovery of the Mithapur coral reef. The beach head at Mithapur was selected for first phase restoration activities. TCL offered to support activities which would lead to the recovery and restoration of corals off the Mithapur coast, and to develop interpretation facilities for coral reef, to generate awareness on the marine ecosystem among local communities and stakeholders. This chapter gives the details of the ecological setting of the Mithapur coral reef (Plate 3), based on which recovery and restoration activities were implemented from October 2008 to May 2013.

1.1 Location of the Mithapur reef project area

The Mithapur reef is located on the western outer limit of the Gulf of Kachchh, facing the Arabian Sea. The reef is less than a kilometre away from Mithapur town. The reef is more than 10 km long, and is located between Shivrajpur village on the southern side and the Arambada on the northern side, on west coast of Gujarat. About 56 hectares of the reef area fall under the protected zone. The present research and experimental project area extends between 68°59'4.071" E, 22°25'10.367"N-68°59'48.333" E 22°26'7.592"N, a total area covering 2.99 km^2 (Map 1). The southern boundary extends a little further to the Chowpati Beach and the northern boundary extends to the cement tower of the Tata Chemicals Limited. The western boundary is about 1.42 km (varying at some points) out into the sea from the coastline and parallel of the Chowpati beach.

1.2 Mithapur reef structure

The Mithapur reef is a kind of fringing reef that extends from the coast. It contains three underwater terrains – the reef flat, channels and pools, and fore reef slope.

1.2.1 Reef flat: The largest portion of the Mithapur reef under the study area is the reef flat, covering about 2.55 km^2 that supports very sparse and scattered coral individuals. The reef flat area is frequently exposed during the low tides, leading to stunted growth of corals. It is mostly covered by macro algae which changes according to the seasons.

1.2.2 Channels and pools: Within the project area of the Mithapur reef, four pools are present, of which three are connected to each other by

Map 1: Project area map

channels. The channel boundaries and pools have a sandy bottom, whereas the edges of the pool support a rich colony of corals. This makes them a potential target for the Mithapur reef recovery and restoration activity. The reason for the rich colonisation is that the areas remain submerged even during the lowest low tide, which provides the corals a better chance for survival. Channels and pools cover a total area of 0.44 km^2 in the reef.

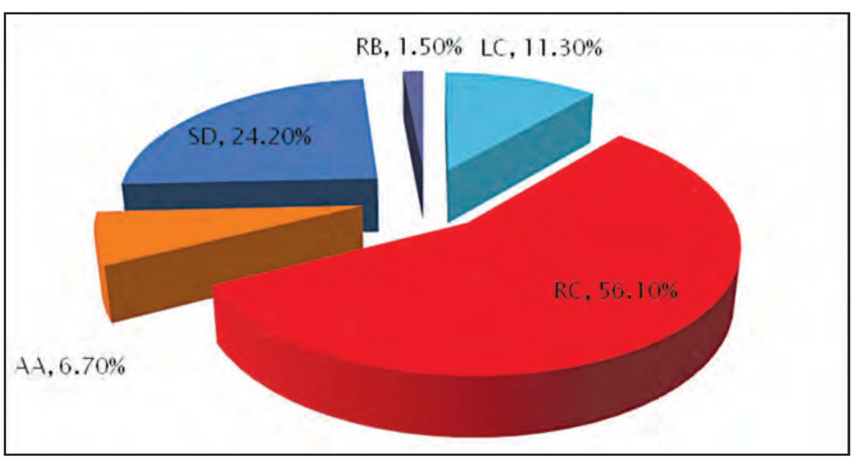
1.2.3 Front reef: The front or outer reef are located approximately 1.5 km from the shoreline. A gradual slope was observed at the southern boundary, and a sudden slope at the end of northern boundary. During high tide, extremely heavy currents are observed at these sites.

1.3. Benthic status of Mithapur reef

Initially, 80 Line Intercept Transects (LIT – 20 metre length) (English *et al.* 1997) were used to estimate the benthic status of Mithapur reef in 2008. The starting point of each transect was marked using a GPS. The biophysical categories were recorded at regular intervals along the transect. The coral species and life form categories were identified in the field, and in cases of uncertainty, photographs were taken for further identification. The biophysical forms were recorded as live coral (LC), rock (RC – all dead corals), algae assemblages (AA), soft coral (SC), rubbles (RB), sand (SD), and others (OT) that include occasional presence of other life forms, for example, holothurians, ascidians, mollusc etc. From the data, the percentage covers of the life form categories were calculated. The reef of Mithapur remain submerged during high tide, but get exposed during low tide. The LIT surveys were carried out in the sub-tidal region. The sub-tidal zones have live coral colonies, including massive and encrusting corals at depths of 0.5–1.5 m during low tide. The surveys were limited in numbers within the boundaries. Data from LIT surveys (Fig. 1) showed 11.30% live corals, 56.60% rocks (dead corals), 24.20% sand, 6.70% algal assemblage, and 1.50% of rubbles in the surveyed area. However, the diversity of other benthic life forms was very low. Most of the live corals were present in the reef flats, their distribution quite sparse. Some patches of live hard corals were found on the slope of the tidal pools and channels. According to the 'linear scale cover' (Gomez *et al.* 1994, a live coral cover between 25% and 50% of any reef is considered to be "Fair" in condition, and less than 25% is considered to be "poor" in condition (Sadhukhan and Rahunathan, 2012). Based on this classification, the coral reef state at Mithapur reef (live coral cover = 11.30%) may be considered as poor in 2008. With the basic information in place, the team were ready for the next set of activities.

1.4. Mithapur reef recovery strategy

As per the coral reef remediation concept and principles (Edwards, and Gomez, 2007),



LC = Live coral. RC = Rock (Dead coral). RB = Rubble. AA= Algal Assemblages. SD = Sand.

Fig 1: Percentage of major benthic categories at Mithapur reef there are two kinds of restoration methods: a) Active restoration b) Passive restoration. Active restoration is achieved through coral transplantation, rehabilitation and relocation; and also by enhancing natural recovery by artificial reef development, removing algae from the substrate, increasing the populations of herbivores, and controlling predators. On the other hand, passive restoration is mostly achieved through the participation of local communities and stakeholders. However, activities are kept under control through community-based management. Also, community participation in restoration activities helps and enhances awareness within the community. Passive coral restoration (management actions) activities need to be implemented before or along with the active restoration process (Edward, 2010).

For the initial stage of reef recovery in Mithapur, WTI initiated three field-level restoration activities: a) coral transplantation, b) enhancement of natural recovery through artificial reef creation and coral rescue operation and rehabilitation c) promote awareness through community participation (Fig 2).

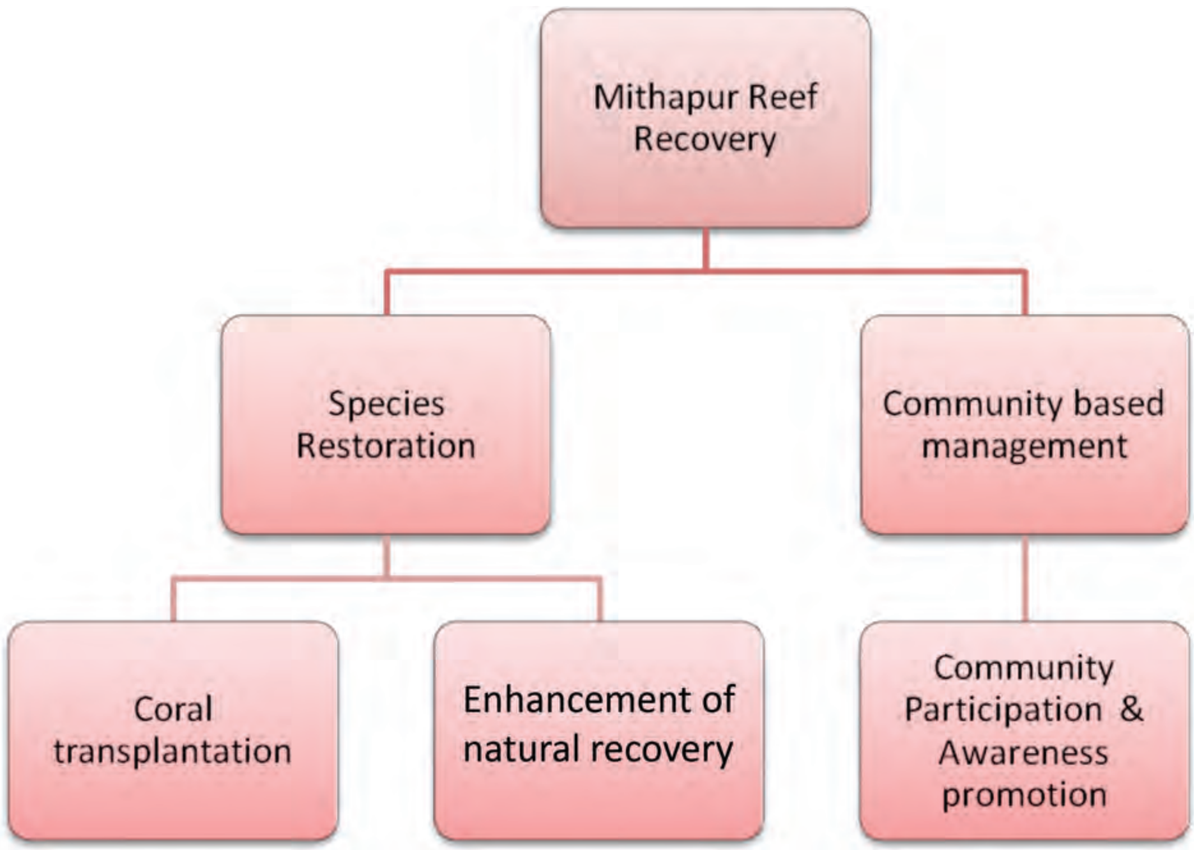


Fig. 2: Mithapur reef recovery strategy

CHAPTER 2

Monitoring: Biodiversity Assessment and Oceanographical Parameters

Ecological monitoring in the intensive project area involves gathering and analysing data, including oceanographic and biological parameters, to assess the status and trends of the reef ecosystem. The permanent transect method is a tool to ecologically monitor the coral reef habitat and generate baseline data on the quality of the reef ecosystems (English *et al.* 1997). The baseline data is useful in establishing restoration and recovery practices, and management of the reef area in relation to present and future development.

2.1. Permanent transect

Therefore, five permanent sites were selected and marked by the GPS locations (Both starting point and end points) (Table 1).

Ecological baseline data is useful in establishing restoration and recovery practices and management of the coral reef in relation to present and future development

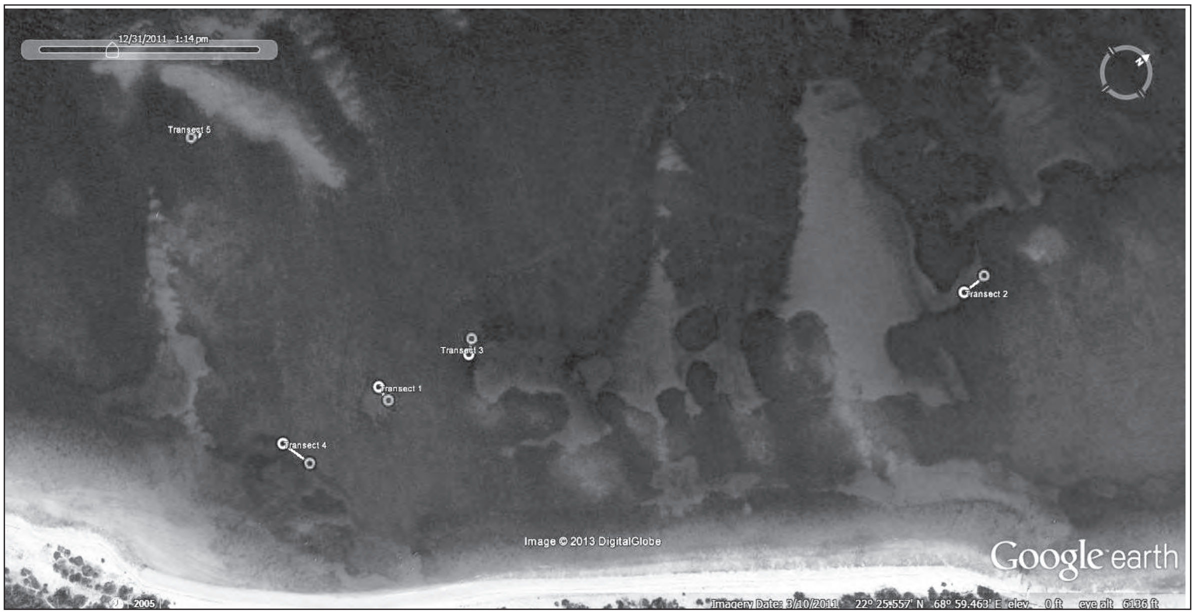
Table 1: GPS locations of the Permanent transect at Mithapur reef:

Sl. No	Permanent Transect	GPS Locations	
		Starting Point	End point
1	PT1	N22º25´348” : E068º59´380”	N22º25´348” : E068º59´407”
2	PT2	N22º25´861” : E068º 59´681”	N22º25´880” : E068º59´686”
3	PT3	N22º25´437” : E068º59´420”	N22º25´448” : E068º59´409”
4	PT4	N22º25´241” : E068º59´376”	N22º25´251” : E068º59´401”
5	PT5	N22º25´251” : E068º59´068”	N22º25´340” : E068º59´068”

A 50 m length of point transect (English *et al.* 1997) was used at each site (Map 2). The biological and oceanographical data were monitored at these sites. Based on the monitoring, some threats were identified as reasons for coral biodiversity decline. Along with natural causes, spatial competition, bleaching, diseases, and anthropogenic impacts such as sand mining, ghost fishing, poison fishing and boat anchoring led to reef loss. Oceanographic parameters such as sedimentation, temperature, pH, salinity and nutrient fluctuations have also contributed to the coral reef decline in Mithapur.

2.2 Biodiversity inventory of Mithapur reef

Biological parameters focus on the major reef resource. These parameters can be used to assess the current status and the



Map 2: Five permanent transect sites at Mithapur

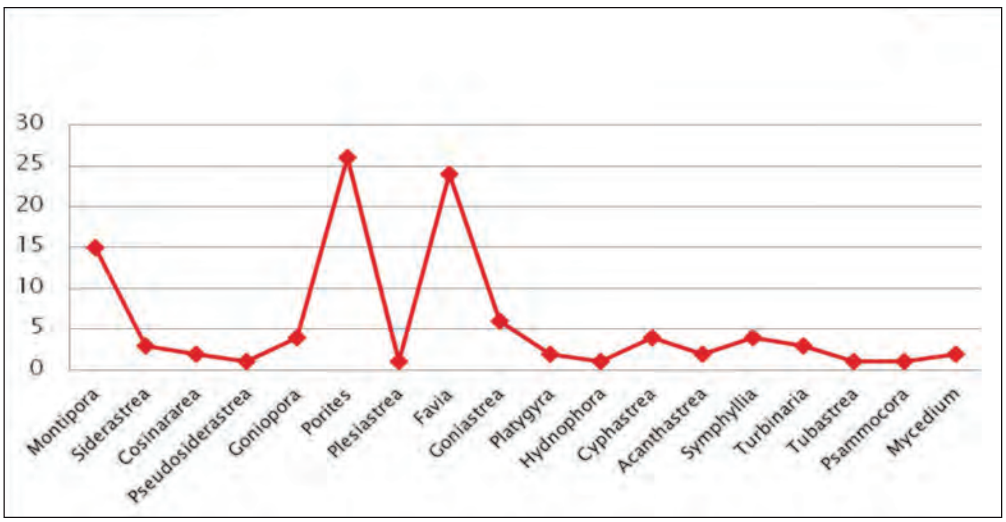


Fig. 3: Percentage of hard coral cover at genus level in Mithapur reef

extent of damage to coral reefs from natural and anthropogenic disturbances. The most frequently used biological parameters include the associated organisms, species composition, and their health status (Sharma *et al.* 2008).

2.2.1. Status of reef building corals of Mithapur reef: The geographical isolation, the extreme environmental variation, strong tidal currents and heavy sediment load, are reason for the low coral diversity in the GoK, among all Indian reefs (Dixit *et al.* 2010). The exact number of species recorded, though, is variable. Patel (1985) reported a total of 44 hard coral species and 12 soft coral species. Pillai and Patel (1988) recorded 37 species under 23 genera. However, Pillai and Patel (1988) reported 23 hard corals at Okha reef, the closest reef (app. 12 km) from Mithapur reef, and Dixit *et al.* (2010) reported 17 hard coral species and eight soft corals at Mithapur reef. WTIs' initial benthic survey in 2008 reported 29 species belonging to eight families of hard corals at the Mithapur reef. The percentages of hard coral genus have been estimated by using the method described by English *et al.* (1997).

$$\text{Percent coverage of one coral genus} = \frac{\text{Total living coverage of one genus from all transects}}{\text{Total living coverage of all the genus in all transects}}$$

A total of 18 genera of reef building coral were been found in the Mithapur reef. Major reef building corals like *Porites sp* (26%), *Favia sp* (24%)., *Montipora* sp (15.5%) and *Goniastrea sp* (6%), are mostly dominant (Fig. 3) and are found in the reef slope and front reef slopes. Other genera are sparsely distributed in the entire reef habitat.

2.2.2. Diversity Index of Mithapur Hard corals: The coral diversity and species richness were calculated by using Shannon-Wiener diversity index (H), and Simpson's richness index (D) and Pielou's evenness index (J). (Turkmen and Kazanci (2010). The detail formulas are given below.

a) Shannon – Wiener Diversity indices (H) = 3.3219 (N log N – Ni log Ni) / N Whereas, Ni = No of individual of the particular species and N = Total number of the individual in the collection.

b) Simpson species richness index (D)= 1- C Whereas, C = Pi2 and Pi2 = ni/N. Ni = Number of Individual of particular species. N =Total number of individuals.

c) Pielou's Evenness (J) = H/Jns Where, H = Species diversity and s = Total number of species.

As per Turkmen and Kazanci (2010), the Shannon and Simpson diversity index value showed the structure of the Mithapur reef habitat as medium, stable and balanced. As per the Pielou's indices, the hard coral species are not distributed equally (Table 2).

Table 2: Reef building coral diversity index at Mithapur reef:

Shannon – Wiener diversity Indices (H)	3.03
Simpson's Species richness indices (D)	0.84
Pielou's Evenness indices (J)	0.78

The checklist of the 29 hard coral species are given in (Table 3). Additionally a checklist of other associated reef's flora and flora were also recorded during the period of 2008–2013 (Table 4–10).

Plate 4: Reticulated puffer fish (*Arothron reticularis)*

Table 3: Checklist of Mithapur Hard Coral Diversity* (for description of species see. Appendix)				
S.NO	Family	*Genus*	Species	Common names
1	Acroporidae	*Montipora*	*Montipora hispida*	Plate Montipora
2			*Montipora monasteriata*	Ridge coral
3			*Montipora foliosa*	Cabbage coral
4			*Montipora turgescens*	Pillar pore coral
5			*Montipora venosa*	Pore coral
6	Siderastreidae	*Siderastrea*	*Siderastrea savignyana*	African pillow coral
7		*Cosinaraea*	*Cosinaraea monile*	Wrinkle coral
8		*Pseudosiderastrea*	*Pseudosiderastrea tayami*	False pillow coral
9	Poritidae	*Goniopora*	*Goniopora planulata*	Purple flower pot coral
10			*Goniopora minor*	Flower pot coral (Plate:1)
11		*Porites*	*Porites lutea*	Hump plate coral
12			*Porites lichen*	Yellow finger coral
13			*Porites compressa*	Hump coral
14	Faviidae	*Plesiastrea*	*Plesiastrea versipora*	Small knob coral
15		*Favia*	*Favia favus*	Knob coral
16			*Favia pallida*	Moon coral
17			*Favia speciosa*	Elliptical star coral
18		*Goniastrea*	*Goniastrea pectinata*	Lesse star coral
19		*Platygyra*	*Platygyra sinensis*	Worm brain coral
20		*Hydnophora*	*Hydnopora exesa*	Velvet horn coral
21		*Cyphastrea*	*Cyphastrea serailia*	Lesser knob coral
22	Mussidae	*Acanthastrea*	*Acanthastrea hillae*	Stary cup coral
23		*Symphyllia*	*Symphyllia radians*	Brain coral
24	Dendrophylliidae	*Turbinaria*	*Turinaria pelTata*	Disc coral
25			*Turbinaria mesentriana*	Pakoda scroll coral
26			*Turbinaria reniformis*	Cup coral
27		*Tubastrea*	*Tubastrea aurea*	Orange tube coral
28	Psammocoridae	*Psammocora*	*Psammocora digiTata*	Stony coral
29	Pectiniidae	*Mycedium*	*Mycedium elephantotus*	Elephant nose coral

Table 4: Diversity of Mithapur Reef Fish in Mithapur Reef* (for description see Appendix)				
S.NO	**Family**	**Genus**	**Species**	**Common names**
1	Apogonidae	*Apogon*	*Apogon pseudotaeniatus*	Double bar cardinal fish
2			*Apogon multitaeniatus*	Multi-stripe cardinal fish
3		*Archamia*	*Archamia bleekri*	Gon's cardinalfish
4	Serranidae	*Cephalopholis*	*Cephalopholis formosa*	Blue-lined hind
5		*Ephinephelus*	*Ephinephelus coioides*	Orange-spotted Grouper
6			*Epinephelus areolatus*	Areolate grouper
7			*Epinephelus erythrurus*	Cloudy grouper
8	Chaetodontidae	*Chaetodon*	*Chaetodon collaris*	Red-tailed Butterfly fish
9			*Chaetodon trifasciatus*	Melon Butterfly fish
10		*Heniochus*	*Heniochus acuminatus*	Pennant coral fish
11	Engraulidae	*Coilia*	*Coilia neglecta*	Neglected grenadier anchovy
12	Diodontidae	*Diodon*	*Diodon hystrix*	Spot-fin porcupine fish
13	Soleidae	*Euryglossa*	*Euryglossa orientalis*	Oriental sole
14	Muraenidae	*Gymnothorax*	*Gymnothorax favagineus*	Highfin moray
15			*Gymnothorax permistus*	Laced moray
16	Labridae	*Halichoeres*	*Halichoeres nigrescens*	Bubblefin wrasse
17	Synodontidae	*Harpadon*	*Harpadon nehereus*	Bombay duck
18		*Saurida*	*Saurida sp*	Lizard fish
19	Lutjanidae	*Lutjanus*	*Lutjanus fulviflamma*	Dory snapper
20			*Lutjanus argentimaculatus*	Mangrove red snapper
21			*Lutjanus lemniscatus*	Yellowstreaked snapper
22	Pomacentridae	*Neopomacentrus*	*Neopomacentrus filamentosus*	Brown demoiselle
23		*Abudefduf*	*Abudefduf bengalensis*	Bengal sergeant
24	Dasyatidae	*Neotrygon*	*Neotrygon kuhlii*	Blue spotted stingray
25	Pempheridae	*Pempheris*	*Pempheris vanicolensis*	Vanikoro sweeper
26	Plotosidae	*Plotosus*	*Plotosus lineatus*	Striped eel catfish
27	Scaridae	*Scarus*	*Scarus ghobban*	Blue-barred parrot fish
28	Terapontidae	*Terapon*	*Terapon jarbua*	Crescent-Banded grunter
29	Engraulidae	*Thryssa*	*Thryssa baelama*	Baelama anchovy
30	Mullidae	*Upeneus*	*Upeneus tragula*	Black Striped Goat Fish
32	Pomacanthidae	*Pomacanthus*	*Pomacanthus annularis*	Blue ring - Angle fish
33	Sparidae	*Acanthopagrus*	*Acanthopagrus latus*	Yellow-fin seabream
34			*Acanthopagrus bifasciatus*	Double bar bream
35			*Acanthopagrus berda*	Goldsilk seabream
36		*Lethrinus*	*Lethrinus nebulosus*	Sweet Lips
37	Haemulidae	*Plectorhinchus*	*Plectorhinchus sordidus*	Sordid Rubber lip
38		*Diagramma*	*Diagramma centurio*	Sailfin rubberlip
39	Myliobatidae	*Aetobatus*	*Aetobatus narinari*	Spotted eagle ray

40	Tetraodontidae	*Arothron*	*Arothron reticularis*	Reticulated puffer fish (Plate: 4)
41			*Arothron immaculatus*	Immaculate puffer fish
42			*Arothron stellatus*	Stellate puffer
43			*Arothron hispidus*	White Spotted Puffer Fish
44	Hemiscylliidae	*Chiloscyllium*	*Chiloscyllium griseum*	Grey bamboo shark
45	Hemiramphidae	*Hemiramphus*	*Hemiramphus archipelagicus*	Jumping halfbeak
46	Gobiidae	*Istigobius*	*Istigobius decorates*	Decorated goby
47	Leiognathidae	*Leiognathus*	*Leiognathus daura*	Gold-stripe ponyfish
48	Haemulidae	*Plectorhinchus*	*Plectorhinchus gibbosus*	Harry hotlips
49	Carangidae	*Caranx*	*Caranx sexfasciatus*	Bigeye trevally
50	Nemipteridae	*Scolopsis*	*Scolopsis vosmeri*	Whitecheek monocle bream
51	Pseudochromidae	*Pseudochromis*	*Pseudochromis sp*	Dotty-back
52	Gerreidae	*Gerres*	*Gerres erythrourus*	
53			*Gerres abbreviates*	Deep-bodied mojarra
54	Acanthuridae	*Acanthurus*	*Acanthurus xanthopterus*	Yellow fin surgeon fish
55	Torpedinidae	*Torpedo*	*Torpedo sinuspersici*	Marbeled Electric Ray (Plate: 6)
56	Syngathidae	*Hippocampus*	*Hippocampus camelopardalis*	Giraffe seahorse (Plate:5)

* Based on biodiversity monitoring till March 2013

Table 5: Diversity of Crustaceans in Mithapur Reef * (for description see Appendix)

S.No.	Family	Genus	Species	Common names
1	Xanthidae	*Atergatis*	*Atergatis integerrimus*	Red Egg Crab
2		*Etisus*	*Etisus laevimanus*	Smooth Spooner
3	Calappidae	*Calappa*	*Calappa lophos*	Common Box Crab
4	Epialtidae	*Doclea*	*Doclea rissoni*	Spider Crab
5	Eriphiidae	*Eriphia*	*Eriphia smithii*	Rough Red-Eyed Crab
6	Grapsidae	*Grapsus*	*Grapsus albolineatus*	Mottled Sally-Light-Foot
7	Palinuridae	*Panulirus*	*Panulirus polyphagus*	Mud Spiny Lobster
8	Porcellanidae	*Petrolisthes*	*Petrolisthes sp*	Porcelain Crabs
9	Pilumnidae	*Pilumnus*	*Pilumnus sp*	Wolf Crab
10	Portunidae	*Portunus*	*Portunus pelagicus*	Blue Swimmer Crab
11		*Thalamita*	*Thalamita crenata*	Crenate Swimming Crab
12	Gonodactylidae	*Gonodactylus*	*Gonodactylus sp*	Mantis Shrimp
13	Ocypodidae	*Ocypode*	*Ocypode platytarsis*	Stalked Eyed Ghost Crab

* Based on biodiversity monitoring till March 2013

Table 6: Diversity of Mollusc (Sea-Shell) in Mithapur Reef * (for description see Aappendix)			
S.NO	**Family**	**Genus**	**Species**
1	Trochidae	*Trochus*	*Trochus radiates*
2		*Monodonta*	*Monodonta australis*
3	Columbellidae	*Pyrene*	*Pyrene splendidula*
4			*Pyrene versicolor*
5	Naticidae	*Polinices*	*Polinices mammilla*
6	Cerithiidae	*Clypeomorus*	*Clypeomorus bifasciatus*
7			*Clypeomorus batillariaeformis*
8	Conidae	*Conus*	*Conus nussatella*
9			*Conus hyaena*
10			*Conus textile*
11	Terebridae	*Terebra*	*Terebra capensis*
12	Buccinidae	*Cantharus*	*Cantharus undosus*
13	Turbinidae	*Turbo*	*Turbo brunneus*
14		*Lunella*	*Lunella coronate*
15	Muricidae	*Chicoreus*	*Chicoreus brunneus*
16		*Thaisella*	*Thaisella tissoti*
17	Mitridae	*Mitra*	*Mitra ambigua*
18	Nassariidae	*Nassarius*	*Nassarius pictus*
19			*Nassarius reeveanus*
20	Turritellidae	*Turritella*	*Turritella radula*
21	Cypraeidae	*Mauratia*	*Mauritia aratica*
22		*Palmadusta*	*Palmadusta lentiginosa*
23	Olividae	*Olivancillaria*	*Olivancillaria nebulosa*
24	Strombidae	*Strombus*	*Strombus plicatus sibbaldi*
25	Littorinidae	*Littoraria*	*Littoraria scabra*
26	Architectonicidae	*Architectonica*	*Architectonica perspectiva*

*Based on biodiversity monitoring till March 2013

Table 7: Diversity of Flatworms in Mithapur Reef *(for description see Appendix)			
S.NO	**Family**	**Genus**	**Species**
1	Pseudocerotidae	*Maiazoon*	*Maiazoon orsaki*
2		*Pseudobicerous*	*Pseudobicerous gratus*
3	Pseudocerotidae	*Pseudocerous*	*Pseudocerous indicus*
4			*Pseudocerous susanae*
5	Euryleptidae	*Maritigrella*	*Maritigrella fuscopuncTata* (Plate: 7)

* Based on biodiversity monitoring till March 2013

Table 8: Diversity of Sea slugs in Mithapur Reef* (for description see Appendix)			
S.NO	**Family**	**Genus**	**Species**
1	Aplysiidae	*Aplysia*	*Aplysia dactylomela*
2	Plankobranchidae	*Elysia*	*Elysia thompsoni*
3			*Elysia tomentosa*
4	Chromodorididae	*Glossodaris*	*Glossodaris pallida*
5		*Hypselodoris*	*Hypselodoris carnea*
6	Discodorididae	*Jorunna*	*Jorunna funebris*
7	Phyllidiidae	*Phyllidiella*	*Phyllidiella zeylanica*

* Based on biodiversity monitoring till March 2013

Table 9: Diversity of other associated fauna in Mithapur Reef *(for description see Appendix)				
S.NO	**Family**	**Genus**	**Species**	**Common names**
1	Cepheidae	*Cephea*	*Cephea sp*	Crowned Jelly Fish
2	Cassiopeidae	*Cassiopea*	*Cassiopea sp.*	Upside-Down Jelly Fish
3	Thysanostomatidae	*Thysanostoma*	*Thysanostoma sp.*	Barrel Jelly Fish
4	Pelagiidae	*Pelagia*	*Pelagia noctiluca ?*	Purple striped jelly
5	Porpitidae	*Porpita*	*Porpita Sp*	Blue button
6	Zoanthidae	*Zoanthus*	*Zoanthus*	Zoanthids
7	Stichodactylidae	*Stichodactyla*	*Stichodactyla mertensii*	Merten's carpet sea anemone (Plate: 2)
8			*Stichodactyla haddoni*	Haddons carpet sea anemone (Plate:15)
9	Elapidae	*Salmacis*	*Salmacis bicolour*	Bi-colour Urchin
10	Temnopleuridae	*Pelamis*	*Pelamis platurus*	Yellow belly Sea Snake or Pelagic Sea Snake
11	Holothuriidae	*Holothuria*	*Holothuria pardalis*	Leopard Sea Cucumber
12	Onchidiidae	*Peronia*	*Peronia verruculata*	Onchdium

* Based on biodiversity monitoring till March 2013

Table 10: Diversity of Seaweeds in Mithapur Reef* (for description see Appendix)				
S.NO	**Family**	**Genus**	**Species**	**Common names**
1.	Rhodymeniaceae	*Botryocladia*	*Botryocladia leptopoda*	-
2.		*Rhodymenia*	*Rhodymenia sp*	
3.	Caulerpaceae	*Caulerpa*	*Caulerpa lantallifolia*	-
4.			*Caulerpa taxifolia*	
5.	Cladophoraceae	*Chaetomorpha*	*Chaetomorpha sp*	-
6.			*Chaetomorpha crassa*	Sea Spaghetti
7.	Siphonocladaceae	*Chamaedoris*	*Chamaedoris sp*	
8.	Champiaceae	*Champia*	*Champia sp*	-
9.		*Gastroclonium*	*Gastroclonium iyengarii*	
10.	Scytosiphonaceae	*Colpomenia*	*Colpomenia sp*	-
11.		*Hydroclathrus*	*Hydroclathrus clathratus*	Sponge Seaweed

12.	Galaxauraceae	*Galaxaura*	*Galaxaura sp*	-
13.	Halymeniaceae	*Halymenia*	*Halymenia porphyroides*	-
14.			*Halymenia venusta*	
15.	Halimedaceae	*Halimeda*	*Halimeda tuna*	-
16.	Cystocloniaceae	*Hypnea*	*Hypnea musciformis*	Hook weed
17.	Dictyotaceae	*Padina*	*Padina gymnospora*	(Plate: 8)
18.			*Padina tetrastromatica*	
19.		*Dictyota*	*Dictyota dichotoma*	Brown Fan Weed
20.		*Spatoglossum*	*Spatoglossum sp*	-
21.	Sargassaceae	*Sargassum*	*Sargassum johnstonii*	Gulfweed
22.			*Sargassum linearifolium*	
23.		*Cystoseira*	*Cystoseira indica*	-
24.	Scinaiaceae	*Scinaia*	*Scinaia moniliformis*	-
25.	Sebdeniaceae	*Sebdenia*	*Sebdenia polydactyla*	-
26.	Solieriaceae	*Solieria*	*Solieria robusta*	Blubber weed
27.	Udoteaceae	*Udotea*	*Udotea indica*	Mermaid's Fan
28.	Ulvaceae	*Ulva*	*Ulva reticulate*	Sea lettuce

* Based on biodiversity monitoring till March 2013

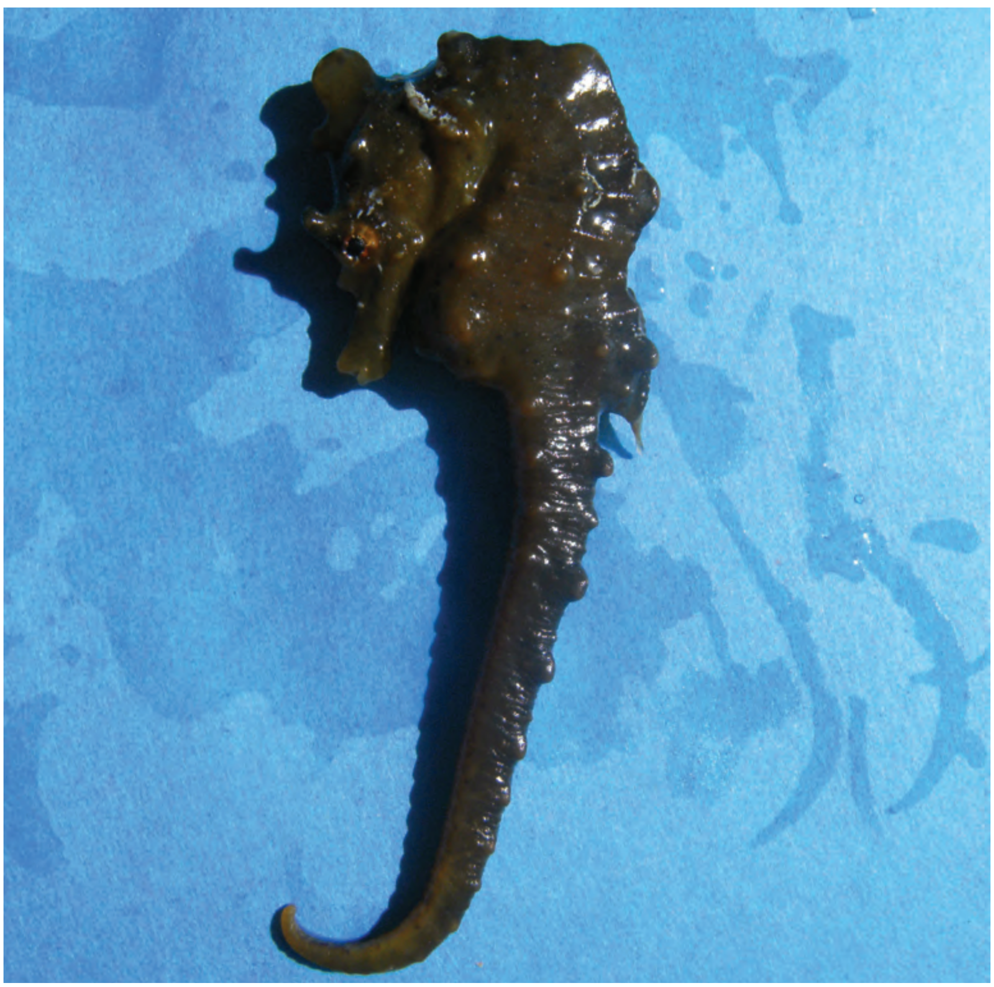


Plate 5: Giraffe seahorse (*Hippocampus camelopardalis*) reported (first time in India) in the Mithapur reef

Plate 6: Marbled electric Ray (*Torpedo sinuspersici*)

Plate 7: Flat Worm (*Maritigrella fuscopuncTata*)

HARD CORALS OF MITHAPUR REEF

Coral reefs are highly productive tropical marine habitats. They are made of fused calcium carbonate exoskeletons secreted by millions of organisms called coral polyps. Popularly known as the 'rainforests-of-the-seas', coral reefs harbor more than 25% of the marine biodiversity in an area covering less than 0.015% of the world's oceans.

Mithapur Coral Reef Recovery Project works to restore the reef along the Mithapur coast through activities, such as transplantation of locally-extinct species as well as facilitating natural recruitment of those diminishing in population. It also conducts regular exercises on coral rescues and beach cleaning involving local communities and children for awareness and participatory conservation.

Starry Cup Coral
(Acanthastrea hillae)

Lesser-Knob Coral
(Cyphastrea serailia)

Knob Coral
(Favia favus)

Lesser Star Coral
(Goniastrea pectinata)

Flower Pot Coral
(Goniopora minor)

Plate Montipora
(Montipora hispida)

Hump Plate Coral
(Porites lutea)

Velvet Horn Coral
(Hydnopora exesa)

Worm Brain Coral
(Platygyra sinensis)

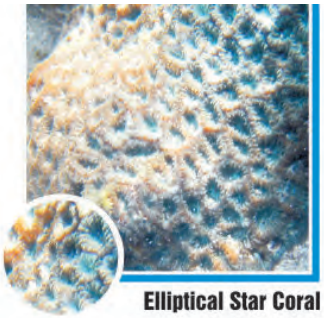
Orange Tube Coral
(Tubastrea aurea)

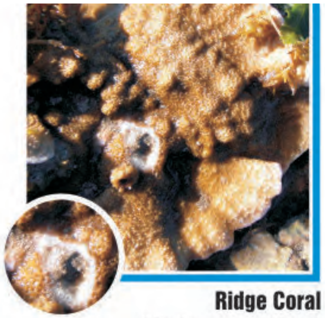
Hump Coral
(Porites compressa)

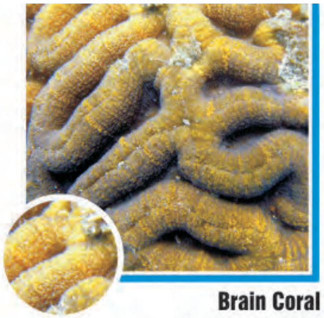
False Pillow Coral
(Pseudosiderastrea tayami)


Stony Coral
(Psammocora digitata)


Cup Coral
(Turbinaria reniformis)

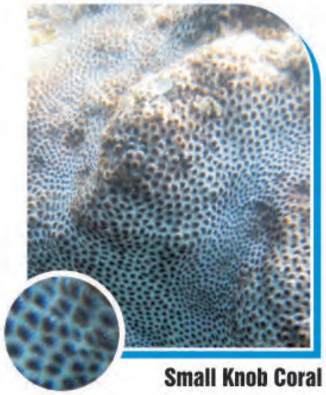

Elliptical Star Coral
(Favia speciosa)


Ridge Coral
(Montipora monasteriata)


Brain Coral
(Symphyllia radians)


African Pillow Coral
(Siderastrea savignyana)


Pore Coral
(Montipora venosa)


Small Knob Coral
(Plesiastrea versipora)


Wrinkle Coral
(Cosinaraea monile)


Pokoda - Scroll Coral
(Turbinaria mesentriana)


Purple Flower Pot Coral
(Goniopora planulata)


Pillar Pore Coral
(Montipora turgescens)


Disc Coral
(Turinaria peltata)


Yellow Finger Coral
(Porites lichen)

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Cabbage Coral
(Montipora foliosa)


Moon Coral
(Favia pallida)

REEF FISH OF MITHAPUR

Coral reefs occupy less than one percent of the world's oceans, and yet they are home to 25% of the 15,000 species of marine fish. Living in a symbiotic relationship, these fish help clean algae from the coral surface ensuring passage of sunlight, vital for coral survival; in return, coral reefs provide them a safe habitat. Unlike open water marine fish, reef fish are built for manoeuvrability over speed, and use coral reefs as hideouts to avoid predators. They are also more colorful and have specialised mouth parts that are suited to deal with food found in reef ecosystems.

Mithapur Coral Reef in Gujarat is one such rich
Over 50 species of fish have been identified in Mit
along a coastline stretching just about 1.2 kilomet

Types of fish (If space permits)

Over 15,000 species of marine fish have been di
the world, and around 160 species are added to
average every year.

Areolate grouper
Epinephelus areolatus
Mithapur S.Goutham

Bengal sergeant
Abudefduf bengalensis
Mithapur S.Goutham

Black spotted puffer
Arothron stellatus
Mithapur S.Goutham

Black-banded bamboo shark
Chiloscyllium griseum
Mithapur S.Goutham

Blue-barred parrot fish
Scarus ghobban
Mithapur Madhu Menon

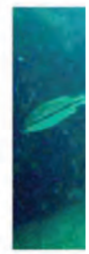
Cloudy grouper
Epinephelus erythrurus
Mithapur Subburaman

Crescent-Banded grunter
Terapon jarbua
Mithapur Subburaman

Decorated goby
Istigobius decoratus
Mithapu S.Goutham

Freckled goatfish
Upeneus tragula
Mithapur Subburaman

Double bar bream
Acanthopagrus bifasciatus
Mithapur S.Goutham



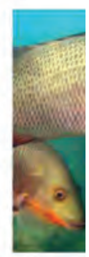
Gold-stripe ponyfish
Leiognathus daura
Mithapur S.Goutham

Harryhotlips
Mithapur S Goutham

Highfin moray
Gymnothorax favagineus
S.Goutham

Immaculate puffer fish
Arothron immaculatus
Mithapur S.Goutham

Jumping halfbeak
Hemiramphus archipelagicus
Mithapur S.Goutham



Rock Blenny
S.Goutham

Multi-stripe cardinal fish
Apogon multitaeniatus
Mithapur S.Goutham

Oriental sole
Euryglossa orientalis
Mithapur Madhu Menon

Pennant coral fish
Heniochus acuminatus
Mithapur S.Goutham

Reticulated puffer fish
Arothron reticularis
Mithapur S.Goutham

Striped eel catfish
Plotosus lineatus
Mithapur Subburaman

White Spotted Puffer Fish
Arothron hispidus
Mithapur S.Goutham

Whitecheek monocle bream
Scolopsis vosmeri
Mithapur S.Goutham

Scorpion fish
Scorpaenpsis sp
S.Goutham

Sordid Rubber lip
Plectorhinchus sordidus
S.Goutham

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Fish are divided into two major groups:

Teleost/Bony Fish (hard skeleton) – such as clown fish and damsel fish

Cartilaginous fish (soft bone) – such as sharks and rays.

They can also classified based on the depth they live in:

Pelagic - fish that swim in open water

Demersal - fish that live close to the sea bottom Benthic - fish that live on the sea floor.

Highfin moray
Gymnothorax pseudothyrsoideus
Mithapur S.Goutham

Highfin moray
Gymnothorax favagineus
S.Goutham

lined hind
lis formosa
S.Goutham

Blue-ring angelfish juvenile
Pomacanthus annularis
Mithapur S.Goutham

Blue-ring angelfish
Pomacanthus annularis
Mithapur S.Goutham

Bluespotted stingray
Neotrygon kuhlii
Mithapur Manoj Matwal

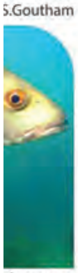
Bubble-fin wrasse
Halichoeres nigrescens
Mithapur S.Goutham

Cave Sweeper
Pempheris vanicolensis
Mithapur S.Goutham

d snapper
emniscatus
S.Goutham

Doublebar cardinalfish
Apogon pseudotaeniatus
Mithapur S.Goutham

Freckled goatfish
Upeneus tragula
Mithapur Subburaman



d snapper
imaculatus
S.Goutham

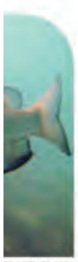
Marbeled Electric Ray
Torpedo sinuspersici
Mithapur S.Goutham

Melon Butterflyfish
Chaetodon trifasciatus
Mithapur Venkatesh

rubberlip
S Goutham

Sordid Rubber lip
Plectorhinchus sordidus
Subburaman

Spot-fin porcupinefish
Diodon hystrix
Madhu Menon



seabream
grus berda
S.Goutham

Laced moray
Gymnothorax favagineus
Mithapur S.Goutham

Striped eel catfish
Plotosus lineatus
Mithapur S.Goutham

S.No.	FAMILY	GENUS	SPECIES
1	Apogonidae	*Apogon*	*Apogon pseudotaeniatus*
2			*Apogon multitaeniatus*
3		*Archamia*	*Archamia bleekri*
4	Serranidae	*Cephalopholis*	*Cephalopholis Formosa*
5		*Ephinephelus*	*Ephinephelus coioides*
6			*Epinephelus areolatus*
7			*Epinephelus erythrurus*
8	Chaetodontidae	*Chaetodon*	*Chaetodon collaris*
9			*Chaetodon trifasciatus*
10		*Heniochus*	*Heniochus acuminatus*
11	Engraulidae	*Coilia*	*Coilia neglecta*
12	Diodontidae	*Diodon*	*Diodon hystrix*
13	Soleidae	*Euryglossa*	*Euryglossa orientalis*
14	Muraenidae	*Gymnothorax*	*Gymnothorax flavimarginatus*
15			*Gymnothorax permistus*
16	Labridae	*Halichoeres*	*Halichoeres nigrescens*
17	Synodontidae	*Harpadon*	*Harpadon nehereus*
18		*Saurida*	*Saurida sp*
19	Lutjanidae	*Lutjanus*	*Lutjanus fulviflamma*
20			*Lutjanus argentimaculatus*
21		*Neopomacentrus*	*Neopomacentrus filamentosus*
22	Pomacentridae	*Abudefduf*	*Abudefduf bengalensis*
23	Dasyatidae	*Neotrygon*	*Neotrygon kuhlii*
24	Pempheridae	*Pempheris*	*Pempheris vanicolensis*
25	Plotosidae	*Plotosus*	*Plotosus lineatus*
26	Scaridae	*Scarus*	*Scarus ghobban*
27	Terapontidae	*Terapon*	*Terapon jarbua*
28	Engraulidae	*Thryssa*	*Thryssa baelama*
29	Mullidae	*Upeneus*	*Upeneus tragula*
30	Pomacanthidae	*Pomacanthus*	*Pomacanthus annularis*
31			*Pomacanthus annularis(Juv)*
32	Sparidae	*Acanthopagrus*	*Acanthopagrus latus*
33			*Acanthopagrus bifasciatus*
34		*Lethrinus Sp.*	*Lethrinus Sp.*
35	Haemulidae	*Plectorhinchus*	*Plectorhinchus sordidus*
36		*Diagramma*	*Diagramma centurio*
37	Myliobatidae	*Aetobatus*	*Aetobatus narinari*
38	Tetraodontidae	*Arothron*	*Arothron reticularis*
39			*Arothron immaculatus*
40			*Arothron stellatus*
41	Hemiscylliidae	*Chiloscyllium*	*Chiloscyllium griseum*
42	Hemiramphidae	*Hemiramphus*	*Hemiramphus archipelagicus*
43	Gobiidae	*Istigobius*	*Istigobius decorates*
44	Leiognathidae	*Leiognathus*	*Leiognathus daura*
45	Haemulidae	*Plectorhinchus*	*Plectorhinchus gibbosus*
46	Carangidae	*Caranx*	*Caranx sexfasciatus*
47	Nemipteridae	*Scolopsis*	*Scolopsis vosmeri*
48	Pseudochromidae	*Pseudochromis*	*Pseudochromis sp*
49	Gerreidae	*Gerres*	*Gerres erythrourus*
50	Acanthuridae	*Acanthurus*	*Acanthurus xanthopterus*
51	Torpedinidae	*Torpedo*	*Torpedo sinuspersici*

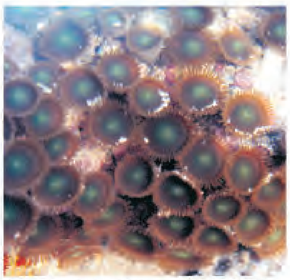
LIFE IN THE MITHAPUR REEF

Coral reefs are highly productive tropical coastal marine habitats. Known as the 'rainforests-of-the-seas', coral reefs harbour more than 25% of the marine biodiversity in an area covering less than 0.2% of the world's oceans.

Mithapur reef extends over 10 km along the Gujarat coastline in the Gulf of Kutch. Although a short stretch, the reef harbours a plethora of colourful organisms.

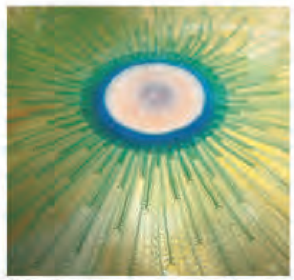
Mithapur Coral Reef Reco
the reef along the Mithapur
transplantation of locally e
facilitating natural recruitn
population. The project a
biodiversity of the reef to cr
around 150 species have bee
species and 55 fish species.

CNIDARIANS (STINGING CREATURES)



Green button polyp © S Goutham
Palythoa mutuki

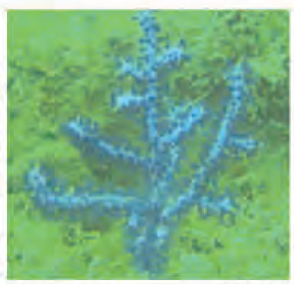
Barrel jellyfish © S Subburaman
Thysanostoma sp



Blue button © S Goutham
Porpita Sp

Zoanthids © S Goutham
Zooanthus sansibaricus

Include jellyfish, anemones and sea pens. Possess special stinging cells shaped like harpoons.



Sea fan © S Goutham
Verucella sp

Crowned jellyfish © S Subburaman
Cephea sp

Merten's carpet sea anemone © M Venkatesh
Stichodactyla mertensii

Sea nettle jellyfish © S Goutham

Upside-down jellyfish © Madhu Menon
Cassiopea sp

Purple-striped jelly © Rahul Kaul
Pelagia noctiluca

ECHINODERM

Bicolour urchin © S Goutham
Salmacis bicolor

Incluc
urchins,
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limbs. P
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REPTILES

Include marine iguanas, snak
tails. Lay eggs along the coa
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Green turtle © Altaf Alias Bhaya
Chelonia mydas

Ornate reef s
Hydrophis or

MARINE MAI

Dugong © Vardhan Patankar
Dugong dugon *Photograph from Andaman

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coral species as well as
of those diminishing in
sesses the rich marine
faunal inventory. So far,
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Leopard sea cucumber © S Subburaman
Holothuria pardalis

ırtles. Have modified limbs or
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crait that lay eggs).

) Altaf Alias Bhaya

Yellow-bellied sea snake © Manoj Matwal
Pelamis platurus

ALS

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reathing
). Have
flippers
efficient
balance.

Humpback dolphin © Anush Shetty
Sousa chinensis *Photograph from Kerala

CRUSTACEANS (WITH SHELLS)

Include 67,000 described species including lobsters, crabs, shrimps, barnacles etc. Possess a hard shell made up of calcium and chitin, which are molted during growth.

Common box crab © S Subburaman
Calappa lophos

Mantis shrimp © S Goutham
Gonodactylus sp

Crenate swimming crab © S Goutham
Thalamita crenata

Blue swimmer crab © S Goutham
Portunus pelagicus

Red egg crab © S Goutham
Atergatis integerrimus

Mud spiny lobster © S Goutham
Panulirus polyphagus

Wolf crab © S Goutham
Pilumnus sp

Rough red-eyed crab © S Goutham
Eriphia smithii

Scalloped spiny lobster © S Goutham
Panulirus homarus

Mottled sally-light-foot © Rahul Kaul
Grapsus albolineatus

Spider crab © S Subburaman
Doclea rissoni

Spotted moon crab © S Goutham
Ashtoret lunaris

Smooth spooner © S Goutham
Etisus laevimanus

Stalked-eyed ghost crab © S Goutham
Ocypode platytarsis

Marine porcelain crab © S Goutham
Petrolisthes sp

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Plate 8: Sea weed (*Padina* sp.) at Mithapur

2.3. Oceanographic monitoring of Mithapur reef

Quality of sea water depends mostly on oceanographic parameters and the magnitude of various forms of pollutants and therefore, monitoring of these parameters is essential (Reddi *et al*. 1993). Corals are sensitive to environmental variables, such as suspended materials, excessive sediment accumulation, sea water dilution from surface drainage and groundwater discharge, temperature fluctuations, emersion of shallow reef during low tides and pollution (Randall *et al.* 1990). Therefore, for better understanding of the Mithapur coral reef, oceanographical parameters were assessed, which are expected to help determine the cause of coral degradation or regeneration.

Plate 9: (Clockwise) Shell measurement, Quadrate, Sediment Trap, Belt Transect by snorkeling, Line Transect, pH meter & (center) Temperature Logger

2.3.1 Data collection:

Field data including sea water temperature, salinity, pH, sedimentation rate, nitrites and phosphates were assessed at Mithapur reef at periodic intervals. During ebb tides, six water samples were collected every two hours, to cover the 12 hrs, and one complete tidal cycle (low tide to high tide to low tide).

Temperature, salinity, and pH were measured in the field using thermometers, salino-meters and pH meters respectively, Sediment samples were collected from the sedimentation trap (60 cm length and 6 cm radius of PVC pipe, which was tied with 1 meter long iron rod), which was fixed to the bottom of the sea (Plate 9). Four sediment traps were placed at the permanent transect sites (Map 2). The dissolved sediment settles in the sedimentation trap. The samples were collected in the plastic bags from the sediment traps, after which the trap was reset.

All sediment samples were transferred to 500 ml beakers and allowed to settle after the seawater was carefully filtered through filter paper (3 mm size). Next, all samples were mixed well with distilled water and again allowed to settle. The process was repeated 2–3 times to reduce the salt in the sediments. Further, 100-ml beakers were weighed without the sediment in a digital weighing balance, for each sample analysis, and the cleaned sediments were then transferred to the beakers. The beakers were placed inside an oven and allowed to dry at 150° C. After drying, the beakers were weighed along with sediments. The sedimentation rate is calculated using the following formula:

$$\text{S. rate} = \frac{\text{Sediment Dry weight}}{\text{Number of days at site} \times \pi r^2}$$

Sedimentation rate = sediment dry weight
Sediment dry weight = total beaker weight with sediment - beaker weight without sediment.
Number of days = the date of collection of sediment from the trap - the date of traps placed at the site.
π value = 3.14159
r^2 = total diameter of the trap.

a. Temperature

Temperature is one of the most important parameters, since all other parameters are dependent on it. Temperature can affect the solubility of chemical compounds; distribution and abundance of organisms; growth rate of biological organisms; water density, mixing of different water densities and current movements; the amount of oxygen that can dissolve in water, fluxing of salinity, pH, nutrients etc. The animal metabolic rates rise as the temperature rises (Robertson and Blaber, 1992). Corals require a water temperature range between 18°C and 32°C (Hill and Wilkinson, 2004). The annual surface seawater temperature (SST) at the reef ranged from 22°C during winter to 30.9°C during summer seasons (Fig 4). The findings revealed that the SST gradually increased from February to August. At the same time, the temperature steadily decreased from October to January.

b. pH

pH is a measure of the activity of the hydrogen ions in the sea water, and ranges from 0 to 14. A pH of 7 is neutral. A pH less than 7 is acidic, while pH greater than 7 is basic. The pH of seawater plays an important role in the ocean's carbon cycles. Corals grow by depositing calcium carbonate as part of their skeletons, and calcium carbonate does not form (or precipitate) at a low pH. A pH of above 8 makes it much easier for corals to lay down their calcium carbonate skeletons, making it possible for them to grow (Robertson and Blaber (1992), Upadhyay, (1988), Rajasekar, (2003)) (Fig 5). The average pH value in seawater is 7.5 to 8.4. In Mithapur reef, the pH varied from 7.3 to 8.2.

c. Salinity

Salinity is the concentration of salt dissolved in water. The salinity of water may increase or decrease due to the loss or gain of water from evaporation, rainfall, freezing, melting, or other processes. The most important aspect of water salinity is its effect on aquatic organisms. Salinity changes can affect the well-being and distribution of biological populations. The average salinity of seawater is 35 parts per thousand (ppt). Corals prefer a salinity range of 32 ppt to 42 ppt (Hill and Wilkinson, 2004). In the Mithapur reef, salinity ranged from 36 ppt to 43 ppt during monsoon and summer seasons respectively (Fig. 6). The minimum salinity was presumably due to the influence of heavy rainfall and the fresh water runoff, which is a regular annual event during monsoon (Saravanakumar *et al*. 2007).

d. Sedimentation Rate

Siltation is the main factor affecting the growth and survival of corals (Wilson *et al*. 2005). Sediment particles reduce the light available for photosynthesis, and excessive sedimentation can adversely affect the structure and function of the coral reef ecosystem by altering both physical and biological processes. The normal sedimentation rate in seawater is 1 to 10 mg/ sq cm/day (Rogers, 1990). During monsoon, especially June, July, August and September, visibility was very low due to heavy sedimentation. Collection of samples during this period from the reef was difficult. For the remaining eight months, samples were collected and the sedimentation was recorded. Heavy monsoon between July and mid-September restricted field activities and sedimentation collection at Mithapur reef. However, the sedimentation gradually decreased from October to February (Fig. 6).

The monsoon, from June to September, is the most critical period for coral health and its survival in the Mithapur reef

e. Nutrients

Nutrients are also an important parameter in coral reef environments. The distribution of nutrients is mainly based on the season, tidal conditions and freshwater inflow from land. Nutrients such as nitrites and phosphates were analysed from the seawater. The nitrite and phosphate values varied from 0.005μg/L to 0.133μg/L and 0.003 μg/L to 0.092μg/L. The highest nitrite and phosphate values were recorded during monsoon periods, especially August, possibly contributed by the rainfall or land runoff (Das *et al.* 1997). Most of the low values of the nutrients were recorded during the non–monsoon periods. These nutrient fluctuations would be due to phytoplankton excretion, oxidation of ammonia, bacterial decomposition of planktonic detritus present in the environments (Govindasamy *et al.*, 2000) (Fig. 8 and 9).

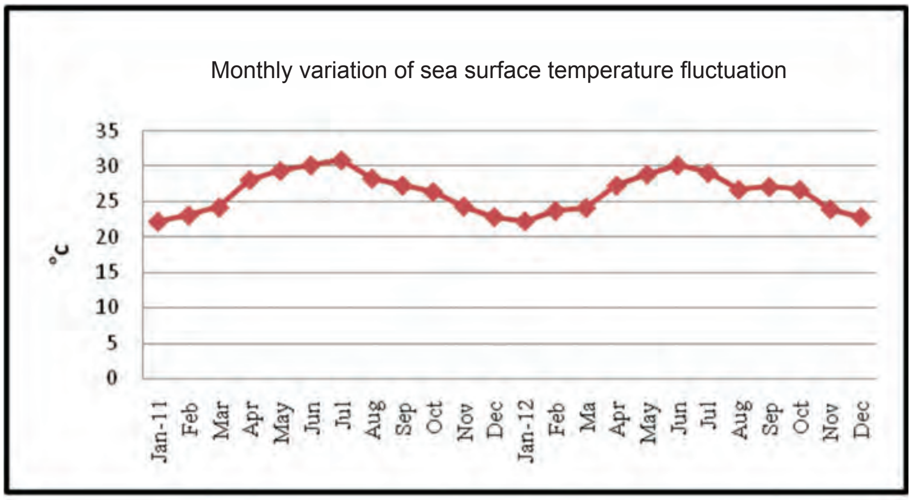


Fig 4: Monthly variation in temperature in the Mithapur reef

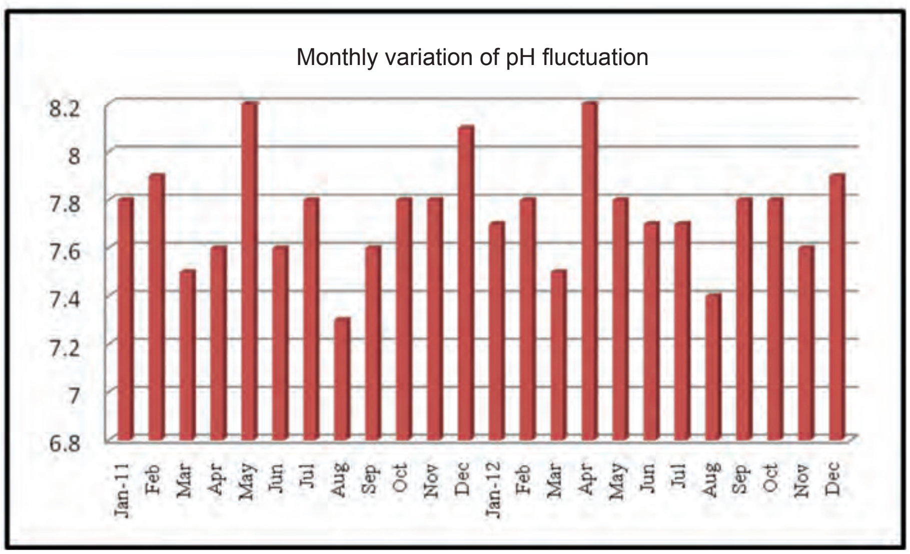


Fig 5: Monthly variation in pH in the Mithapur reef

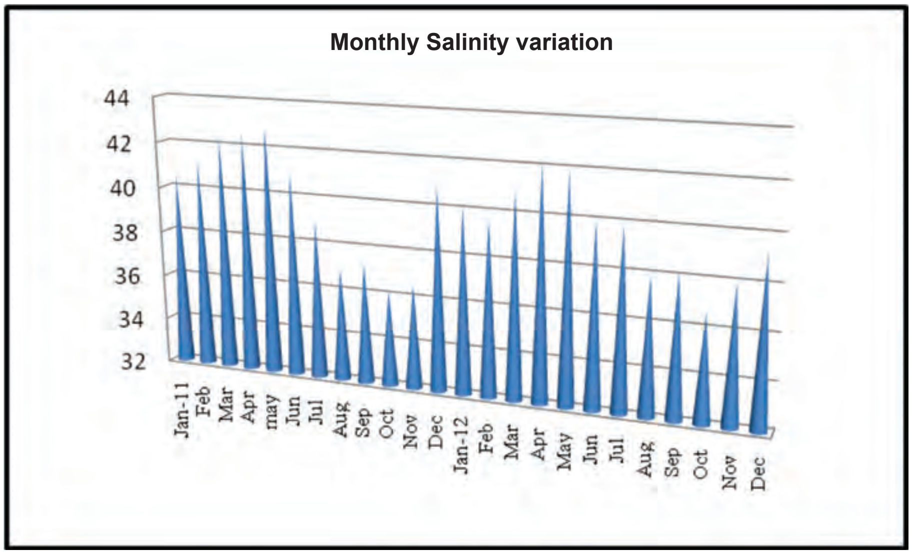


Fig 6: Monthly variation in salinity in the Mithapur reef

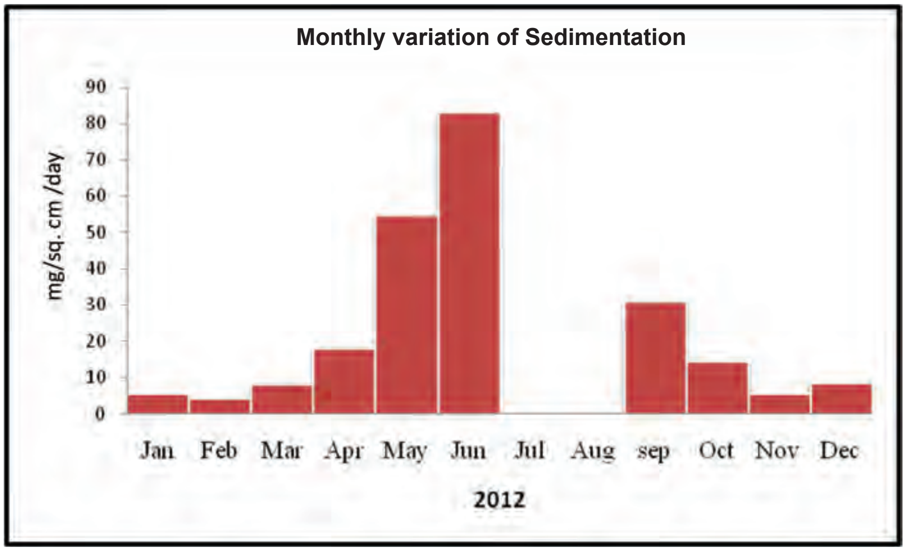


Fig 7: Monthly variation in sedimentation in Mithapur reef

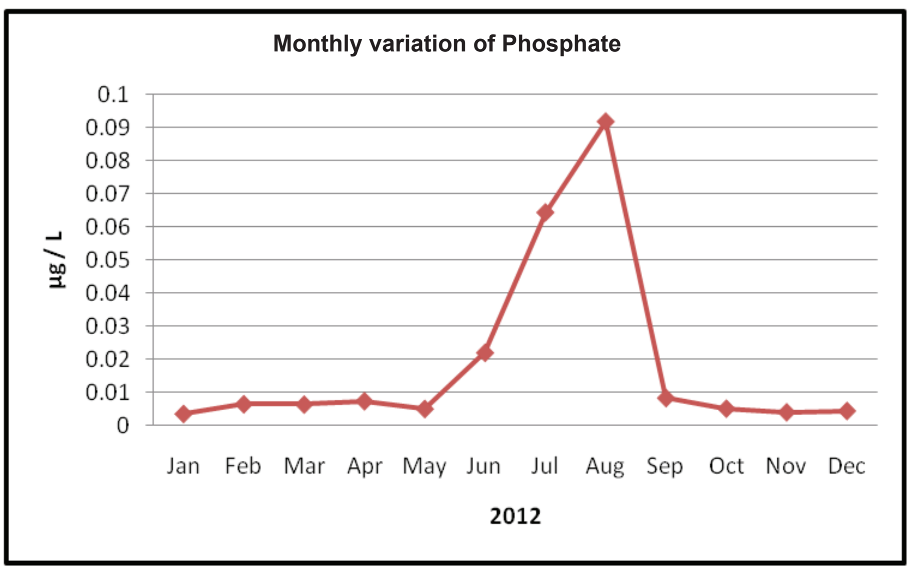


Fig 8: Monthly variation of phosphate content in the Mithapur reef

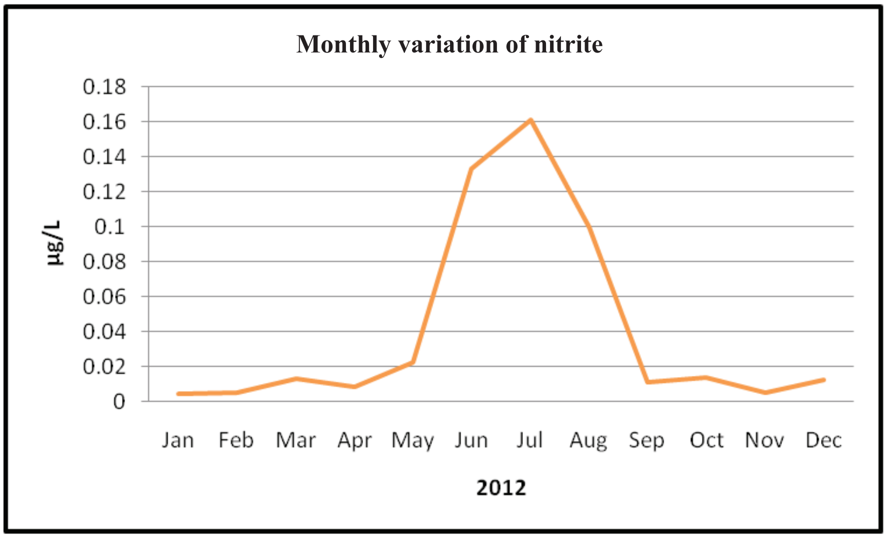


Fig 9: Monthly variation of nitrite in the Mithapur reef

2.4. Threats to Mithapur coral reef

Some anthropogenic and natural threats were identified through biological and oceanographical monitoring at Mithapur reef. Most of the physical disturbances were observed, and photographed for further assessments, while additional information was gathered through interaction with local fishing communities and other stakeholders.

2.4.1. Anthropogenic activities

a. Sand mining

Sand and gravel mining were observed through visual observations. Mining is occurring on a small scale (carts, 2 to 3 tons) to medium scale (small trucks, less than 5 tons) along Mithapur coast. The mined sand and gravel are mainly used for construction activities in nearby villages. Sand mining is a major anthropogenic physical disturbance, leading, to a rise in sediment levels, temporary though in water. High sedimentation in sea water is one of the reasons for severe degradation of coral reef ecosystem (Rogers, 1990) (Plate-10)

Plate 10: Sand mining using tractors

b. Using of bamboo poles for propelling of boats and boat anchoring

The Mithapur reef is shallow. Boatmen use bamboo poles to push their boats on the reef for better maneuverability (Plate 11). The bamboo poles rub on the corals and sometimes damage the coral polyps. Some coral polyps are killed immediately, while others are uprooted when they are struck by the bamboo poles. Visual aids were used to define and document the damage.

The Mithapur reef is used by small boats belonging to the surrounding villages of Mithapur, Arambada, Surajkaradi and Dwaraka, for fishing. 25 to 30 boats are anchored on the Mithapur reef on most days, of which about 15 boats are motorized and the remaining non-motorized. Several boats use Mithapur reef as an anchor point, to stock ice blocks from Surajkaradi ice plants to freeze fish catch. A strong substrate, for example, stone or corals, is used to anchor the boats. The anchored stone damages and breaks the corals. Several corals damaged by anchored rope were observed in Mithapur.

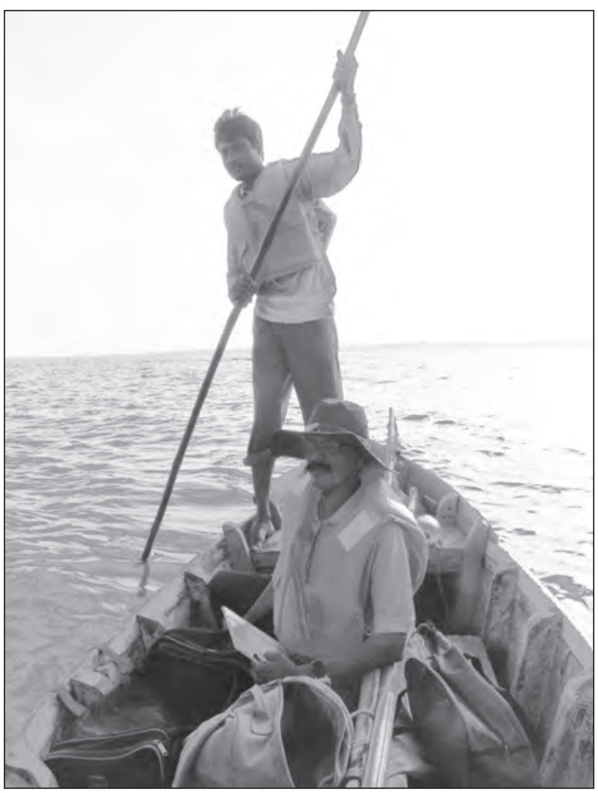


Plate 11: Boatman using bamboo poles for driving the boat

c. Poison Fishing

In Mithapur, fishing is banned in the sea for four months i.e June, July, August and September, each year. During the four months, local fishermen engage in 'poison-fishing' in Mithapur reef. They pour an extract of a Euphorbiacae (cactus) sap in the seawater, to poison fish and sell the dead fish in the market. According to Burns (2003), these poisons are a major threat to the survival of coral reefs, and they reduce coral reef biodiversity as they affect not just the target fish but other marine organisms too (Plate 12).

Plate 12 : Sting ray along with juvenile affected by poisonous fishing.

d. Overturned coral colonies

Normally during low tide, fishermen overturn the corals on the reef flats to capture fish, especiallygroupers, and snappers that hide beneath them. Sometimes the iron anchors of boat also overturn the live corals in the reef, which cause acute stress and death to the over-turned corals. (Dinsdale and Harriott 2004) (Plate 13).

Plate 13: Boat anchor on reef

Such activities are so intense that 24 overturned corals were observed within a 25m^2 area in Mithapur reef. This also contributes to degradation of the habitat.

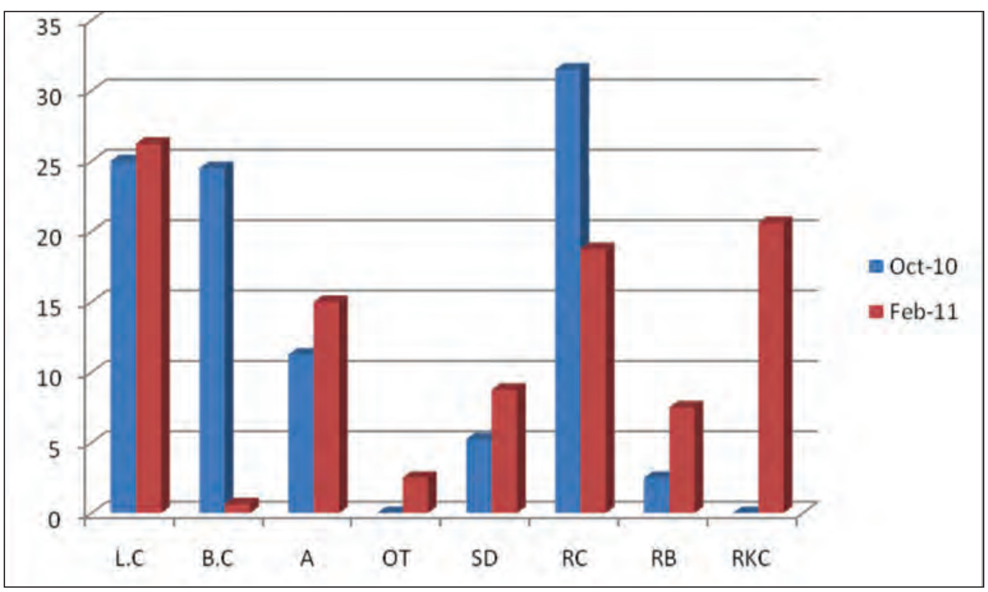
2.4.2. Natural disturbance on corals

a. Coral bleaching effects

Coral bleaching is the release of zooxanthellae from the corals due to environmental stresses such as sea temperature fluctuation (thermal shocks), solar irradiance, sedimentation, xenobiotics, freshwater dilution, predators, diseases and anthropogenic activities (Buchheim, 1998). Mass coral bleaching is predominantly induced by rising of seawater temperature (GBRMP, 2007). A rise in water temperature is usually caused by global warming and El-Nino. El-Nino is a shift in ocean temperatures and atmospheric conditions in the tropical Pacific, which disrupts weather patterns around the world. El-Nino was implicated in the mass coral bleaching across the tropical world in the early 1980s (Wilkinsion, 2000). The 1998 El–Nino increased sea surface temperature by more than 3° C, causing mass coral bleaching around the world (Schuttenberg and Obura, 2001). An estimated 16% of the coral reefs were destroyed by the 1998 El-Nino (Wilkinsion, 2000).

In 2006 and 2008 coral bleaching was observed subsequently in various parts of the world, but the 1998 mass bleaching was the worst. Coral bleaching was observed in various parts of the world, during the summers of 2009 and 2010 as well. Muley *et al.* (2000) reported, nearly 70% dead coral cover at GoK, apparently caused by El-Nino in 1998. During the recent El-Nino in 2010, coral bleaching was reported in various parts of the world, and many countries started early warning systems and bleach monitoring programmes (GBRMP, 2010). In India, the Andaman sea (Khokiattiwong and Yu, 2010), Gulf of Mannar and Lakshadweep Islands also reported coral bleaching. Coral bleaching was also observed in Mithapur reef in Arabian Sea in September 2010. In the Mithapur reef, coral bleaching was assessed in October 2010, during the post-monsoon period, and again during February 2011 (Fig 10). Data was collected twice from permanent transects.

There were 25 % live (healthy) corals and 24.5% of bleached corals observed during October 2010. After 4 months (February – 2011, Post El-Nino period), 26.25 % live corals were observed, implying there was some marginal (1.25%) recovery from the mass bleaching effects. However, bleached corals were reduced from 24.5% to 0.625 %; indicating that badly



LC – Live coral; B.C – Bleached coral; A – Macro algae; OT - Other animals (Like ascidians, sea squirt, etc); RC – Rock; RB – Rubble; RKC – Recently Killed corals

Fig. 10: Coral bleaching status at the Mithapur reef (Oct. 2010 and Feb. 2011)

impacted corals had perished. A large number of dead corals (RKC) (20.625%) were observed in February 2011. The dead corals were due to the sediment deposition on the corallites and algal assemblages. The findings revealed that about 20% of the hard corals had declined in Mithapur, due to the 2010 El-Nino bleaching effects (Fig. 4). *Montipora sp*. (plate corals) was the most severely affected species in the Mithapur reef (Plate 14), post El-Nino period (after March 2011)

Post El–Nino (2010), corals regenerated (1.25%) at Mithapur reef within four months

Regeneration of *Montipora sp*.

In 2012 (October) again, mass bleaching was observed in Mithapur reefs. The sea surface temperature (SST) rose from 25°C (March 2012) to 30°C (June, 2012) in the Mithapur reef (Fig. 4). This was the peak temperature during the year. Due to the SST fluctuations, some bleached corals were also observed in October 2012 permanent monitoring survey. During this survey, 27.4% of live corals and 1.73% of bleached corals were observed. Compared to the February 2011 survey, live coral coverage had increased 3.08% within 19 months (Plate 9). The *Montipora sp.* had regenerated around the reef, which may indicate that the corals getting regenerated post El-Nino (2010).

b. Spatial Competition between organisms

Coral reefs around the world are in an extremely competitive environment and space is a critical resource in the marine habitat. The competition for space on the benthic substrate between corals and other benthic species is a constant factor within the coral reef ecosystems (Jackson and Buss, 1975). Weakened, diseased or bleached corals are more vulnerable to space competitive species. Similarly, when a coral is killed by disease or other disturbances, the empty spaces of reef substrate are made available to other species for colonization (Sokolow, 2009). However, competition for space is an important process that helps determine the coral reef community structure (Chornesky, 1989). Our studies revealed that the spatial competitors for corals in Mithapur reef are macro algae encrusting sponges, ascidians and other species of corals (Plate 15). All these have been recognised as significant sources of competition for space with corals.

c. Coral Diseases

Coral diseases and syndromes generally occur in response to biotic stresses such as bacteria, fungi and viruses, and/or abiotic stresses such as increased sea water temperatures, ultraviolet radiation, sedimentation and pollutants. One type of stress may exacerbate the other (Santavy and Peters, 1997). The frequency of coral diseases appears to have increased significantly,

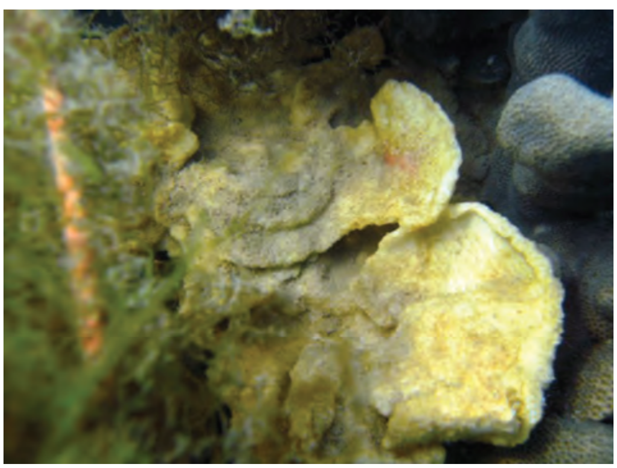


Plate 14: *Montipora* sp. (plate coral) during mass bleaching and post mass bleaching event at Mithapur reef

causing widespread mortality among reef-building corals. Many scientists believe the increase is related to deteriorating water quality associated with anthropogenic pollutants and increased sea surface temperatures. This may, in turn, allow for the proliferation and colonization of disease-causing microbes. However, the exact causes for most coral diseases remain elusive. Two major coral diseases were identified in the Mithapur reefs: i) coral tumour, and ii) white-band diseases(Plate 16.

i. Coral tumour

Coral tumour is an unusual growth of fungi that appears as odd-shaped tumour on the coral skeleton. This results in the zooxanthallae being released from the coral. (Plate 16: a and b) The fungi break up the skeleton, creating holes that look like a swelling or tumour (Mcclanathan, 2009).

ii. White syndome diseases

White syndrome is a name given to a number of 'white diseases' like white pox, white band, and white plaque; and is a major threat to the Mithpur coral reef. Here, the coral loses tissue or zooxanthallae, due to pollution and environmental stress (Plate 11: c,d, e and f).

For better reef recovery, these kinds of threats need to be controlled. While community participation and raising awareness may help reduce the anthropogenic pressure, physical restoration methods may help reduce natural hurdles to maintaining the coral health. There is also a need to study the level of contaminants, pollutants and other factors that operate in the Mithapur reef.

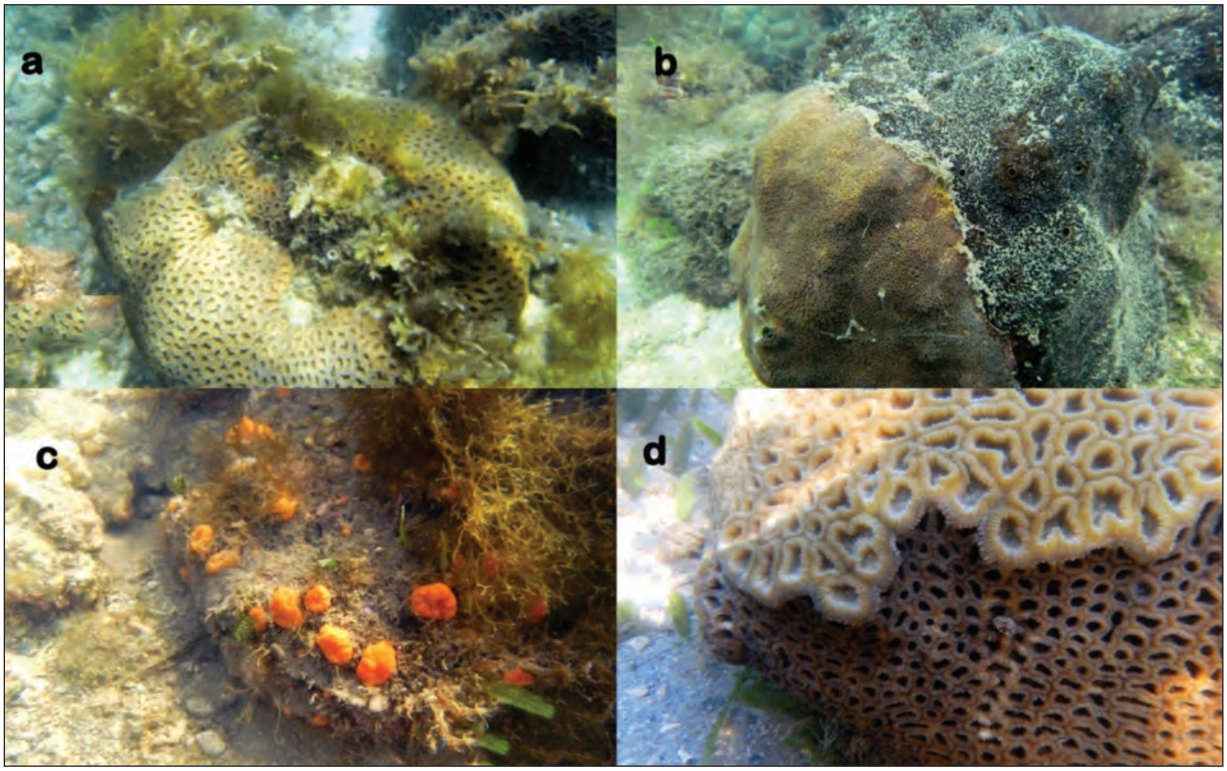


Plate 15: (a)Macro algae (b), Encrusted sponges (c), Ascidians (d) Coral inter specific competition

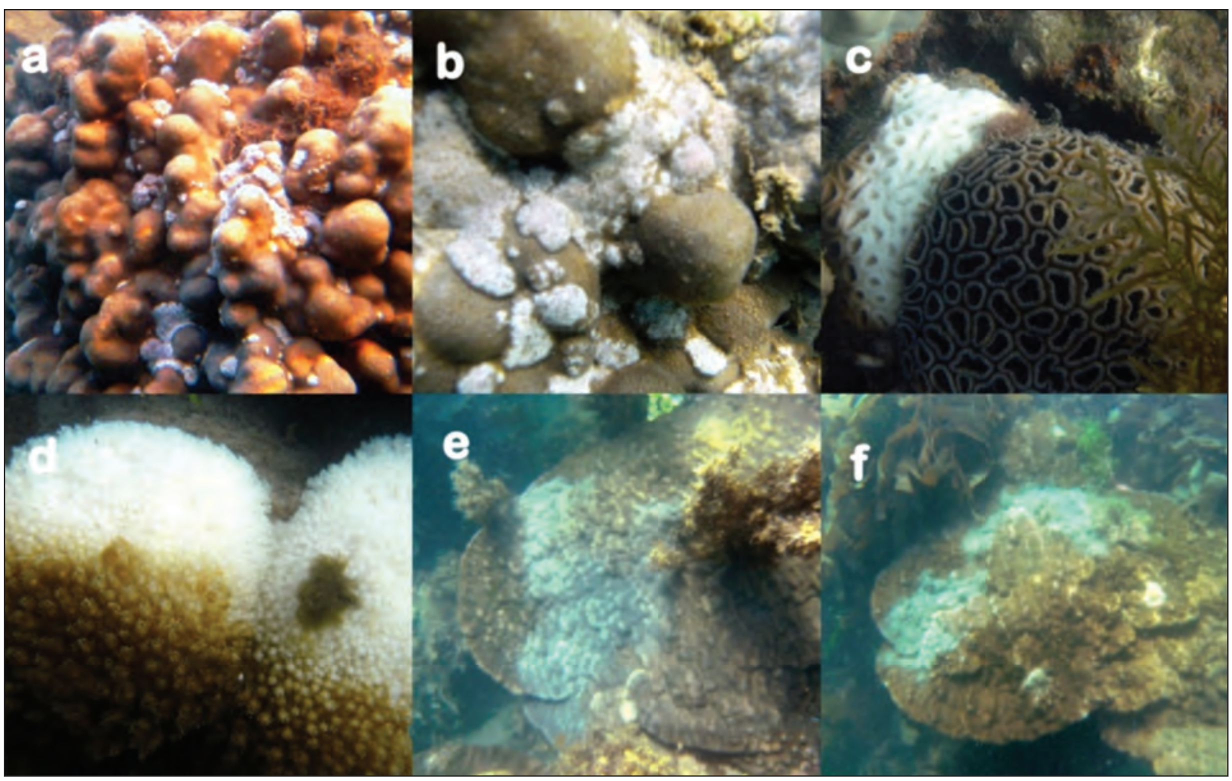


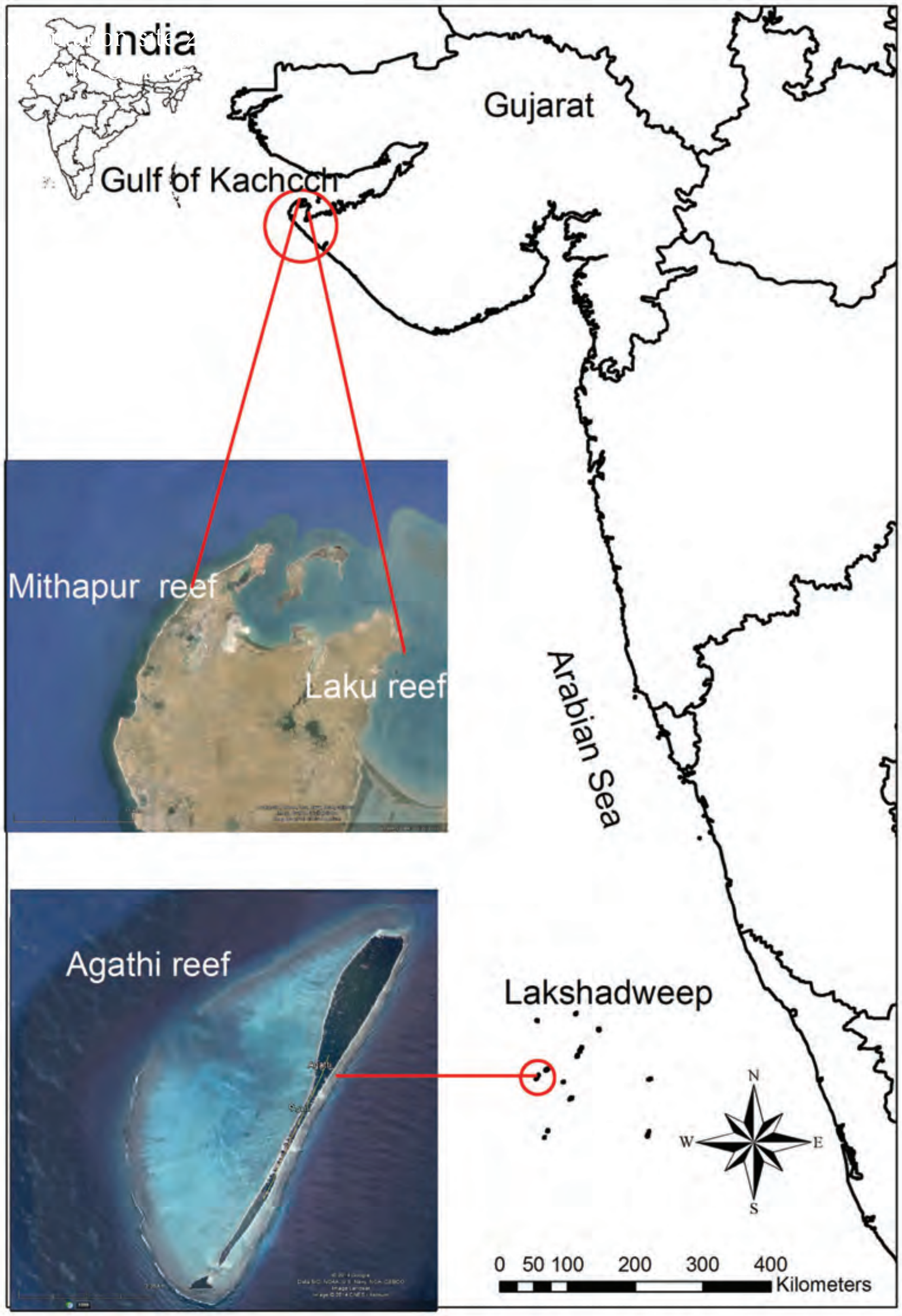
Plate 16: Diseases: (a) and (b) Tumour (c, d, e and f) – White syndrome disease

Plate 17: Haddon's carpet sea anemone (*Stichodactyla haddoni*)

Plate 18: Arabian cowrie (*Mauritia arabica*)

CHAPTER 3

Experimental *Acropora sp.* Coral Transportation and Transplantation



Map 3: Coral transplantation sites (Donor and Recipient)

Coral reefs are declining and both natural and man-made causes are implicated (Harris, (2009), Riedmiller, (2001)). In the first step of the active restoration process, WTI initiated coral transplantation with *Acropora* spcies Internationally, mass coral transplantation activities have been carried out at several places for example, a liquefied natural gas plant at Yemen in 2007, with 36 species of hard corals (Seguin *et al*. 2008). Around 8000 fragments from 36 species of various hard corals were harvested and transplanted to a floating nursery ground on the Gulf of Eliat in the Red sea during 2004. Experimental transplantations have also been tried in different degraded areas such as a blast fishing site in Indonesia and in the Philippines (Raymundo *et al.* 2007 and Fox *et al.* 2005), tourist resorts in Maldives Islands (Guignard and Berre, 2008), ship grounding site at Mona Island, USA (Bruckner and Bruckner, 2001), bleach affected areas in Japan and Fiji Islands (Job *et al*. 2005, Fujiwara and Katsukoshi, 2007) and a hurricane-damaged site at Mexico (Flip and Gill, 2006). Some successful reef restoration and mitigation programmes have also been carried out in Japan (Omori and Fujiwara, 2014), and Sri Lanka (Ekaratne and Jinendradasa, 1998) using coral transplantation methods.

In India, hard corals were transplanted in the Gulf of Mannar by Suganthi Devadason Marine Research Institute (SDMRI) in 2004 and 89.3% survival rates were observed after an eight-month period (Mathews and Edward, 2005). Experimental transplantation with *Acropora* and *Pocillopora* species was carried out by National Institute of Oceanography in Lakshadweep islands, where the transplants survived for more than a year (Venkatesh and Koya, 2006).

Coral decline in the Gulf of Kachchh is possibly due to reef exposure to tectonic activities, siltation, bleaching and diseases (Pillai *et al.* (1979), Arthur (2000), Singh *et al.* (2006), Biswas (2009), Dixit *et al.* (2010). Mithapur apparently had faced similar problems. Based on the available literature (Patel (1976), Pillai *et al*. (1979), Pillai, (1983), Pillai and Patel, (1988), Desmukhe *et al*. (2000), and WTI Field visits, skeletons of *Acropora* species were found along the coast of the GoK. There have been no live forms of this species reported, leading to the conclusion that *Acropora* species may have died out or become restricted in distribution in GoK waters (Pillai et al, 1979).

It is also known that *A. humilis* is a relatively more common species compared to *A. squarrosa* in the other three Indian major reefs and other islands (Pillai, 1971), Venkatraman *et al.* (2003), Patterson *et al.* (2004). As an initial step of coral transplantation, WTI, TCL, Gujarat Forest Department and Lakshadweep Forest Department jointly decided on *A. humilis* transplantation at the Mithapur reef and the Laku Island on an experimental basis in March 2012 so that a locally extinct species that is an important structural coral for reef building could be restored in the GoK.

3.1 Project sites

3.1.1 The recipient reefs

a. Mithapur Reef

Mithapur reef, facing the Arabian Sea, is ecologically suitable to be recipient of *A. humilis* as the species is known to occur in the Lakshadweep waters in the Arabian Sea, and also apparently in the reef off the Malvan coast. After close monitoring of the Mithapur site by WTI, it was decided to hone in on Mithapur, as a primary recipient site on the basis of favourable oceanographic characteristics (Map 3) .

b. Laku reef

Laku Island is one of the adjacent reefs (Map 3), located inside the GoK, near Poshitra village with a total area of 1.2 sq km (Baguna, 1998). Nineteen coral species have been reported from the Laku Island. Some Acropora skeletons also were observed on the northern side of the island. The northern portion of the island has one of the best tidal pools, with a sandy bottom. The pool is 2-3 metres deep at low tides, compared to Mithapur, Laku tidal pools generally have poor visibility due to turbid waters, even during low tide. The team decided to choose two recipeint reefs to experiment with reefs inside and outside of the GoK.

The team decided to restore the locally extinct *Acropora humilis,* by transporting fragments from Lakshadweep to GoK on an experimental basis

3.1.2. Donor reef in Lakshadweep

a. Agatti reef

Agatti is one of the several islands in Lakshadweep. Lakshadweep Islands are one of the major coral reef areas in India, comprising 12 coral atolls with 36 islands. Lakshadweep coral reefs are the closest to the reefs of Gulf of Kachchh as both are located in the Arabian Sea (Pillai and Patel, 1988). More than 15 Acropora species have been recorded in Lakshadweep waters (Venkatraman *et al.* 2003). *A. humilis* is the most abundant species in Agatti Island (Suresh, 1991). It is located at 10°51'N 72°11' E and 459 km from Cochin and has a area of 2.7sq. km The small island of Kalpetti is located at the southern end of this island. The western side of the island has a semi-circular lagoon. The lagoon bottom contains a higher percentage of dead corals than live corals. Most of the Acropora corals are found predominantly in the lagoon's inner reef slope areas. Branching and massive coral types are spread all over the region. The maximum depth of the lagoon is around 15 metres, which is very close to the western gate. The open sea base is located on the eastern side of the island. The reef flat extends 100 metres from the shore, after which the reef slope starts with 2 metres depth. The project chose Agatti Island as a donor site and started the survey during mid October 2011.

3.2. Material and methods

3.2.1. *Acropora humilis* identification:

Assessment of *A. humilis* status were made at Agatti Island as per Dana (1846) and Veron (2000). These surveys were focused only on finding *A. humilis* colonies, based on the following generic key characters.

1. Colony structure: Digitate forms with finger like projection.
2. Axial corallites: Dome shaped, larger than the radial corallites.
3. Radial corallites: Larger corallites are formed in a row, with increasing size from top to bottom.

Plate 19: Survey methods (clockwise) Boat, Manta tow, Snorkeling, Scuba

3.2.2. Survey methods

The 8-km-long coastline on both the eastern and western sides of the Agatti Island was surveyed by manta tow, snorkeling and scuba diving (Plate 19).

i. Western side

On the western side, a survey was carried out using the Manta tow method while snorkeling over the lagoon and reef flat areas. When digitate forms of coral species were observed, a closer examination was carried out by skin diving. Once the species was confirmed as *A. humilis*, the location was marked by GPS and floats for further identification. Other digitate-forms like *A. gemmifera, A. corymbosa, A. moticulousa, A. globiceps* and *A. hyacinthus* also tended to be common and were differentiated by their key identifying characters. *A. humilis* was found to be relatively sparsely distributed and most of the forms were found on the upper reef slope, reef flat and back reef margins. Nearly 50 colonies with more than 30 to 70 fragments of *A. humilis* were found within a 2.5 sq km area, and the areas were suitably marked for further investigations. Four regions were surveyed at the western front reef, with varying depths of 20-25 metres, and up to an hour of survey was conducted in each region using scuba. Non–Acoropora corals were dominant in these regions. A few dead digitate-form skeletons were also observed in those areas. A large number of *Acanthastrea planchi* (Crown-of-thorn Star fish) were observed at this location.

ii. Eastern side

During the neap tide, surveys were conducted on the eastern side of Agatti Island. Because of rough weather, snorkeling and scuba diving were minimised on the eastern part of reef flat. About 21 *A. humilis* colonies (young colonies with few fragments) were observed on the reef flat near the eastern jetty on the Agatti Island. A roughly five-sq-km area (along the shore at the reef flat from south to north) and two regions (one was near the eastern jetty and another near the airport) were covered, with scuba diving, along the 20–25 metre depth of the front reef. Four live *A. humilis* colonies were found at the 20-metre depth, but they were affected by white band diseases. The remaining more than 10 colonies were found to be dead. Most of the corals were non–*Acropora* species especially *Porites sp., Goniopora sp.*, and other boulder corals like *Symphyllia sp.* and *Platygyra sp.*.

3.3. *Acropora* transplantation methods

3.3.1. Materials

a. Lakshadweep: Three iron table frames were deployed (2 m long, 1 m wide, and 1/2 m high, with the top covered with iron mesh (mesh size 2 cm), at Agatti lagoon. (Lat and long. 10°51'.316"N; 72°10'.918"E) for placement of coral fragments in the donor reef.

b. Gujarat: Three mesh topped iron table frames with 1m X 1m X 5cm dimensions were deployed at recipient sites in Gujarat: at Mithapur – N22°.25'.861"; E068°.59'.681" and N22°.25'.437"; E068°.59'.420") and at Laku island. The size of the table was – 1.1 m and were 50 cm high.

The fragments were planned to be translocated to the culture tables and fixed along with the substrate for culturing, at both the donor and recipient sites.

3.3.2. Methods of harvesting of coral fragments at Agatti island:

An initial snorkeling survey at Agatti lagoon in Lakshadweep revealed that many coral colonies were affected, probably by the El–Nino 2010. Some colonies were dead, but many were regenerating. However, some colonies were found to be in a very good condition inside the lagoon, compared to the corals at the front reef. Most of the young colonies were found in the reef flat areas.

Six colour variants of *A. humilis* were observed (Plate 20). Based on the key characters, 50 out of the 70 colonies were identified for coral

Plate 20: Six colour variations of *A. humilis* were observed in the Agatti Islands

Plate 21a: Harvesting of healthy *A. humilis* fragments in Agatti lagoon

21b: Abdul Raheem (right), Environment Warden – Agatti, assisting in coral transplantation

Plate 22: Coral fragment at the time of transplantation and fragment established after 42 days

harvesting. In all, 100 *A. humilis* fragments were collected from the colonies in the lagoon on two different occasions using hammer and sesile (Plate 21a and b). Initially, 30 fragments were harvested and attached with limestone blocks on 20th December 2011. Later on another occasion (22nd January 2012) 70 more coral fragments were attached to concrete blocks, which were fabricated at Agatti island. Each fragment was tied onto a single substrate (limestone or small concrete block) using tags and the prepared substrates were fixed on a culture table in the nursery ground, about 1 km away from harvesting areas. The approximate fragment sizes were 5–7 cm. The harvested fragments were allowed to establish themselves on the substrate, which also helped reduce post-harvesting stress.

3.3.3. Methods of culture and monitoring process at Lakshadweep

After placing the fragments on the culture tables in the Agatti lagoon, they were monitored once every five days. Algae and other bio-foulers were removed from the culture tables and the substrate using 2-mm painting brushes, and each fragment was closely observed. Due to fragmentation stress, all corals initially got bleached, after three days. All the corals were carefully monitored and their health condition was assessed by comparing their photographs taken at various intervals. After 45 days, the Acropora fragments were observed to have been well established (Plate 22) on the substrate, and all fragments had recovered completely from bleaching and regained their original colour.

3.3.4. *Acropora* transportation methods

These coral fragments were transported from Lakshadweep to Mithapur, using the revised wet method (Baker, 2010). In this method, coral fragments along with the substrate are affixed to the bottom of a container (in this case, a 20-litre capacity plastic tank) and filled with sea water. During transportation aeration through an aerator (atmospheric air/air pressure – 3.2MPa / Output air – 3.2 l/min) was supplied regularly, with a provision of sunlight or artificial (40 watt) lighting. It was also ensured that the substrate was firmly fixed to the base of the container so that the fragments did not get disturbed during transportation.

4.3.5. Coral transportation process from Lakshadweep to Gujarat

Transportation of coral fragments from Lakshadweep to Gujarat was the biggest challenge, as corals would have had to be kept alive over the 1500 km long journey. Moreover, the GoK has highly turbid waters compared to Lakshadweep (Pillai, 1979). For the initial survival of the coral fragments in turbid conditions, they would need to be in a healthy condition. The Lakshadweep transplantation revealed that corals get bleached if they are under stress. A stressed coral would be affected easily during and after transportation and transplantation. Therefore, a revised transportation and transplantation exercise involving *A. humilis* was carried out. Based on the distance, travel time, handling stress, Baker's (2010) "Coral Transportation Protocol" (long distance) was tried at Agatti island in a controlled environment. The results revealed that the corals could not survive for more than two days using this method. Therefore, the travel time would have to be minimised so that the corals could reach Mithapur in less than 48 hours from the time of packing them in transportation vessels.
Air transportation was the best mode of travel in this case but it had certain limitations such as high expense and unsupervised cargo transportation.

a. **High expense**
   Air transport of coral fragments, packed in several water container, all the way from Agatti Island to Cochin and Jamnagar via Mumbai, would have been logistically a very difficult and expensive exercise, even on regular passenger flights, let alone a special chartered plane. Also, no cargo facilities are available from Agatti Island to Cochin.

b. Cargo issues

From Agatti to Cochin to Mumbai to Ahmadabad and/or Jamnagar/Porbandar, the corals would have had to be handed over to the air cargo department. The timing was not conducive, and there was possible absence of care as none of our personnel would be able to access the cargo once it was booked. The cargo would be kept on open tarmac where temperatures could be high. Since there are no direct flights from Agatti to Ahmedabad, changing flights and managing layover time were also issues.

3.3.6. Season and time of transportation and transplantation

The physical parameters of the donor and recipient waters at Lakshadweep and GoK were monitored from October 2011 onwards (Table 11). The temperature and salinity at both places were approximately equal in March, which was the basis of the decision to transport and transplant the cultured fragments from Agatti to Mithapur in March 2012 to avoid thermal shock.

3.3.7. Revised transportation protocol

The transportation protocols were revised and re-tested with some coral fragments. These trials revealed that corals could survive for more than 10 days, if exposed to periodic light with continuous aeration. The revised wet method was, therefore, chosen for coral transportation. Moreover, it would be suitable for boat, train and road transportation under constant observation.

The choice of travel route for the coral transportation and minimising travel time and costs, were challenging. It was decided to transport the fragments by three means i.e. ship, train and road. This method ensured that connections between various modes of travel could be obtained without delays and that the fragments could be transported in temperature controlled environments (air−conditioned). Twenty five *A. humilis* fragments were removed from the culture table, on 9th March, 2012 for the first experimental transplantation basis from the now 60-day-old culture table. The fragments were affixed in 10 plastic containers with two fragments in each container. The base of each container was modified to provide an inward bolt which would secure each fragment to the base. Due to damage to one of the containers, only 22 fragments were transported in nine containers on 10th March, 2012 from Agatti Island. Rest of the three fragments were again replanted at the culture table in Agatti lagoon.

> **The coral fragments were transported by ship, train and road, from Agatti Island, to GoK with light and air ensured during the journey**

i. By ship

The team chose a passenger ship to carry *Acropora* fragments from Agatti island to Cochin. The transportation took place from Agatti on 10th March, 2012 at 2 pm by "Amidivi passenger ship", supported by continuous aeration and lights and reached Cochin on 11th March, 2012 at 1.30 pm. During the 24-hrs ship journey, two coral fragments got slightly bleached but were

Table 11: Physical parameters of the donor and recipient reef

Temperature (°C)	Salinity	pH	Temperature (°C)	Salinity	pH
30.1	36.2	7.4	31	38	7.6
29.1	36.6	7.4	-	-	-
-	-	-	30	38	8.5
20.8	40.2	7.2	29	39	8.4
25.1	39.8	7.3	28	39	8.2
29	39	7.5	29.5	38	8.4

alive. The seawater was changed twice, when a fleshy smell (caused by stress) was observed. In Cochin, the coral fragments were transported to the railway station after ensuring continuous aeration and lighting.

ii. By train

The corals were shifted to an air conditioned train cabin, and supplied with aeration and light to reduce stress. (Plate 23). One of the coral fragments perished and another was found to be severely stressed. After reaching Mumbai (20 hrs later – 3rd day, 12th March), two corals started getting bleached, and they were allowed to de-stress at the railway station.

Plate 23: Transport by train

iii. By road

After a gap of two hours, further journey started from Mumbai to Mithapur by road in an air–conditioned vehicle (Plate 24). The corals were transported with regular aeration and light support, and continuously monitored. The vehicle reached Mithapur at 4 pm on 13th March, 2012. Due to long travel by road, two more coral fragments perished and a further four were getting bleached. The remaining 14 coral fragments were in a healthy condition.

3.3.8. Acclimatization process

After reaching Mithapur, all coral fragments were shifted from transportation container to plastic trays for acclimatizing them to Mithapur waters. The tray sizes were 2 feet long and 1.5 feet wide. They were placed in trays filled with seawater from the source (Agatti) which was carried along

Plate 24: Transport by road

in cans to initiate the acclimatization process. Continuous aeration and light were provided throughout (Plate 19). After 12 hours, all corals were slowly introduced into mixed seawater in a 1:1 ratio (Lakshadweep water and Gujarat waters). No changes were observed after 12 hrs of continuous observations. After 12 hrs, the corals were slowly introduced into 100% Mithapur water by gradually increasing the concentration, and observations continued. The corals were placed in Mithapur water up to 42 hrs for acclimatization. During acclimatization, only one coral was found to be bleached.

Plate 25: Acclimatization process at Mithapur

3.4. Transplant operations in Mithapur

a. Mithapur

Ten live fragments were selected and placed on two culture tables on 15th March 2012, using SCUBA. Among them, six were healthy corals and four were slightly stressed. The fragments and their substrates were fixed on to the culture tables around 1300 hrs (Plate 26 and 27).

Plate 26: R.D Kamboj, CCF & Director GoK, MNP, Gujarat handing over the coral fragment to be transplanted.

Plate 27: TCL staff handing over fragment to be transplanted.

b. Laku Island

Seven healthy corals and one stressed coral were fixed on to the culture table at the Laku Island at an identified site on 16th March 2012. Because of the heavy currents and highly turbid conditions, the coral fragments were fixed on the culture table prior to lowering them into the waters and fixed (Plate 28).

Plate 28: Coral Fragments at Mithapur at the beginning of monsoon

3.5. Monitoring of corals at the transplanted site in Gujarat

After transplantation, monitoring protocols were developed. Regular monitoring was expected to provide the status and survival rate of transplanted coral fragments. After transplantation, the Mithapur coral fragments were observed daily up to first five days (21st March) for any immediate changes. At the end of the first fortnight, six healthy corals had retained their health, but the bleached ones were dead. The status of coral monitoring was maintained until the last observation, before the monsoon rendered monitoring difficult.

> **The transplanted corals at Laku survived for four months and the fragments at Mithapur reef for six months**

In Laku Island, due to heavy current movements, monitoring could only be undertaken during the neap tide. Four monitorings were carried out at the Laku site. Five corals were healthy, whereas the two bleached ones had died. One was missing from the table. On the second visit, four healthy corals and three dead corals were observed. The corals had probably died due to the upturning of the table by some anthropogenic pressure (very frequent in the area) or heavy current flow. In third monitoring only one fragment was survived and that was partially lived in the fourth monitoring in July 2012.

The transplanted corals at Laku survived for four months and the fragments at Mithapur reef for six months (Fig 11). In Laku, due to physical damage (upturning of culture table caused by heavy currents), two fragments (25%) perished. One stressed coral (12.5%) died within two days after transplantation, and three (37.5%) corals perished for unknown reasons, and the remaining two (25%) fragments were missing from the culture table.
In the Mithapur reef, four (40%) stressed corals perished after few days of transplantation. One coral was missing from the table and five (50%) of coral fragments perished after six months of survival.

The sea surface temperature was continuously monitored at GoK (Fig 4). It revealed that the temperature had increased gradually up to 31 degrees Celsius between June and July 2012, followed by a gradual decrease from mid-July onwards, which could be the cause for Laku coral fragments perishing, but surprisingly the Mithapur corals survived. But later, an unusual SST rise during last week of August 2012 was noticed, which might have initiated the degradation of the transplanted coral fragments at Mithapur reef. The resident corals of the reef like *Favia, Favites* and *Porites sp*. (Plate 29) were also found to be affected severely, leading to coral bleaching. Additionally in the months of May, June, July, August and September the turbidity increased, reducing the water visibility to almost zero.

Post-monsoon monitoring revealed that none of the coral fragments survived. Many speculations have arisen on the cause of death of the transplanted corals, including heavy sediment load.

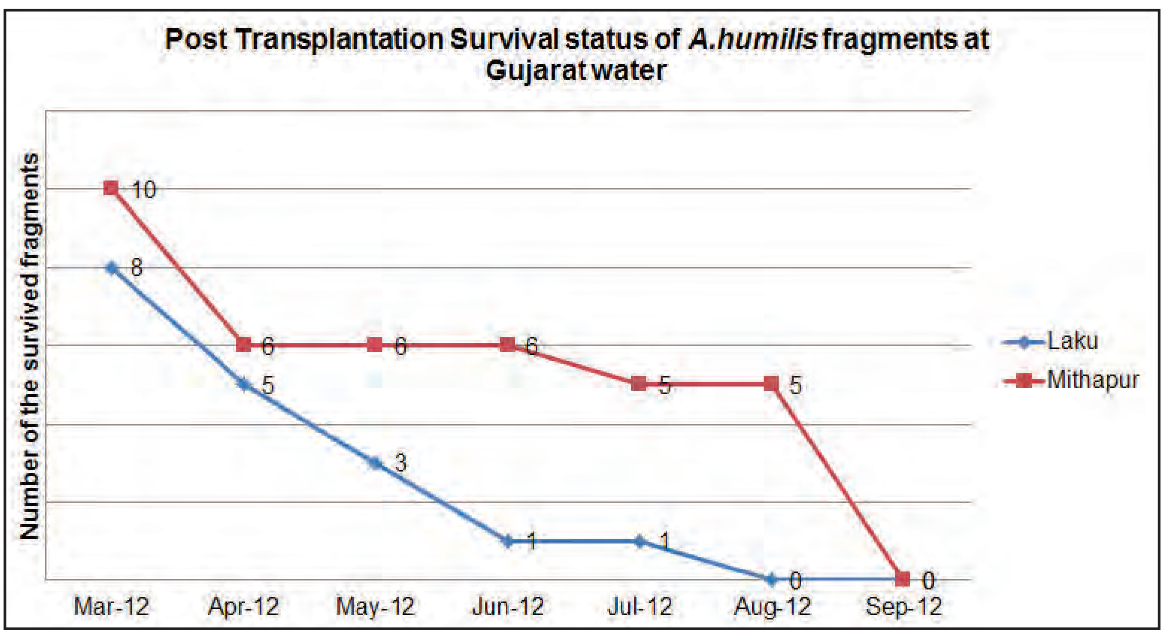


Fig. 11: Post transplantation survival status of *A.humilis* fragments at Mithapur and Laku reefs

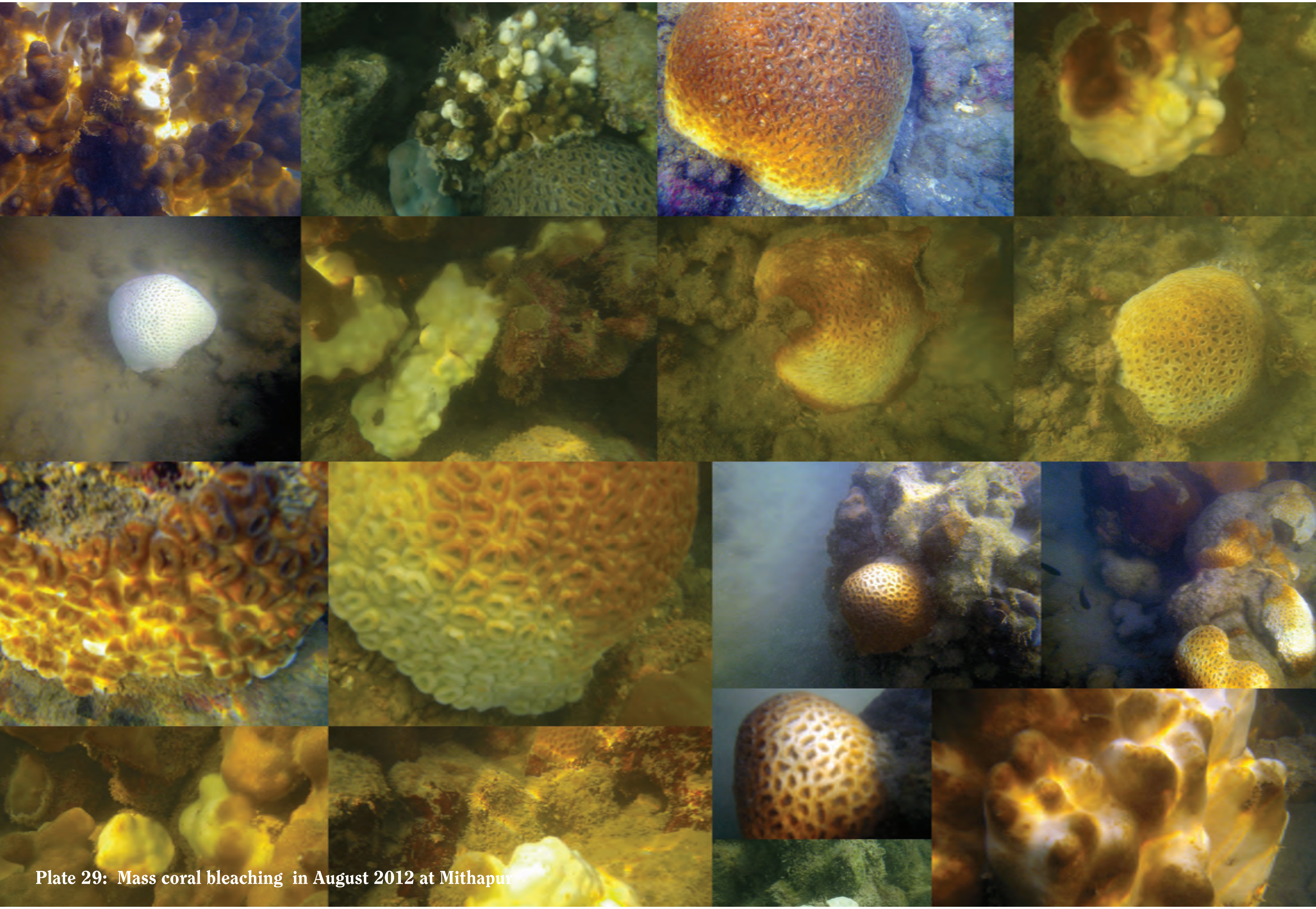


Plate 29: Mass coral bleaching in August 2012 at Mithapur

Team involved in coral restoration activities

3.6. Second coral transportation from Lakshadweep to Gujarat

The second experimental transportation and transplantation in the GoK–MNP was proposed from October-November 2012. The rationale for the second experiment was to understand how well the coral fragments established in the Agatti wild nursery respond to transportation trauma, as well as how they would survive in the GoK–MNP from November 2012 to September 2013. The assumption was that the 11-month-old Agatti wild nursery-grown fragments (Fig. 13) would have a greater resilience for transport trauma, and would get an adaptation time of over 9 months of clear water in the GoK–MNP. With the permission from CWLW Lakshadweep, WTI set in motion Phase II of the transport and transplantation experiment in October 2012. During the 3rd week of October 2012, the coral fragments growing in Agatti lagoon were monitored and it was gratifying to see that almost 78 fragments had established well, albeit with some overgrowth of algae and other debris, which were cleaned (Plate 30).

It was also observed that some Ascidians and other local reef species had invaded them. WTI considered that it would be unethical to take fragments with local species to Gujarat, as it was not sure if some of the species that had invaded were locally present in GoK–MNP or not. The decided to clean at least 50 fragments of the invaders, before transporting them out of Lakshadweep, which was done during the last week of October 2012. The transportation date was fixed for 2nd December, 2012 to take advantage of the vessel service from Agatti to Cochin. It was also decided to shift two to three fragments with their substrate base in 50 litre water container specially fitted with an additional pre-fabricated cement base to fasten the fragments. The base was fabricated using cement and local coral sand, and cured with fresh sea water for 3 - 4 days.

On 1st December, 2012, 48 fragments were taken into the transport container and the standard protocol of aeration was carried out. On 2nd December, 2012 the heavy transport container were shifted to the Agatti-Cochin ship around 0800hrs, under choppy sea conditions, which posed both difficulty and some amount of shifting trauma. On reaching Cochin, the transport container had to face another round of handling by the porters, and inspection by wildlife officials of the Kerala Forest Department for certification. The transport container had to be taken out of the harbour before they were exposed to sunlight. By late afternoon, container containing the coral fragments emitted a fishy smell, and the fragments were showing signs of bleaching.

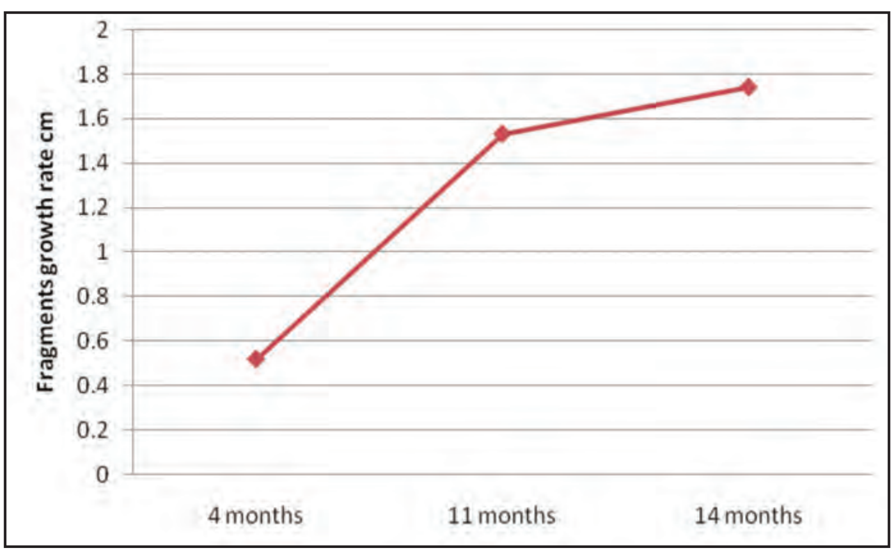


Fig 12: Overall growth rates patterns of *A. humilis* fragments (in height) at Lakshadweep

Plate 30: Corals at the nursary in Lakshadweep as on Nov 2012 (left) and the fragments being cleaned for debris (right)

It was decided to take the transport container in an air-conditioned transport vehicle along the west coast highway close to the Arabian Sea, keep the vehicle stationary to allow the fragments to settle down with aeration, and expose them to artificial light. On the morning of 3rd December, the transport container was exposed to sunlight and aeration. However, the fragments continued to deteriorate. The cause of the sudden bleaching of fragments despite following the procedure and protocols of the first transportation baffled the team and then they examined what could have gone wrong. By the afternoon of 4th December, with great regret the transportation was called off as the fragments appeared to be completely listless. The possible causes of the fragments' death during the second transportation could have been due to the following reasons:

1. Although the invading associated species with the coral fragments were incised and cleaned off, there still remained some bits of dead tissue which started decaying in the transport container, which exerted a stress on the coral fragments and may have led to their bleaching.

2. The transport container had faced considerable amount of shifting trauma in the Agatti lagoon, during shifting to the vessel, and again during shifting in Cochin harbour.

3. The bases used to stabilise the container and to fasten the fragments were prepared out of coral sand and cement, which were probably under-cured, and may have released gypsum and carbon dioxide in the container, forcing the coral fragments to be stressed.

> **Despite following the protocol, the coral fragments died during the second experimental tranportation and the excercise had to be called off**

However, 32 fragments were still in Agatti lagoons, which were over two and half years old. The cultured coral fragments have by now developed into branched colonies. Initially, they were placed on a table in a sandy area where natural coral settlement was not possible. This local transplantation (in Agatti Lagoon) itself has served as a reef conservation activity.

3.7. Lesson learnt from coral transplantation

Acropora corals are highly sensitive to stress caused by environmental and climatic changes, pollution and anthropogenic pressures. Therefore, if they are to be transplanted from Lakshadweep to Gujarat (highly turbid) waters, they need to have the capacity to tolerate and survive in a new habitat before adapting to it. Only healthy corals, without any stress, bleaching, disease or transportation trauma, are likely to survive and persist.

The new protocols were specifically developed to reduce stress, provide support and absorb shock during transportation. Aeration and light proved to be very important (wet method) to maintain the health and to reduce transportation stress. If there was any deterioration in the physico-chemical parameters (mostly heat), or heavy shock or stress, or poor aeration, a fleshy smell was observed to emanate from the water containing the fragments. It is believed that zooxanthallae are released from the corals and mix with waters, causing the smell. When continuous aeration was provided, the fleshy smell was found to slowly reduce, and the corals turned healthier. If the degraded smell persisted, it usually resulted in the coral's death. Based on observations, the degraded smell follows the fleshy odour. If the fleshy smell disappears, the corals tend to survive.

A long distance transportation protocol for corals has been prepared as part of the project. The experimental transportation showed that corals could be transported at a relatively low cost

Continuous monitoring of the transplanted corals at Mithapur and Laku Island showed that the transplanted *Acropora humilis* fragments were in a healthy condition in both areas. The coral polyps were also in a good condition, but the stressed corals were disturbed and a few corals died, possibly due to sedimentation, heavy current movement, and anthropogenic disturbances. The experimental transportation showed that corals could be transported at relatively low cost following a revised method. A long-distance transportation protocol for corals has been prepared under the project.

CHAPTER 4

Artificial Reef Building at Mithapur Reef

Artificial reefs are providing suitable substrates for coral development even in barren areas

Coral reefs play an important physiological and ecological role in coastal ecosystems, acting as natural breakwaters and improving marine health (Barber, 2009, Riedmiller *et al.* 2001). About 400 metric tons of corals are removed daily from the wild throughout the world for commercial trade (Bowden and Kerby, 1999). Moreover, anthropogenic and natural pressures affect coral health, often degrading them into rubble (Harris, 2009). The rubbles are dynamic, and can be easily shifted and moved by currents and waves, effectively forming "killing fields" for coral juveniles, and hindering coral recovery (Edward, 2010). After sexual reproduction, if coral larvae settle down on those rubbles, they would not survive, and further reef development would be affected (Winstanley, 2008).

Artificial reef building technique is one of the tools of restoration, which provides a suitable and stable substrate for reef ecosystem development (Yip, 1998). In most areas, artificial reefs are created as breakwaters to stabilise beaches and minimise adverse impacts on adjacent beaches, particularly in harbours and jetties. (Harris, 2009). They mimic a natural reef for some marine benthic animals also. However, most of the coral reef restoration activities are focused on repairing damage, and potential recruitment of coral larvae (Bowden and Kerby, 1999). Globally, more than 40 countries use artificial reefs for various purposes, especially recreational purposes. A few regions of Africa, Asia and Europe; and some countries such as Japan, Korea and the Philippines have developed artificial reefs for commercial purposes, as fish aggregating devices (FAD) (Woods, 1999).

In, India, the CMFRI developed artificial reefs as artificial fish habitats in the early 2000s in Chennai in south India. The Kerala government constructed a 500 metre long artificial reef wall at Kovalam coast for recreation. This project chose to create an artificial reef at Mithapur, which is the first of its kind to be deployed along the India's Gujarat coast. Its main purpose is to assist in the establishment of a new coral ecosystem to replace those that have been lost or become extinct locally.

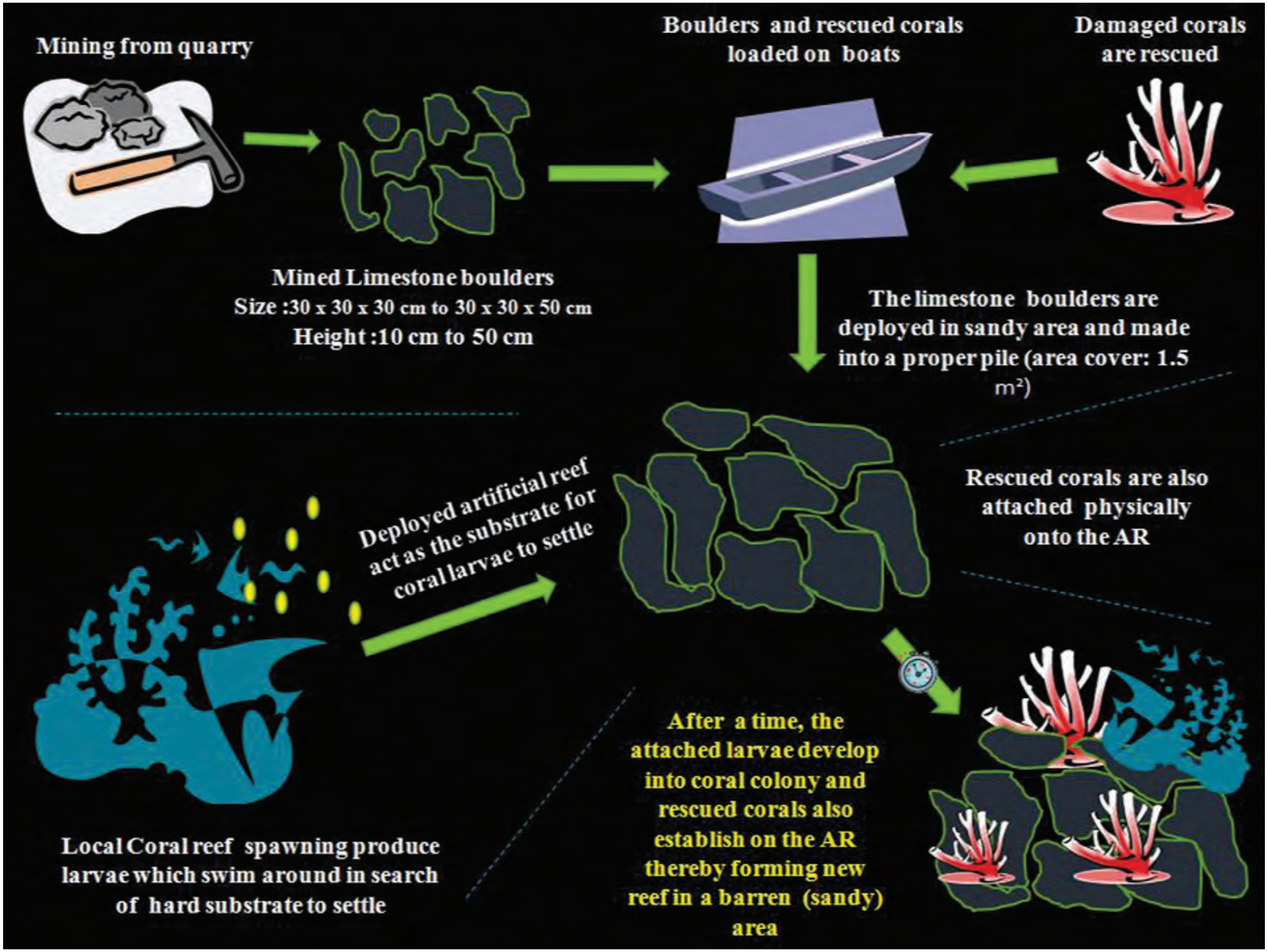


Plate 30: A pictorial representation of the process involved in creation of artificial reefs

4.1 Materials and methods

Mithapur's platform reef region has four tidal pools. The front reef is located approximately 1.5 km from the shore. Beyond the front reef, the bottom is muddy and has heavy currents. The tidal pools on the reef flat are 1–3 metres deep, and water movement through the channels is calm, compared to the front reef. The tidal pools and channels with their sandy bottom are suitable for artificial reef deployment. The deployment sites were selected on the basis of hydrological and biological factors.

Artificial substrates were selected based on the "Material Opportunity Concept" (Barber, 2009), for Mithapur reef restoration activities (Plate 30).

1. **Choosing bottom substrate –** bottom should be sandy, not on the rock/ reef.

2. **Avoidance of a biologically sensitive site –** The bottom was investigated before deployment, to avoid sea grass beds, and non-moving faunal habitats like corals, sponges, tunicates, and other kinds of faunas; and locate a site close to live corals areas.

3. **Movement of currents –** Low current movements provide a good supply of larvae and juveniles. Good colony development is not possible or gets delayed due to strong current movements (Mathews, 1981).

4. **Wave actions –** Strong wave actions damage the artificial reef structures and, therefore, the site must be protected from waves.

5. **Depth –** An artificial reef should be submerged even during low tide, since corals grow and survive up to the water mark level only.

6. **Monitoring –** It should be feasible to regularly monitor the chosen sites.

Based on these criteria, the artificial reef sites were identified after snorkeling and SCUBA surveys. After choosing the locations, the sites were marked using a GPS unit.

Globally, most artificial substrates are made using land-based materials such as reef balls, eco-reefs, wood, steel, concrete and tyres. In some countries, materials such as volcanic rocks, coral rocks, and limestone boulders, depending on their local availability, are used.

Mithapur and its surrounding areas do not have volcanic rocks, but limestone rocks are available abundantly. Limestone is a sedimentary rock that is composed of calcium carbonate (CaCO3). It is cheap, eco–friendly, extremely stable in sea water, and similar to the rocks found in the Mithapur reef front. The limestone was obtained from the nearby quarry of Tata Chemicals Ltd. Irregular limestone boulders were chosen for deployment. Limestone provides rough surfaces suitable for coral larval recruitment, and other marine life easily attach to its surface, which eventually develops into a natural biological reef. Furthermore, there is no need to balance the pH or leach chemicals, compared to other man–made materials, and there is no threat to the reef ecosystem.

Limestone boulders, roughly 1-2 cubic feet in size, were carried from a quarry to the Mithapur beach, and dumped on the shore. The boulders were carefully chosen based on size (30 x 30 x 30 cubic cm to 30 x 30 x 50 cubic cm and weighing a minimum of 5 kg), and were carried by motor boats to the site for deployment. 20 to 25 boulders (Plate 31). were deployed at each site. After using scuba diving deployment, they were piled one over the other, with an average surface cover of 1.5 sq metres, The boulders were tightly packed to ensure that they did not get washed away during any increased tidal actions.

4.2 Results

Ten sites were selected (Map 4) to deploy limestone boulders hnear different species of corals that were dominant at the sites. Artificial reef site (ARS), 1, 3, 6 and 8 had an average depth of 1 metre each, while ARS 2, 5, 7, 9 and10 had an average depth of 2 metres each, and ARS 4 was 3 metres-deep. The depths were measured

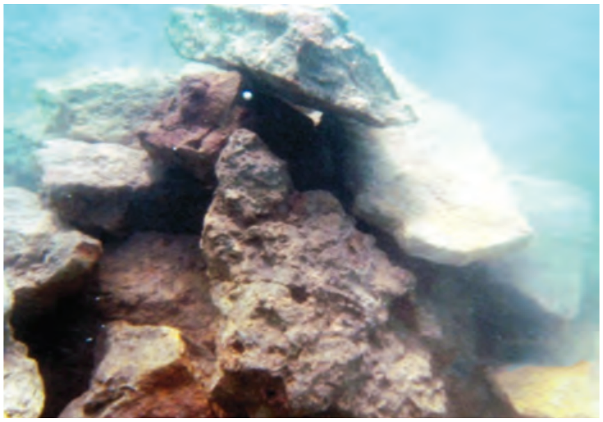


Plate 31: A tightly packed artificial reef

during low tide such that artificial reefs are submerged even during the lowest low tide, to ensure protection of their life forms. *Favia sp*. corals were dominant near the ARS – 1, 3, 8 and 10 and *Porites sp.* were dominant near the ARS 2, 4 and 9. Likewise *Goniopora* sp. was dominant near ARS 5, and *Symphyllia* sp. near ARS 7.

Monitoring surveys showed new coral juveniles a year after deploying artificial reefs

A year later (in April 2012) monitoring surveys of ARs revealed new coral juveniles at four sites. *Favia*, *Favites* and *Montipora* species

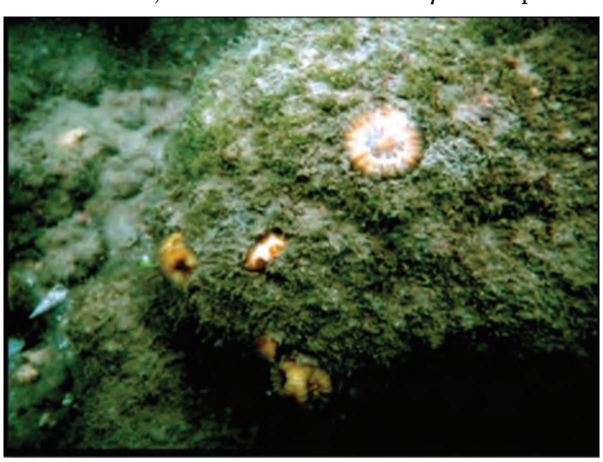


Plate 32: Photo of a coral settled on artificial reef at Mithapur reef

were recorded (Plate 32) on the artificial reefs. Artificial reefs were created in Mithapur for reef habitat enhancement, as well as increasing the associated faunal potentials. In Mithapur, artificial substrates were placed adjacent to the existing coral species, so that the tentative coral spawning season may be identified through regular monitoring, and new coral recruitment on the AR is made easier. All the substrates were carefully chosen to ensure that in future, they could be transplanted to barren areas. It is an easier method than the coral fragments transplantation technique, and will help enhance fishery resources as well. South Korea reported that fish catching efficiency increased by four times after artificial reefs were developed (Vivekanandan *et al*. 2005). So, initiation of the Mithapur artificial reef can be considered as one of the milestone events of coral reef restoration activities of Wildlife Trust of India, Gujarat Forest Department and Tata Chemicals Ltd.

The Mithapur artificial reef building is one of the milestones in coral restoration activities of WTI, Gujarat Forest Department and TCL

4. 3 Artificial Reef deployment: Phase II

Another batch of twenty two artificial reefs were deployed at Mithapur and Laku, in a two-day programme, with participation and support from the Indian Navy, Coast Guard, Zoological Survey of India, Tata eco-club volunteers and the local fishermen (see Chapter 5).

4.4 Future plans

The following activities should be carried out in future at Mithapur reef:

1. Regular oceanographic and biological monitoring (using quadrate method – 1 metre) at the artificial reef site.
2. Identification of suitable barren areas in Mithapur reef for creating artificial reefs and transplanting corals.

3. Re-location of suitable artificial substrates, along with the corals, to the new sites.
4. Monitoring the relocated site along with the corals and associated faunal development.

However some practical difficulties need to be considered during monitoring:

1. User conflict – Local fishermen use reef for fishing, and this may disturb the artificial substrates.
2. Seasonal disturbances – Mithapur has five months (May to September) of zero visibility, when monitoring is impossible.
3. Long growth rates – Post larval settlement, coral growth is slow and requires patient monitoring
4. Small scale – Given the small size of the Mithapur reef, the number of suitable sites (based on site criteria) will also be small. Achieving a considerable level of coral growth on the substrate will take more than 1-2 years.

Map 4: Artificial reef deployed sites

CHAPTER 5

Community Participation in Coral Restoration Activities

Physical restoration is an effort to repair the reef environment with an engineering focus (Edward and Gomoz, 2007). Minor reef repair and emergency triages are important for active physical restoration. Upturned corals, uprooted corals, and corals damaged by boat anchoring are a major cause of physical damage on the Mithapur coral reef. As per the concept of "pre- and post-impact control", WTI initiated passive restoration activities like coral rescue programme, artificial reef building programme, beach clean up programme in participation with local community, school children and other stake holders, along with active restoration. Local Mithapur communities and fishermen were also engaged in reef restoration activities.

5.1 Coral rescue programme

For the first time in India, WTI initiated a "Coral Rescue Programme" at the Mithapur reef and rescued more than 200 corals

For the first time in India, WTI initated "Coral Rescue Programme" at Mithapur reef in February 2011, supported by coral rescue team members (Plate 33).

The team included volunteers from Tata Chemicals Limited (TCL), local fishing communities, Gujarat Forest Department staff, and WTI rescue team. Three coral rescue programmes were conducted in the Mithapur reef in February and May 2011, and July 2012. During low tide, the team members rescued upturned corals and placed them in the correct position in suitable places. The physical restoration activities helped create an awareness on corals and coral reefs among the local people. The five rescue exercises helped rescue about 229 upturned and disturbed coral substances.

5.2 Participation in artificial reef building programme

Following the successful experiments on the artificial reef building at Mithapur it was extended to other reefs of GoK. The director of MNP at Jamnagar expressed his willingness to conduct a program at Laku. A two-day event was organised to deploy artificial reefs at Laku and Mithapur respectively. The Laku event (Plate 34) was spear-headed by MNP authorities, while the Mithapur (Plate 35) event was initiated by WTI.

Plate 33: First Coral Rescue Team, from left: Subburaman, Avinash, Satish Trivedi, Pandiya, Rajive Dave, Siddique Adam, Hameed.

Plate 34: Team involved in the artifiical reef building at Laku

Plate 35: Team involved in the artificial reef building program at Mithapur

A total of 22 artificial reefs were deployed during the two day programme on April 27-28 2013, with the participation and support from the Indian Navy, Coast Guard, Zoological Survey of India, Tata eco-club volunteers and local fishermen. Over 120 people were involved in the event. An additional rescue operation was also conducted along with this programme.

The participants were divided into two teams. One team was involved in coral rescue operations and the other team was developed artificial reef. The coral rescue team collected the damaged corals which were taken and placed on the artificial reefs, giving them a better chance of survival and re-growth (Plate 36). An area of 110 cubic metres has been restored in the two regions. More such activities have been planned in the future.

Plate 36: Rescued coral placed on deployed artificial reef

5.3 Beach clean-up

Wildlife Trust of India initiated a beach cleaning programme at Mithapur, along with Tata Chemicals Limited DAV Public School. Both students and teachers actively participated in beach cleaning (Plate 37). The opportunity was used to educate students about the importance of coral reefs and the need to conserve them. More than 200 kg of plastic materials (ghost fishing nets, plastic bags, ropes and household materials) were collected from a 100-sq.-metre area in the Mithapur beach head. The collected garbage was sent to a recycling facility.

Plate 37: School children and staff participated in the beach cleaning programme

CHAPTER 6

Coral Spawning and Monitoring at Gujarat and Lakshadweep

Mass coral spawning was seen at Mithapur (2012) and Lakshadweep (2013)

Coral reefs are one of the most important and complex ecosystems in the sea world, and support over 25% of all marine life. Corals create reefs through asexual and sexual methods. The asexual method can be described as multiplication of existing polyps of individual coral development or fragmentation to form new colonies which are genetic clones of the old colonies. But the sexual reproduction method increases the biodiversity, with contribution to a gene pool in a single reef. During sexual reproduction corals spawn either as 'broadcasters' or 'brooders'. The coral spawning is synchronous and happens once, or rarely, a few times, in a year. The release of gametes by billions of live polyps from different corals in a reef at the same time is called "mass coral spawning" or "multi specific synchronous spawning". It is triggered by environmental factors and resembles an "oil slick" on the sea water surface. After a few days, the fertilised eggs develop into planula larva, which settle, attach to a suitable substratum, and metamorphose into coral polyps.

The first record of mass coral spawning was observed in the Indian Ocean, on March 1984, after the 8th and 9th nights of full moon (Simpson, 1985). Later, coral spawning patterns and seasons were observed in various locations, such as the Great Barrier Reef, (Harrison *et al*. 1984), Taiwan (Chiau, 2005., Dai, *et al.* 1992) Japan, (Heyward, 1987), Singapore (Guest *et al.* 2002), Philippines (Bermas, 1992), Gulf of Mexico (Hagmen *et al.* 1998), the Solomon Islands (Baird *et al.* 2001), the Central Pacific (Richmond and Hunter, 1990) and the Maldives (Loch, 1998). In India, coral spawning has been reported earlier at Gulf of Mannar–Southeast coast of India (Raj and Edward, 2010). The purple and white colour slicks (Plate 38) were drifting in the currents on the surface of the water extended over a 2 km area and under water observation (Plate 39) also confirmed coral spawning at Mithapur reef. Globally, coral spawning events were recorded on 2nd to 3rd days, 4th to 6th day, 8th to 9th day, after the full moon, and they have also been reported around the new moon day. According to Hoppe (2010), the intensity of moonlight triggers coral spawning event. The Mithapur reef's sea water temperature data showed that the SST gradually increased from 27.007°C to 28.3005°C between 23rd April and May 4th, 2013. According to Raj and Edward (2010), sea water temperature rise plays a major role in coral spawning. However, it fell from 27.9° C to 27.4° C from 05 May to 07 May, 2012 (Fig. 13). Nosratpour (2008) stated that significant sea water temperature fluctuations may also induce coral spawning.

In March 2013, the team observed another coral spawning slicks in Lakshadweep. This was observed both during underwater observations at Agatti, Bangaram (Plate 40) and Thinakara islands as well as aerial observation at Kavaratti island. These two observations on mass coral spawning event at Gujarat and Lakshadweep revealed that corals are still surviving in healthy condition and there they are generating new colonies at both habitats.

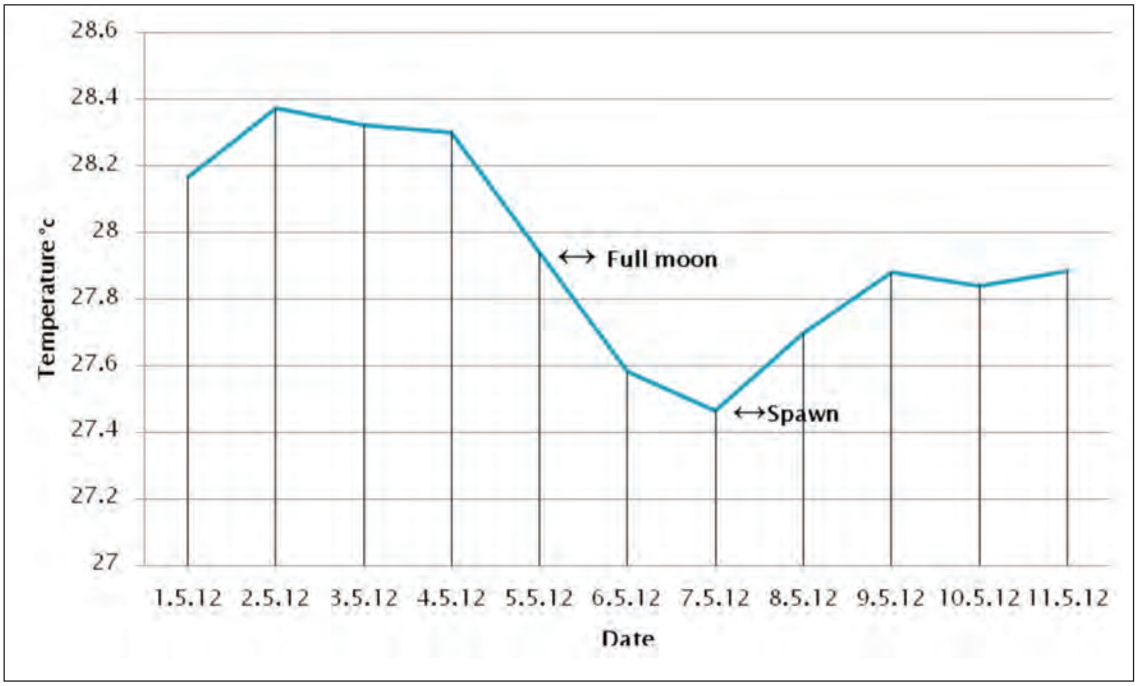


Fig 13: Sea surface temperature fluctuation between full moon and the day of spawning in Mithapur

Plate 38: Mass coral spawning slicks at Mithapur reef

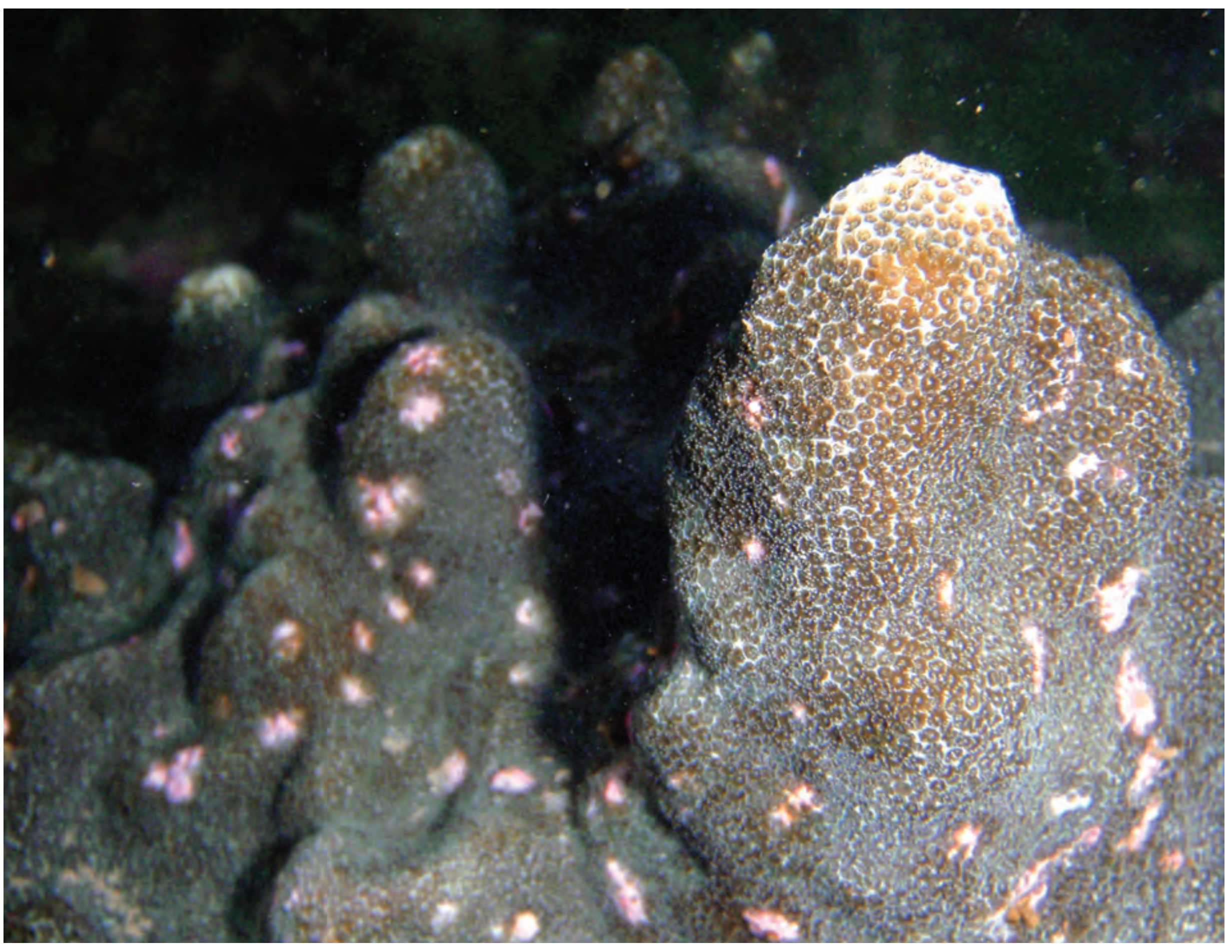


Plate 39: Underwater observation– Coral spawning – *Porites* sp., at Mithapur reef

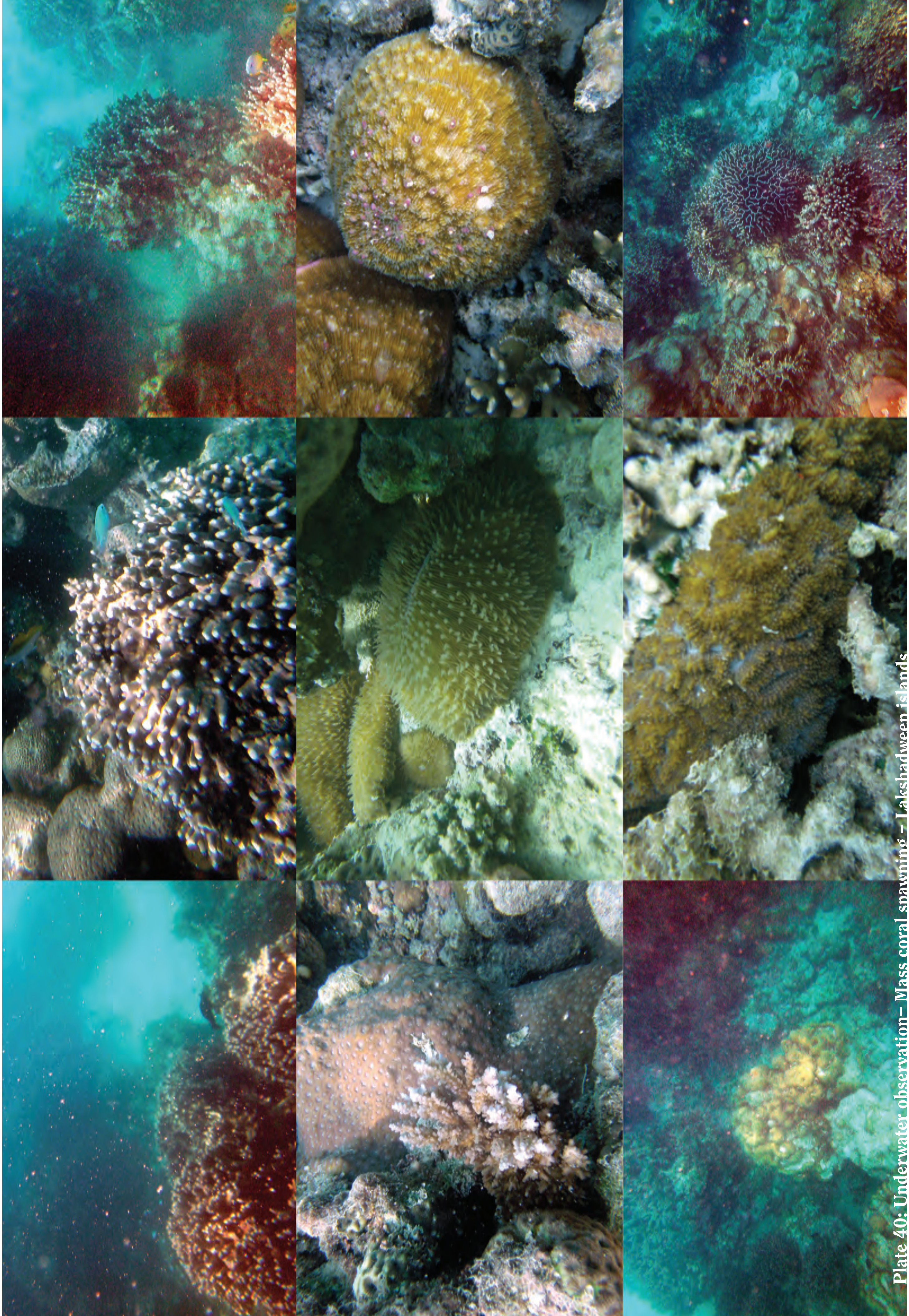


Plate 40: Underwater observation– Mass coral spawning – Lakshadweep islands

CHAPTER 7

Future Plan: Mithapur Reef Recovery

The following activities are planned for the future recovery of the Mithapur reef.

7.1. Continuation of experimental *Acropora* coral transplantation from Lakshadweep to Gujarat

A total 100 of *A.humilis* fragments were harvested and cultured at Agatti lagoon. Of these 70 fragments were transplanted from Lakshadweep during the first and second transplantation. The rest of the fragments are under monitoring at Lakshadweep and will be transplanted to Gujarat waters in future (Plate 41).

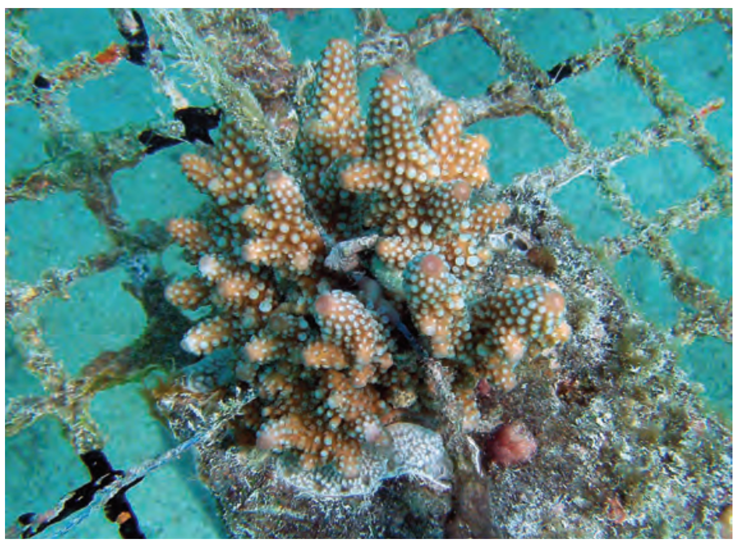


Plate 41: *A.humilis at Lakshadweep waters*

7.2. Coral rescue and rehabilitation in Mithapur reef

Heavy currents and anthropogenic activities like boat anchoring, pole propelled boats etc, create a lot of rubble on the reef which gets exposed to the neap tide. Some corals are also found attached to rubble. The mobile rubble fields create unstable coral colonies and have emerged as a 'killing field' for corals (Edward and Gomez, 2007). Unstable live corals, damaged corals, overturned and uprooted corals (Plate 42) would be targeted for rescue and rehabilitation into deep areas. Species like *Porites sp., Favia sp., and Favites sp* would be the primary targets for new recruites. Young coral that may get attached to the rubble needs to be placed in the right place for it to survive.

Plate 42: Unstable live coral

7.3. Coral larvae rearing and *ex-situ* nursery centre

WTI has already identified the season of coral spawning for the western coast of India. Published scientific literature suggests that after spawning, most of the coral egg masses and larvae drift in the currents, and many perish due to lack of a suitable substrate for settlement, and predation. In order to address these issues, WTI plans to set up an *ex-situ* nursery for coral larvae rearing and culture. In this method, most of the drifting egg mass (Plate 43) will be collected from the wild after spawning, and cultured under controlled conditions for a specific period. After they successfully settle on the substrates and grow, the corals will be shifted to the wild. The method will help in mass-scale reef restoration without damaging the wild stock.

Plate 43: Coral spawning - egg mass

7.4. Coral Garden

A garden refers to a variety of species grown in a single area. Similarly, a coral garden refers to several coral species located in a single identified area. The concept of a 'coral garden' is fascinating an d is a recent trend in marine conservation activity across the globle.

The total length of Mithapur reef is approximately 10 km. The entire reef of Mithapur is a kind of fringing reef. The present restoration and recovery project area is about 2.99 km^2 and is a platform reef with a fringing reef for the reef frong. Within it is a 2.55 km^2 area of reef flats. The remaining 0.44 sq. km area has tidal pools and channels, which consist of sandy bottoms (Map 5).

Reef development (extension) is a slow process. Coral larvae attach only on a hard substrates, which do not get exposed during low tides. Even though Mithapur has a large rocky flats, it is frequently exposed during low tide, making them unsuitable for new coral recruitment. For a fringing reef, usually reef restoration activity is carried out at the front side (reef slope) of the reef only. Unfortunately in Mithapur, the reef front has very strong currents during high tide.

However, the present project area (within 3–2.55 km^2 area) has good tidal pools with low current movements and a suitable depth (less than 10 m during high tide). Seawater exchange occurs through the channels during high and low tides. The initial stage of restoration activities, such as coral culturing, is not possible in the reef front at Mithapur, but placing of the culture table, coral culturing and close monitoring are possible in the tidal pools. Outside the project boundaries, there are a few tidal pools but they are too far. The project area has a cluster of tidal pools. Coral growth from the larval stages to suitable transplantable size may take more than 2 to 3 years for certain species. Up to that time, corals need to be placed in nurseries. Therefore, continuing to culture various species of corals in the area and restoring the reef justifies the term "coral gardening". Depending on the nursery ground size, one can increase the number and size of coral species in each ground. After a certain period when the cultured corals reach transplantable size, they need to be transplanted to the degraded or front reef for further reef development, and to barren areas for new reef formation. The nursery area then should be replaced by a fresh stock of the same species, so that more areas can be restored in a continuous process.

Artificial reefs have been installed at 22 places to facilitate coral larval attachment and development. One can collect various species through natural settlements also. In this way, the reef productivity will be improved, serving as a nursery and breeding ground for various organisms. The project site is the best site of Mithapur reef for restoration activities, and can be aptly called a "coral garden" (Plate 44).

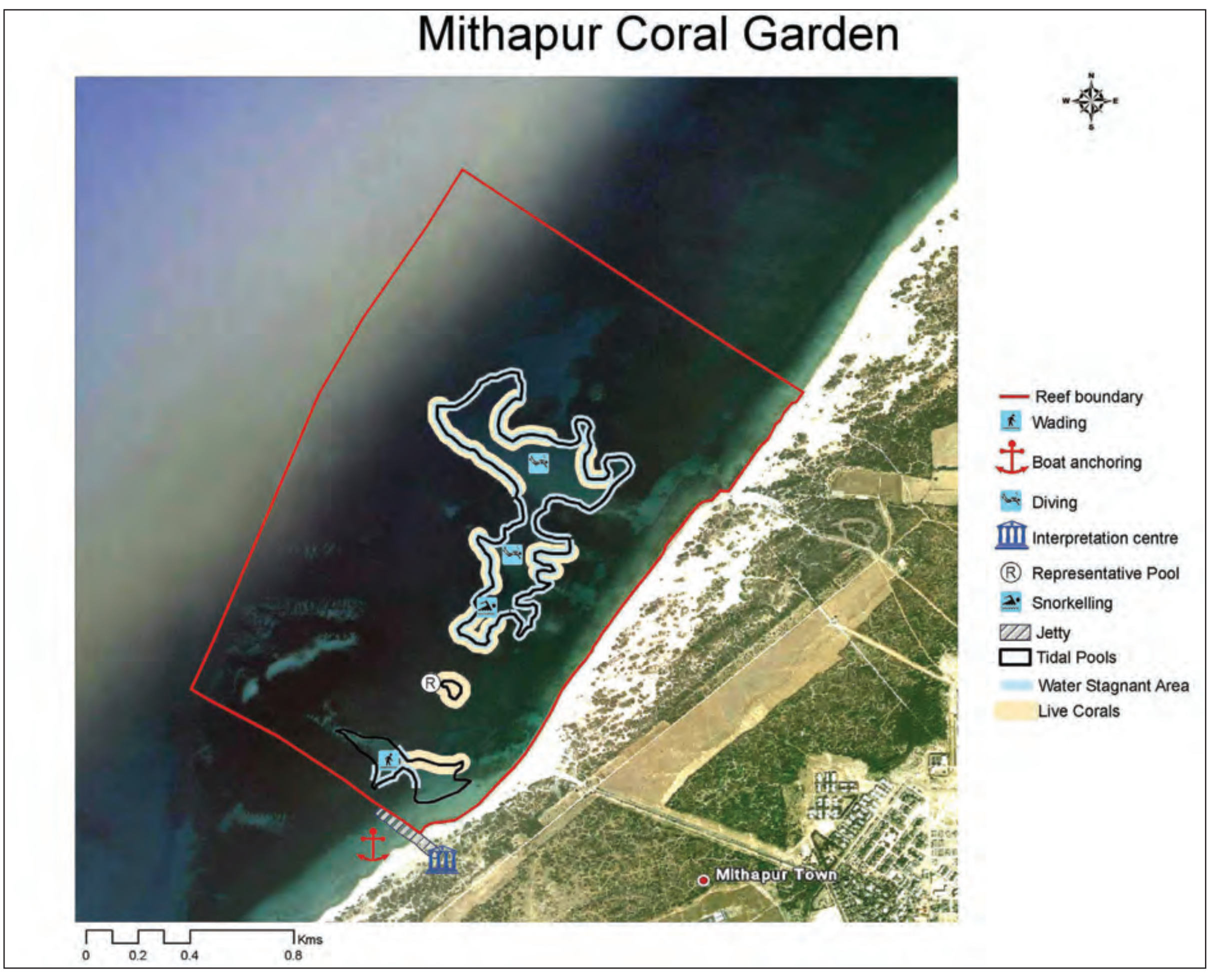
7.4.1. 'Coral Garden' of Mithapur

The 'coral garden' at Mithapur will be one of its kind. The reef will house nearly all coral species found in GoK. Just as in a terrestrial botanical park or garden, the reef will be separated into various sections, based on accessibility. The tidal pools are primarily targeted for the coral garden, as discussed earlier. Each pool will contain a variety of corals, and will give a special emphasis to the placement of different species (Map 5). It would be useful not only for education and tourism, but also restoration of the reef.

7.4.2. Advantage of Mithapur coral garden

There are two main benefits of a coral garden:

1. An opportunity to create the first coral garden in the country, which will have a major role in conservation by serving as the mother reef for new sites.



Map 5: A proposed plan of the 'Mithpur Coral Garden'

2. Controlled and regulated tourism and diving can be allowed near coral gardens, ultimately helping conservation awareness for the common people. Proper interpretation will play an additional role in fulfilling these objectives.

7.4.3 Components of the 'Mithapur Coral Garden'

a. Wading Area

It will be suitable for beach swimmers and non-swimmers who do not want to hire a boat; as well as for those who just want to enjoy a bath or swim, and wear underwater glasses to watch live animals from the safety of the beach-wading area.

Location: The southern boundary near the jetty, about 100 sq metre in size, has a large sandy flat bottom, and is only a metre deep, making it safe. Sometimes, rays frequent the area, making hand feeding possible. A tidal pool, 3 m deep, is located 100 m beyond. It is similar to the front reef in terrain, and houses corals present in the front reef; such as *Porites lutea* and *Porites lichen* which are dominant in the area. Reef associated fauna like fishes, crabs, etc. are found in abundance in this area.

b. Snorkeling Area

The snorkeling area is for good swimmers as it may sometimes have currents. Snorkelers have to hire a boat to get there.

Location: It overlaps with the diving area, and is a little deeper than the wading area. The depth ranges between 1 m and 6 m. The area will also double up as a nursery area. It has a large area with a path of a sandy bottom, where the coral nursery tables will be placed. Snorkelers will be able to see all steps of the restoration activity.

c. Diving Area

This area will be the core of the 'coral garden', and aims to provide divers a unique opportunity to see and learn about corals. It is the deepest and biggest pool in the area. This area will house all the coral species in different corners of the pool. It will also have underwater sign boards to let divers find their way through the garden. The coral species will have adjacent underwater explanatory info boards. All corals will be placed near the pool edges, so that divers can go around the entire pool to see all the species. The sandy patch/bottom area will contain nursery (tables) activity and another part will contain an 'artificial reef structure' and 'fish houses' which

Plate 44. A graphic module of the coral garden

will attract reef-associated organisms and also enhance natural settlements of coral larvae.

Location: The biggest pool in the Mithapur reef. It already has a good population of corals. The pool is located near the northern boundary. The depth ranges from 3-6m. It directly opens into the front ocean through a small channel and occasionally faces some currents..

d. Representative Pool Area

It will act as a template for the whole reef, and will contain all corals present in the reef in small concentrations. At low tide, people who cannot dive or snorkel can just walk and have a look.

Location: It is the smallest and shallowest among the pools in the project area, with a depth of 3 m between tides. Such areas are found sandwiched between the wading and snorkeling area. They already have a good concentration of corals.

e. Jetty

It will be located on the southern boundary, directly adjacent to the interpretation centre. The jetty will extend to about 50 m from the shore into the reef, and will house a glass bottom boat and dive boats.

f. Boat anchoring area

It is an area for anchoring fishing boats. It will be created outside the northern and southern boundaries of the project area, to ensure no disturbance in the garden area. Small mooring buoys can be installed to help anchor boats.

7.5. Interpretation Centre

Once the coral garden takes shape and the detailed information of the Mithapur reef is completely understood, an attempt will be made to gradually open up the Mithapur reef to students, local communities and other visitors to enhance their understanding and awareness of marine biodiversity. There are some ideas an establishing a modern, integrated in-situ and ex-situ interpretation facility that will benefit both swimmers and non-swimmers to experience the wonders of underwater marine biodiversity.

The interpretation centre needs to target the common public. Some extra collaterals need to be generated for students. (e.g. brochures, pamphlets, books, etc). The interpretation centre will contain different models of organisms and ecosystem.

7.5.1 Proposed components in the information centre (Plate 45)

a. Amphitheatre: An open-house theatre to show movies in case of special events.

b. Museum: With preserved animals, posters and banners of marine organisms from all over the Gujarat coast.

c. Library: A general library with a dedicated section for books on marine organisms of Gujarat.

d. Research Centre/ Lab: A research centre with a fully equipped lab which will help research on conservation of various reefs across Gujarat.

e. Camp Area: A small camping area for conducting nature camps and summer camps for school children could be provided.

f**. Scuba Diving Centre**: A diving centre for all dive related activities which can also be extended as a dive training centre.

g. Nature Trail: A trail with various signages giving the information on the Mithapur Reef leading to the jetty.

h. Aquarium: A small aquarium housing fishes in the reef and also some exotic fishes from other reefs across the country. Another live aquarium(Plate 46) could also be designed. Since Mithapur has man-made channels for salt pans, similar a channel could be dug near the interpretation centre, and an underground room with a glass window set up next to the channel, to provide an underwater view of the channel from the chamber. The existing channels can house nearly all the fishes in the reef, which could be seen from safety of the

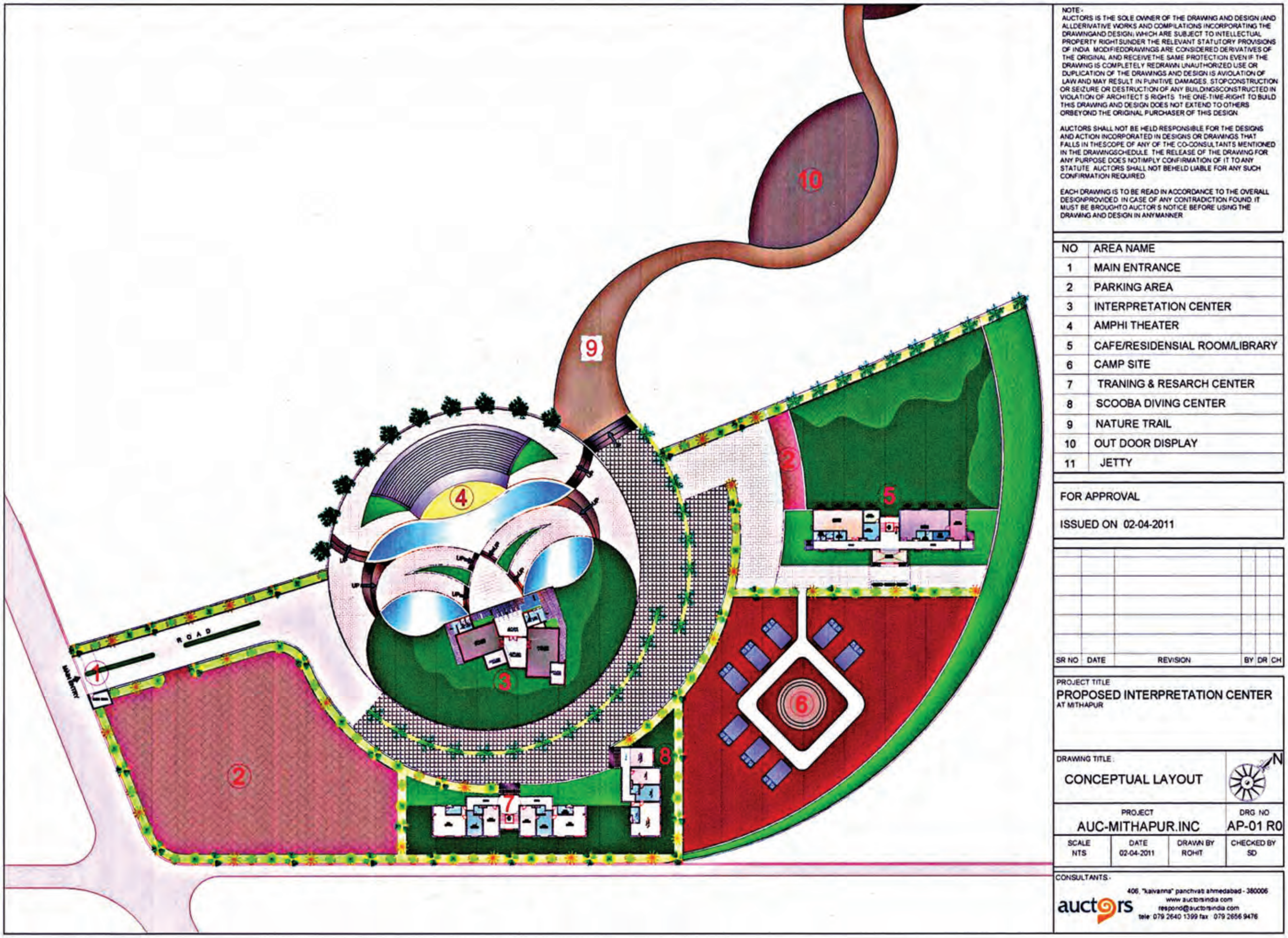


Plate 45: A conceptual plan of the proposed inpretation centre at Mithapur (courtesy: Auctors)

land. Adjacent to the glass, a small 'fish house' and 'fish aggregating device' could be deployed. . It would be maintenance-free, save the need to maintain the water level by check dams. Water exchange can be made continuous by connecting to the existing channels.

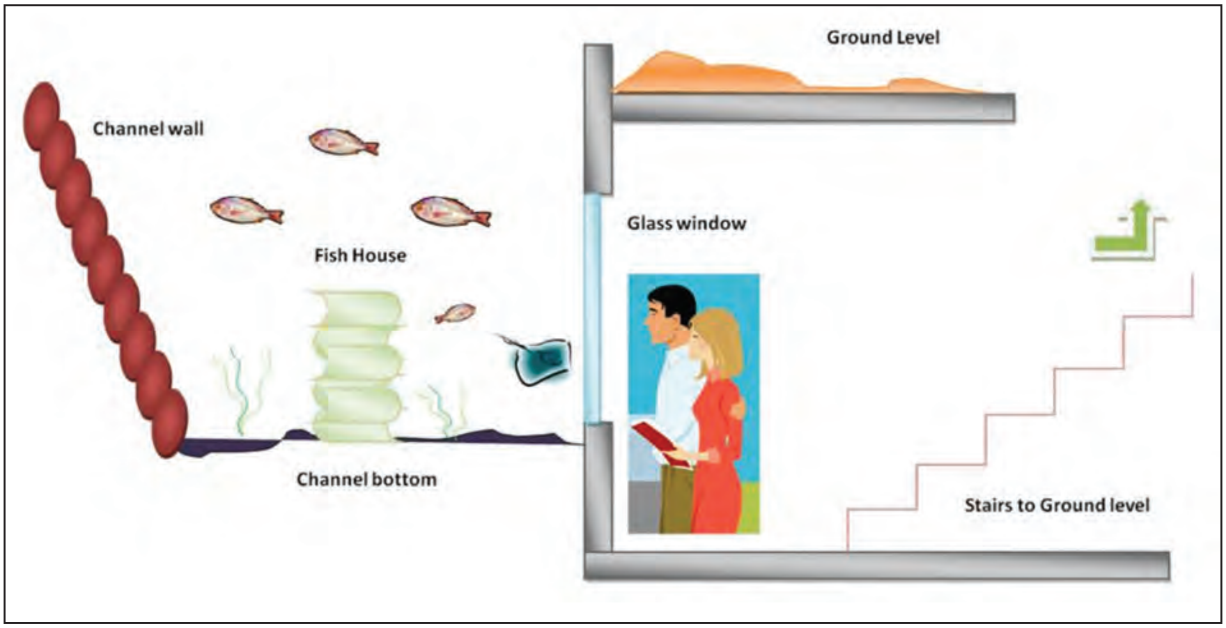


Plate 46. Suggested layout of an aquarium in the inpretation centre

Appendix

I. Diversity of Hard corals in Mithapur reef

Order : Scleractinia Bourne, 1905.
Suborder : Astrocoeniia Vaughan and Wells, 1943.
Family : ACROPORIDAE (Verrill, 1902)
Acroporidae family corals are colonial and hermatypic corals. Corallites (except Asteropora) are small with septa in two cycles or less, columellae are poorly developed. There are five species belonging to one genus recorded at the Mithapur reef.

1. *Montipora hispida* (Dana, 1846)

1846. *Montipora hispida* Dana, U.S. Exploring Expedition 1838-1842, 7: p.496.
Description: Columnar, encrusting, plate like or combination of these forms. Corallites both immersed and exert shape with conspicuous calices.
Habitat : All reef habitat.
Distribution: Widely distributed from Red Sea, Eastern Africa, Comoros,Chaogos Archipelago, Maldives, India, Sri Lanka, Myanmar, Thailand, Southeast India, South china sea, Japan, New Guinea, Australia, Solomon islands, Marshall Islands, Fiji, Cook Islands.In India is reported from Gulf of Kutch, and Gulf of Mannar.
Discussion: *M.hispida* commonly found in high turbid waters.

2. *Montipora monasteriata* (Forskal, 1775)

1775. Madrepora monasteriata Forskal, vermium que inintinere oriental observavit Petrus Forskal. IV Corallia. Hauniae. 131 – 9.
Description: Colonies are thick plate which may be uni-facial or bi-facial. Corallites mostly immersed. Elaborated spines composed with all papillae and tuberculae.
Habitat: Upper reef flats and reef slopes. Mostly found protected from strong wave action areas.
Distribution : Widely distributed from tropical and subtropical Indo–Pacific waters. In India, it is reported from Gulf of Kutch and Gulf of Mannar.
Remarks: This species is uncommon at Mithapur reef.

3. *Montipora foliosa* (Pallas, 1766)

1976. Montipora foliosa Pillai andScheer, Results of the Xarifa Expedition 1957/58. Zoologica (stuttg.) 43 (126), 1- 83, pl. 1-32.
Description: Mostly plate or encrusting forms, sometimes forming tiers or whorls. Corallites are arranged in rows between coenostum ridges.
Habitat: Reef flats, Reef slopes.
Distribution: Widely distributed from Red Sea to Fiji islands. In India is reported from Gulf of Kutch, Gulf of Mannar, Andaman and Nicobar Islands and Lakshadweep.
Remarks:This species is uncommon at Mithapur reef.

4. *Montipora turgescens* (Bernard, 1897)

1974. ***Montipora turgescens*** Scheer and Pillai, Report on Scleractinia from the Nicobar Islands. Zoologica (Stusttg.) 42 , 1-75, pl. 1-33.
Description: Colonies are sub-massive, massive or hemispherical. Corallites are immeresed and uniformly distributed on and between monds. Living corals usually cream, pale green or brown in colour.
Habitat: All reef habitats.
Distribution: Widely distributed from Red Sea to East China sea, and in India it is reported from the Gulf of Kutch, Gulf of mannar, Andaman and Nicobar waters.
Remarks: This is a common species at Mithapur reef.

5. *Montipora venosa* (Ehrenberg, 1834)

1982. *Montipora venosa* Veron, hermatypic scleractinia of Hong Kong-an annotated list of species. In Morten, B.R. (Ed). Proceedings of the first international workshop on the marine flora and fauna of Hong Kong.
Description: Colonies are sub-massive, massive forms. Corallites are a mixture, some slightly exert. Tuberculae and papillae are absent.
Habitat: All reef habitats.
Distribution: Red Sea, Gulf of Aden, Arabian Sea, Indian and Pacific oceans, Japan, Australia, East China sea, to Marianas. In India, it is reported from Gulf of Kutch and Gulf of Mannar.
Remarks: This species is mostly common at Mithapur reef.

Family: **SIDERASTREIDAE**

Corals of this family are mostly extant, colonial and hermatypic corals. Colonies are massive or columnar. Very small corallites which, under magnification, can be seen to be crowded with septae. They have granulated upper margins and are closely compacted and evenly spaced. Totally, three species Siderastrea savignyana, Cosinaraea monile and Pseudosiderastrea tayami were recorded at Mithapur reef.

6 . ***Siderastrea savignyana*** (Edwards and Haime, 1850).

1850. *Siderastrea savignyana* Edwards and Haime, recherché sur les polypiers. Mem. 4 monographie des Astreides, Ann, Sci, Nat.Zool, 3e.Ser., 13, 63-110, pl 3-4.
Description: Colonies are encrusting to massive. Corallites polygonal 2-4 mm diameter. Septa are neatly arranged. Fusing in neat fan-like groups. Walls have a fine ridge along the top.
Habitat: Shallow reef environments or sandy lagoons. Colonies are often partly buried in sand.
Distribution: Worldwide – It is reported from Red Sea to Coral Sea. In India – It is reported only from Gulf of Kutch.
Remarks; It is very similar to the *Pseudosiderastrea tayami* which has a similar growth form but septa have saw-like teeth. Mostly found on shallow reef environments or sandy lagoons.

7. ***Cosinaraea monile*** (Forskal, 1775).

1907, *Cosinaraea monile* Marenzeller Riffkorallen. Expeditionen S.M.Schiffpola in das Rote Meer.Zool.Ergeb.XXV tiefseekorallen, 13-27, pl, 1-2, Riffkorallen, 27-97, pl, 1-29, Denkschr. Akad,Wiss,XXVL,Wien 80.
Description: Colonies encrusting or dome-shaped, calices 6-8 mm in diameter, about 2mm deep, often 2 to 3 calicinal centres run together to form short valleys. Intercorallite walls poorly developed. Septa are even and finely serrated giving colonies a smooth appearance. Axial fossa circular and with a papilliform columella.
Habitat: Shallow reef environment.
Distribution: Widely distributed from Red Sea to Mergui Archipelago and Indian Ocean. In India it is reported from Gulf of Kutch and Gulf of Mannar.
Remarks: This is the only species was reported from India out of eight species of cosinaraea genus. It little bit confused with Pseudisiderastrea and Psammocora.

8. *Pseudosiderastrea tayami* (Yabe and Sugiyama, 1935)

1935. *Pseudosiderastea tayami* Yabe and Sugiyama, Proc.Jpn.Acad., 11 (9) : 378 -8, 2
1956. *Anomastraea (pseudosiderastrea) tayami* Wells, J.W. Scleractinia, in Moore, R.C. 'Treatise on Invertebrate palaeontology'. Coelenterata. Univ. Kansas press, F., F328-F440.
Description: Colonies are massive to encrusting forms. Corallites are cerioid, polygonal shape. Septa are evenly spaced and usually fuse with each other in fan – like groups. They have fine, saw-like teeth. Columellae consist of one to four pinnules.
Habitat: All shallow reef habitats.
Distribution: Western Indian Ocean to Australia. In India is reported from Gulf of Kutch, Gulf of Mannar, Andaman and Nicobar Islands.
Remarks: This specie is rarely observed at the Mithapur reef.

Family : PORITIDAE

Highly variable colony structure like flat, encrusting, boulder-like or branching forms. Colonies have numerous round corallites, which are close together that are filled with septa, and have a porous fine structure. This is 2nd major family in the Mithapur and supported by two genera with 5 species.

9. *Goniopora minor* (Crossland, 1952).

1952. *Goniopora minor* Crossland, Madreporaria, hydro corallinae, Helliopora and tubipora. Sci.Rep.Great Barrier reef Exped. 1928-29. Br.Mus. (Nat.Hist.), 6 (3), 85-257, pl. 1-56.
Description: Colonies are hemispherical or encrusting. Calices are circular in outline, with thick walls. There are usually six thick pali, All septal structures are heavily granulated. The live coral is brown or green, usually with distinguished coloured oral discs and pale tips to the tentacles.
Habitat: Lagoon and shallow sub-tidal regions.
Distribution: Widely distributed: Indo-Pacific and East Pacific regions, and in India it is reported from Gulf of Kutch,achchh, Lakshadweep, and Andaman and Nicobar Islands.
Remarks: This is a very dominant species in high turbid waters.

10. *Goniopora planulata* (Ehrenberg, 1834).

1834, *Goniopora planulata* Ehrenberg, Beitrage zur physiologischen Kenntnis der corallenthiere imallgemeinen, und besonders des rothen Meeres, nebst einem Versuchezur physiologischen systematic derselben. – Phys. Abh.konigl.Akad.Wiss.Berlin a.d.Jahre 1832, 1. Teil, 225-380.
Description; Colonies are columnar, corallites polygonal and calice oval or rounded. Septa mostly regular, the tertiary fuse to the secondaries. Septa are descending vertically at the wall, edges with 4 to 5 teeth. 6 to 12 pali present of which those of the primaries are very prominent and frosted. They stand high above the columella. Columella are loose trabecular or sometimes solid.
Habitat: lagoon and shallow sub tidal reef environment.
Distribution: Worldwide : Red Sea, Madagascar and Sri Lanka to tip of western Australia, and in India is reported from Gulf of Kutch, Gulf of Mannar, and Andaman and Nicobar Islands.

11. *Porites lichen* (Dana, 1846).

1846. *Porites lichen* Dana, U.S. Exploring Expedition 1838-1842, 7, p. 1-740, pl. 61.
Description: Colonies form flat laminae or plates, or fused nodules and columns. Corallites are usually aligned in irregular rows separated by low ridges. Septal structures are variable and irregular. Colonies are bright yellowish – green, sometimes brown in colour.
Habitat: Lagoons and Front reef environments.
Distribution: Widely distributed: Tropical Indo–Pacific, Red Sea to Ellice and Marshall Islands, Fiji and Samoa and Great Barrier Reef; and in India it is reported from Gulf of Kutch, Lakshadweep, Gulf of Mannar, and Andaman and Nicobar Islands.
Remarks: In Mithapur, it is one of the common branching corals dominant in front reef slope and reef edges.

12. *Porites lutea* (Milne Edwards and Haime, 1860).

1860, *Porites lutea* Edwards and Haime, histoire naturelledes coralliaires. Paris. 1,2 and 3, 1-326, 1-632, 1-560. 1976. Porites lutea Pillai and Scheer, Report on the stony corals from the Maldive Archipelago. Results of the xarifa Expedition 1957/58. Zoologica (stuttg.0. 43 (126), 1-83, pl. 1-32.

Description: These species mostly flat form structure at Mithapur. Some colonies form like spherical and hemispherical structure. The surface is usually smooth. Dark brown or yellow in colour which is very brightly.
Habitat: Shallow water reef environments, sandy bottoms on back and front reefs and windward side.
Distribution: Widely distributed: Red Sea east to the Tuamotu archipelago and the Great Barrier Reef.
Remarks: Mostly closed with P.lobata , but easily differentiable.

13. *Porites compressa* (Dana, 1846).

1846. *Porites compressa,* Dana, U.S. Exploring expedition 1838 – 1842, 7, p. 1-740, pl. 61.
Description: Colonies composed of vertical flabellate thick plate arising from a solid base. Calices are polygonal in shape. Walls thin, with twisted mural tentacles. A single septal tentacle is present between the palus and the wall. Ventral triplets do not form a trident. Two rings of synapteculae. Pali poorly developed, one each on the lateral pairs of septa and the fifth on the ventral directive. Columella thin, compressed style joined to the fused ends of septa by radii.
Habitat: Lagoons, Back reef environments.
Distribution: World wide it is reported from St.Malacca, Palau Islands and Hawaii, and in India it is reported from Gulf of Kutch, Gulf of mannar,.
Remarks: *P.compressa* is one of common and major branching form at Mithapur. This species has high tolerant capacity of sediment environments. These kinds of branching forms give the very good support of associated faunas as a habitat.This species mainly support to the reef development toward windward side.

Family: FAVIIDAE (Gregory, 1900).

Faviidae species are mostly dominant in Mithapur reef. The colonies are massive or encrusting forms. All extant species are hermatypic and colonial. Septa, paliform lobes, columellae and wall structures, when present, all appear to be structurally similar. Moreover, the majority of Faviid genera are easily recognised because they are composed of a small number of species all of which have a number of distinctive characters. There are 8 species observed belongs to 6 genera.

14. *Plesiastrea versipora* (Lamarck, 1816)

1974. *Plesiastrea versipora* Scheer and Pillai, Report on the Scleractinia from the Nicobar Islands. Zoologica (Stuttg.,). 42, 3, heft 122, 1-75, pl, 1-33.
Description: Colonies are massive, encrusting forms. Corallites are monocentric and plocoid. Paliform lobes form a neat circle around small columellae. Polyps are usually extended only at night. Tentacles are short and are of two alternating sizes. Living colonies are dark green, brown in colours.
Habitat: Tidal pool walls and Back reef slope (esp.Protected from wave actions).
Distribution: Worldwidely distributed from St. Vincent's Gulf to South Australia, and in India it is recorded from Gulf of Kutch, , Lakshadweep and Andaman and Nicobar Islands.
Remarks: *P. versipora* is rarely observed at the Mithapur reef.

15. *Favia favus* (Forskal, 1775)

1974. *Favia favus* Forskal; Scheer and Pillai, Report on the Scleractinia from the Nicobar Islands. Zoologica (stuttg). 42, 3, heft 122, 1-75, pl.1-33.

Description: Most of the colonies are massive, encrusting or flat. Corallites are conical in shape. Septa have an irregular appearance. Paliform lobes are poorly developed.
Habitat: Dominant in the reef flat and shallow reef environments.
Distribution: Widely distributed from Red Sea, Japan, Marshall Islands, Samoa, The Great barrier Reef, and the Coral Sea and in India, it is reported from Gulf of Kutch, , Lakshadweep, Gulf of Mannar and Andaman and Nicobar Islands.
Remarks: F.favus is one of the most common species in Mithapur reef. Profusely distributed on the reef flats.

16. *Favia speciosa* (Dana, 1846).

1846.*Favia speciosa* Dana, U.S. Exploring Expedition 1838-1842, 7, p. 1-740, pl. 61.

Description: Colonies are massive or encrusting. Corallites are crowded together, sub circular in shape. Septa are fine, numerous and regular. Paliform lobes are poorly developed.
Habitat: The entire reef habitat.
Distribution: Worldwide it is reported from Red Sea, East Africa, Tuamotu archipelago, The Great Barrier Reef to the Coral Sea, and in India it is reported from Gulf of Kutch, Lakshadweep, Gulf

of Mannar, and Andaman and Nicobar Islands.
Remarks: It is an uncommon species in Mithapur reef. Mostly it was observed from reef flat and tidal pools.

17. *Favia pallida* (Dana, 1846).

1846. *Astrea denticulate* Dana, U.S. Exploring Expedition 1838 – 1842, 7, p. 1-740, pl. 61.
Description: Colonies are hemispherical or massive in forms. Corallites are angular or circular in shape. Septa have widely spaced and irregular. Paliform lobes are poorly developed. Colonies are pale yellow, cram or green in colour.
Habitat: Wide range of reef habitat.
Distribution: It is reported throughout Indo-Pacific, Red Sea, Fiji, and Coral Sea and in India; it is reported from Gulf of Kutch, Lakshdweep and Andaman and Nicobar Islands.
Remarks: It is a common species at Mithapur reef and mostly found in tidal pools and the Reef flats.

18. ***Platygyra sinensis*** (Mine Edwards and Haime 1849).

1976. *Platygyra sinensis* Wijsman – best, Systematics and ecology of New Caledonian Faviinae (Coelentrata, Scleractinia). Bijdr. Dierkd. 2 (1), 1- 76, pl. 1-14.
Description: Colonies are massive, encrusting or flat. Usually fully meandroid with thin walls. Septa are thin and slightly exsert. Columellae are weakly developed and there are no columella centres.
Habitat: Most reef environments.
Distribution: Worldwide : Indo-Pacific, Red Sea, Samoa, The Great barrier Reef, The Coral Sea, and in India it is reported from Gulf of Kutch, Lakshadweep, Gulf of Mannar, Andaman and Nicobar Islands.
Remarks: This is a common species in Mithapur reef. Mostly found in reef flat areas.

19. ***Hydnopora exesa*** (Pallas, 1766)

1974. *Hydnopora exesa* Scheer and pillai, Report on Scleractinia from the Nicobar Islands. Zoologica (stuttg.). 42 (122), 1-75, pl. 1-33.
Description: Colonies are sub-massive, encrusting or sub – arborescent. Monticules are evenly distributed over the corallum, in some parts arranged in regular rows, separating continuous valleys. Septal dentations are obsolute on the monticules, but better developed on the lower part of the septa. The columellar structure is irregularly developed.

Habitat: Reef flat and Rref slopes.
Distribution: Widely distributed from the Indo–Pacific, Red Sea, Ellice islands and Great Barrier Reef, and in India it is reported from Gulf of Kutch, Gulf of mannar, and Andaman and Nicobar Islands.
Remarks: It is rare species at Mithapur reef.

20. ***Cyphastrea serailia*** (Forskal, 1775).

Description: Colonies are massive, sub-massive or encrusting to columnar with a smooth or hillocky surface. Corallites are rounded and equal in size. The corallites have 12 seta. The columella are usually inconspicuous and trabecular. The costae are equal or subequal and are poorly developed. The coenosteum is often largely composed of dissepimental blisters and always covered with granulated exothecal spines.
Habitat: All reef environments.
Distribution: Worldwide: Indo – Pacific – from Red Sea to Marshall Islands, Philippines and the Great Barrier Reef, and in India it is reported from Gulf of Kutch, , Lakshadweep, Gulf of Mannar and Andaman and Nicobar Island.
Remarks: This is an uncommon species at Mithapur. Mostly found in Leeward side. *C.serailia* corallites have a very wide range of variation so that colonies from different habitats may appear to be different species.

21. ***Goniastrea pectinata*** (Milne Edwards and Haime, 1848).

1974. *Goniastrea pectinata* Scheer and Pillai, Report on the Scleractinia from the Nicobar Islands. Zoologica (stuttg). 42, 3, heft 122, 1-75, pl. 1-33.

Description: Colonies are Massive, spherical or elongate. Corallites are submeandroid to cerioid. Paliform lobes are well developed. Living colonies are pale brown or pink, dark brown colours.
Habitat: Mostly found in all reef environments.
Distribution: Worldwide - Palau, Mergui Archipelago, Indonesia, Philippines, New Caledonia, The Great Barrier Reef, and the Coral Sea and in India it is reported from Gulf of Kutch, Andaman and Nicobar Islands, Gulf of Mannar, Lakshadweep.
Remarks: It can tolerate several hours of exposure to the tropical sun during the low tide and also muddy or low salinity conditions. This is mostly abundant all reef environments at Mithapur.

Family: MUSSIDAE Ortmann, 1890.

In this family the corallites are very large and have a very spiky appearance, due to the presence of long projections called teeth along the blade of the septa. Skeletal structures are solid. There are two species were observed in Mithapur.

22. ***Acanthastrea hillae*** (Wells, 1955).

1955. *Acanthastrea hillae* Wells, Recent and subfossile corals of Moreton Bay, Queensland. Univ. Queensl. Pap. Dep. Geol. 4 (10), 1-18, pl. 1-3.
Description: *A.hillae* is quite a prominent corals, with the thick, fleshy polyps typical of Acanthastrea species. Colonies are cerioid and usually small but sometimes over 1.5 metres across. Each colony is formed from numerous tiny polyps, anemone-like animals which secrete the hard coral skeleton. The skeleton of each individual polyp is known as a corallites and in this species these share common walls and can be quite irregular in shape. Each polyp bears numerous sturdy tentacles, which surround a central mouth.
Habitat: Wide range of shallow reef environments.
Distribution: Worldwide: Reported from Madagasgar to Coral Sea and in India is reported from Gulf of Kutch only.
Remarks: This is very common species in Mithapur reef. Usually it is abundant in reef flat. It is high tolerant species of sediments and high turbid waters.

23. *Symphyllia radians* (Milne Edwards and Haime, 1849).

1974. *Symphyllia radians* Scheer and Pillai, report on Scleractinia from the Nicobar Island. Zoologica (stuttg). 42 (122), 1-75, pl. 1-33.
Description: Colonies are massive, encrusting or flat. Valleys are fairly straight, especially if colonies have flat surfaces, otherwise irregularly sinuous. Valleys are in a radiating pattern.
Habitat: All shallow reef environments.
Distribution: Worldwide – it is reported from Maldives and the Great Barrier Reef and in India it is reported from Gulf of Kutch, Lakshadweep, Gulf of Mannar and Andaman and Nicobar Islands.
Remarks: It is uncommon species in Mithapur. Mostly found in flat and slope area.

Family: DENDROPHYLLIDAE Gray, 1847.

Most of the Dendrophyllid species do not rely on unicellular, photosynthetic zooxanthellae symbionts, they can live in deep water environments and shallow water habitats that do not receive light. Only a few genera (Turbinaria and Duncanopsammia and some species of Heteropsammia) contain zooxanthellae in their polyps and consequently manufacture large skeletons that contribute to shallow water reef structure.

24. *Turbinaria peltata* (Esper, 1794)

Description: Colonies are encrusting without stalks, thickened, ridges with budding margins bifacial fronds columns. Corallites are widely spaced. Colony margins mostly composed of closely packed and outward projecting corallites. The central corallites density is decreased than the outside.
Habitat: Reef flat and mostly abundant windward side of the reef environments.
Distribution: Worldwide: East Africa, Japan, Marshall Islands, Fiji, and the Great Barrier Reef and in India, it is reported from Gulf of Kutch, Gulf of Mannar, Andaman and Nicobar islands.
Remarks: This is common species at Mithapur reef and a tolerant species of high turbid water.

25. ***Turbinaria mesenterina*** (Lamarck, 1816)

Description: Colonies are composed of unifacial laminae, crowded corallites with slightly exsert.
Habitat: All reef environments with high turbid conditions.
Distribution: Red Sea, Gulf of Aden, Arabian sea, Indian ocean, and the western and central pacific oceans, and in India it is reported from Gulf of Kutch, , Gulf of Mannar, Andaman and Nicobar.
Remarks: It is un common species at Mithapur reef.

26. ***Tubastrea aurea*** (Quoy and Gaimard, 1833)

1986. *Tubastrea aurea.* Pillai, Recent corals of the southeast coast of India, Advances in M. Biology, New Delhi, pp.107 – 109.
Description: Colonies are hard and tubular forms with larger polyps. Septa are in three cycles. Usually orange, yellow, red in colour.
Habitat: All reef environments, common in heavy turbid waters.
Distribution : Worldwide, it is distributed from Red Sea, and western Indian Ocean to the southern Pacific waters and in India, it is reported from Gulf of Kutch, , Gulf of Mannar, Andaman and Nicobar waters.
Remarks: It does not create the reef.

27. ***Psammacora digiTata*** (Milne Edwards and Haime, 1851)

1974. *Psammacora digiTata* Scheer and Pillai, report on Scleractinia from the Nicobar Island. Zoologica (stuttg). 42 (122), 1-75, pl. 1-33.
Description: Colonies are encrusting, plate–like and columnar shape. Small and shallow corallites and it is irregularly arranged and slightly exsert. Colour range from grey, brown.
Habitat: All reef environments.
Distribution: Throughout the Indian ocean, The central Indo – Pacific waters, Australia, South – East Asia, Japan, East China sea and in India it is reported from Gulf of Kutch, Andman and Nicobar Islands and Lakshadweep.
Remarks: This is most common species in mithapur reef.

II. Fish Diversity in Mithapur reef

There were 40 species of fish recorded from Mithapur reef.

1. ***Apogon pseudotaeniatus:***

Classification: Actinopterygii | Perciformes | Apogonidae | Apogoninae.
Description: Found mostly in seaward reefs, harbours, pilings and walls. Max size 10.5 cm. Distribution: Indo-West Pacific: Red Sea and the Persian Gulf to the Indo-Malayan region, north to Japan.

2. ***Cephalopholis formosa***:

Classification: Actinopterygii | Perciformes |Serranidae|Epinephelinae. Description: A reef-associated species that prefers shallow (10 to 30 m) dead or silty reefs. It grows to a size of 34cm in length. Distribution: Found from Indo-West Pacific. IUCN Red List Status: Least Concern (LC).

3. ***Chaetodon collaris***:

Classification: Actinopterygii | Perciformes | Chaetodontidae.
Description: Occur in coral reefs in pairs or several aggregations. Feed on coral polyps. It can grow to 18 cm (over 7 in) in length. Distribution: It can be found in reefs of the Indo-Pacific oceans. IUCN Red List Status: Not Evaluated

4. ***Chaetodon trifasciatus***:

Classification: Actinopterygii | Perciformes | Chaetodontidae.
Description: Found at depths between 2 and 20 m, growing to a maximum of 15 cm long. Feed exclusively on coral polyps, particularly of the Pocillopora type. Distribution: It is found in the Indian Ocean from East Africa to Western Java. IUCN Red List Status: Not Evaluated

5. ***Coilia neglecta***:

Classification: Actinopterygii | Clupeiformes | Engraulidae.
Description: Found in saline coastal waters and estuaries to a depth of 50 m. It is often found in the vicinity of mangrove forests. Distribution: Indian Ocean: Karachi eastward to the Andaman Sea and Penang. Western Central Pacific: Singapore south to Barito River, Kalimantan). IUCN Red List Status: Least Concern (LC)

6. ***Diodon hystrix***:

Classification: Actinopterygii | Tetraodontiformes | Diodontidae.
Description: Size up to 91cm long and weigh as much as 2.8kg. Solitary and nocturnal that feed on hard shelled invertebrates like sea urchins, gastropods, and hermit crabs. They are poisonous to eat. Distribution: Circum-tropical. IUCN Red List Status: Not Evaluated

7. ***Ephinephelus coioides***:

Classification: Actinopterygii | Perciformes | Serranidae | Epinephelinae.
Description: Inhabit turbid coastal reefs and are often found in brackish water. Juveniles are common in estuaries over sand, mud and gravel and among mangroves. Feed on small fishes, shrimps, and crabs. Distribution: Indo-West Pacific. Recently reported from the Mediterranean coast of Israel. IUCN Red List Status: Near Threatened (NT)

8. ***Epinephelus areolatus***:

Classification: Actinopterygii | Perciformes | Serranidae | Epinephelinae.
Description: Usually found in sea grass beds or on fine sediment bottoms near rocky reefs, dead coral, or alcyonarians, in shallow continental shelf waters. Feed on fish and benthic invertebrates, primarily prawns and crabs.
Distribution: Indo-Pacific region, Northern Australia. IUCN Red List Status: Least Concern (LC)

9. ***Epinephelus erythrurus***:

Classification: Actinopterygii | Perciformes | Serranidae | Epinephelinae.
Description: Inhabits areas with muddy or silty-sand bottoms. Max length: 45.0 cm. Distribution: Indo-West Pacific. IUCN Red List Status: Data deficient (DD)

10. ***Euryglossa orientalis***:

Classification: Actinopterygii | Pleuronectiformes | Soleidae.
Description: Inhabits shallow sand and mud bottoms in coastal waters. Reported to enter brackish waters and fresh waters. Feeds mainly on bottom-dwelling invertebrates, especially small crustaceans. Max length: 30.0 cm. (The Largest ever recorded Oriental sole in India was caught at Gujarat coast with a size of 385mm total length and 1170g weight on Aug 2004. Distribution: Indo-West Pacific. IUCN Red List Status: Not Evaluated

11. ***Gymnothorax flavimarginatus***:

Classification: Actinopterygii | Anguilliformes |Muraenidae | Muraeninae.
Description: Occurs in coral or rocky areas of reef flats and protected shorelines to seaward reefs. Feeds on cephalopods, fishes, and crustaceans. Its length is up to 240 cm. Distribution: Indo-Pacific, Eastern Pacific. IUCN Red List Status: Not Evaluated

12. ***Gymnothorax permistus***:

Classification: Actinopterygii | Anguilliformes | Muraenidae | Muraeninae.

Description: Inhabits reef flats and outer reef slopes of continental reefs. One of the two largest of Indo-Pacific morays. Often in holes with cleaner wrasses or shrimps. Feeds on cephalopods and small fishes. Large adults may be aggressive. Reports of ciguatera poisoning. IUCN Red List Status: Not Evaluated

13. ***Halichoeres nigrescens***:

Classification: Actinopterygii | Perciformes | Labridae | Corinae.
Description: Inhabit shallow weedy areas of rocky shorelines with little coral growth. Max length: 14.0 cm. Distribution: Indo-West Pacific: south to Durban, South Africa; southeast India to Philippines, north to Hong Kong, south to northwest Australia. IUCN Red List Status: Least Concern (LC)

14. ***Harpadon nehereus***:

Classification: Actinopterygii | Aulopiformes | Synodontidae | Harpadontinae.
Description: Inhabit deep water offshore on sandy mud bottom for most of the year, but also gathers in large shoals in deltas of rivers to feed during monsoons, Benthopelagic. Very phosphorescent. An aggressive predator. Distribution: It is native to the waters between Mumbai (formerly Bombay) and Kutch in the Arabian Sea, and a small number are also found in the Bay of Bengal. Great numbers are also caught in the China Sea. IUCN Red List Status: Not Evaluated

15. ***Lutjanus fulviflamma***:

Classification: Actinopterygii | Perciformes | Lutjanidae | Lutjaninae. Description: Inhabit coral reefs, Juveniles are sometimes found in mangrove estuaries or in the lower reaches of freshwater streams. Feed mainly on fishes, shrimps, crabs and other crustaceans. Max total length 35 cm.
Distribution: Widespread in the Indo-Pacific from Samoa to East Africa, and from Australia northward to the Ryukyu Islands. IUCN Red List Status: Not Evaluated

16. ***Neopomacentrus filamentosus***:

Classification: Actinopterygii | Perciformes |Pomacentridae | Pomacentrinae.
Description: Inhabits soft bottoms of lagoons and inshore reefs around coral outcrops, rocks, debris, etc. Max length: 11.0 cm. Distribution: Western Central Pacific. IUCN Red List Status: Not Evaluated

17. ***Neotrygon kuhlii:***

Classification: Elasmobranchii | Rajiformes | Dasyatidae.
Description: A solitary species found on sandy bottoms near rocky or coral reefs. Occasionally covers itself with sand, leaving only its eyes and tail visible. Feeds on crabs and shrimps. The venomous spine can inflict a painful wound. Distribution: Indo-West Pacific. IUCN Red List Status: Data deficient (DD)

18. ***Pempheris vanicolensis:***

Classification: Actinopterygii | Perciformes | Pempheridae
Description: Inhabits shallow rocky and coral reefs. At night, they forage on planktonic organisms in open waters, returning to their caverns in the reefs shortly before sunrise. Max. Length 20 cm. Distribution: Ranges between Red Sea to Samoa,n. to phillipnes IUCN Red List Status: Not Evaluated.

19. ***Plotosus lineatus:***

Classification: Actinopterygii | Siluriformes | Plotosidae.
Description: The only catfish found in coral reefs. Also found in estuaries, tide pools and open coasts. Juveniles in dense ball-shaped schools over reefs and among sea grasses, adults solitary and under ledges by day. The highly venomous serrate spine of the first dorsal and each of the pectoral fins are dangerous, and even fatal in rare cases. Distribution: Indo-Pacific. IUCN Red List Status: Not Evaluated

20. ***Pomacanthus annularis:***

Classification: Actinopterygii | Perciformes | Pomacanthidae.
Description: Habitats coastal rocky coral reef areas and caves. Feeds on Sponges, Tunicates... etc. Juvenile: black with alternating white and black curved well – spaced stripes on the sides. Max length: 45.0 cm. Distribution: Indo – west Pacific waters IUCN Red List Status: Least Concern (LC)

21. ***Scarus ghobban:***

Classification: Actinopterygii | Perciformes |Scaridae |Scarinae.
Description: Often near Sandy areas in silty environments. Adults inhabit lagoon and seaward reefs. Usually solitary, but juveniles in groups. Feed by scraping algae from rocks and corals. Distribution: Indo-Pacific, Eastern Pacific Eastern, Mediterranean. IUCN Red List Status: Least Concern (LC)

22. ***Terapon jarbua:***

Classification: Actinopterygii | Perciformes | Terapontidae.
Description: Found over shallow sandy bottoms, in the vicinity of river mouths. Feeds on fishes, insects, algae, and sand-dwelling invertebrates. Length-36 cm. Distribution: Ranges from Red Sea to Samoa, n. to s. Japan, s. to L. Howe Is. IUCN Red List Status: Not Evaluated

23. ***Thryssa baelama:***

Classification: Actinopterygii | Clupeiformes | Engraulidae.
Description: Mostly in inshore bays, lagoons, harbours, mangrove pools and estuaries, thus apparently able to tolerate lowered salinities. Inhabits turbid waters, forming large schools. Max length: 16.0 cm.
Distribution: Indo-Pacific: Red Sea to Mozambique, Madagascar and Mauritius, east to Samoa, north to the Philippine, Caroline and Mariana islands. IUCN Red List Status: Not Evaluated

24.***Upeneus tragula:***

Classification: Actinopterygii | Perciformes | Mullidae.
Description: Found in Shallow sandy or silty areas of the lagoon and sheltered coastal reefs. Known to enter lower reaches of rivers. Generally solitary, but forms small to moderately large aggregations at all sizes. Max length: 33.0 c.m. Distribution: Indo-West Pacific, East Africa to New Caledonia, north to Japan. IUCN Red List Status: Not Evaluated

25. ***Abudefduf bengalensis:***

Classification: Actinopterygii | Perciformes | Pomacentridae | Pomacentrinae.
Description: Occurs singly or in small groups in inshore reef and lagoon environments. Max length: 45.0 cm. Distribution: Western Pacific. IUCN Red List Status: Not Evaluated

26. ***Acanthopagrus latus:***

Classification: Actinopterygii | Perciformes | Sparidae.

Description: occurs in shallow coastal waters and enters river mouths and estuaries. Used in Chinese medicine. Distribution: Indo-West Pacific. IUCN Red List Status: Not Evaluated

27. ***Lethrinus sp.:***

Classification: Actinopterygii | Perciformes | Sparidae. Description: Reef-associated; non-migratory.

28. ***Plectorhinchus sordidus:***

Classification: Actinopterygii | Perciformes | Haemulidae.
Description: Found over rocks and corals, as well as shallow weedy areas. Max length: 60.0 cm. Distribution: Western Indian Ocean. IUCN Red List Status: Not Evaluated

29. ***Arothron immaculatus:***

Classification: Actinopterygii | Tetraodontiformes | Tetraodontidae.
Description: Inhabits weedy areas, often in estuaries; seagrass beds and mangrove areas in 1-1.5 m. Specimens caught by trawling over silty bottoms in 17 m. Max length: 30.0 cm. Distribution: Indo-West Pacific: Red Sea and East Africa to Indonesia, north to southern Japan. IUCN Red List Status: Not Evaluated

30. ***Apogon multitaeniatus:***

Classification: Actinopterygii | Perciformes | Apogonidae | Apogoninae.
Description: Marine; reef-associated; non-migratory. Remains hidden by day. Max length: 18.0 cm. Distribution: Western Indian Ocean: endemic to the Red Sea and Gulf of Aden. IUCN Red List Status: Not Evaluated

31. ***Arothron reticularis:***

Classification: Actinopterygii | Tetraodontiformes | Tetraodontidae.
Description: Marine; brackish; reef-associated; depth range 1 - 25 m. Adults at moderate depths, often laying on the mud during the day. Feeds on corals, mollusks, and other sand-dwelling invertebrates. Max length: 45.0 cm Distribution: Indo-West Pacific: north to Ryukyu Islands. IUCN Red List Status: Not Evaluated

32. ***Aetobatus narinari:***

Classification: Elasmobranchii | Rajiformes | Myliobatidae | Myliobatinae.
Description: Commonly found in shallow inshore waters such as bays and coral reefs but may cross oceanic basins. Benthopelagic, found near land at 1-60 m. Swims close to the surface, occasionally leaping out of the water, or close to the bottom. Feeds mainly on bivalves but also eats shrimps, crabs, octopus and worms, whelks, and small fishes. Distribution: N.C. (summer), Bermuda, se. Florida, and n. Gulf of Mexico to Brazil; nearly worldwide in tropical waters. IUCN Red List Status: Near Threatened (NT)

33. ***Arothron stellatus:***

Classification: Actinopterygii | Tetraodontiformes | Tetraodontidae.
Description: Relatively uncommon in patch reefs and coral slopes near sandy areas of clear lagoon and seaward reefs. Juveniles occur in sandy and weedy inner reefs, adults on clear lagoons and seaward reefs. Considered as the giant among puffers reaching a total length well in excess of a meter. Max length: 120 cm. Distribution: Indo-Pacific: Red Sea and East Africa to the Tuamoto Islands, north to southern Japan, south to Lord Howe Island. Southeast Atlantic: south coast of South Africa. IUCN Red List Status: Not Evaluated

34. ***Chiloscyllium griseum:***

Classification: Elasmobranchii | Orectolobiformes | Hemiscylliidae.
Description: common inshore bottom shark. Often found in estuaries. Probably feeds mainly on invertebrates. Oviparous. Max length: 74 cm. Distribution: Indo-West Pacific: Arabian Sea to Pakistan, India, Malaysia, Thailand, Indonesia, China, Japan, the Philippines, Papua New Guinea. IUCN Red List Status: Near Threatened (NT)

35. ***Hemiramphus archipelagicus:***

Classification: Actinopterygii | Beloniformes | Hemiramphidae | Hemiramphinae.
Description: Inhabits the immediate vicinity of coasts, but juveniles may sometimes be found with floating plants carried out to sea. Taken with purse seines at Karwar on the west coast of India and with dol nets at Bombay. Max length: 34.0 cm. Distribution: Indo-Pacific: west coast of India and Sri Lanka and from the Gulf of Thailand, Philippines, and East Indies eastward to New Guinea and western Polynesia. IUCN Red List Status: Not Evaluated

36. ***Heniochus acuminatus:***

Classification: Actinopterygii | Perciformes | Chaetodontidae.
Description: Inhabit deep, protected lagoons and channels, and the deeper parts of outer reef slopes. Juveniles are often solitary while adults occur in pairs. A planktivorous species that generally remains within a few meters of the reef. Juveniles may sometimes pick on parasites on the epidermis of other fish. Max length: 25.0 cm. Distribution: Indo-Pacific: East Africa and Persian Gulf to the Society Islands, north to southern Japan, south to Lord Howe Island. Throughout Micronesia. IUCN Red List Status: Least Concern (LC)

37. ***Istigobius decorates:***

Classification: Actinopterygii | Perciformes | Gobiidae | Gobiinae. Description: Common species that inhabits areas of coralline sand of clear lagoon and seaward reefs. Found singly. Max length: 13.0 cm. Distribution: Indo-West Pacific: Red Sea to Samoa, north to Taiwan, south to Lord Howe Island. IUCN Red List Status: Not Evaluated

38. ***Lutjanus argentimaculatus:***

Classification: Actinopterygii | Perciformes | Lutjanidae | Lutjaninae.
Description: Euryhaline species. Juveniles and young adults occur in mangrove estuaries, the lower reaches of freshwater streams and tidal creeks. Adults are often found in groups around coral reefs. Eventually migrate offshore to deeper reef areas, sometimes penetrating to depths in excess of 100 m. mainly nocturnal, this species feeds mostly on fishes and crustaceans. Excellent food fish. Max length is 150 cm, max weight 14.5 kg. Distribution: Indo-West Pacific: East Africa to Samoa and the Line Islands, north to the Ryukyu Islands, south to Australia. Has dispersed into the eastern Mediterranean (off Lebanon) via the Suez Canal but not well established there. IUCN Red List Status: Not Evaluated

39. ***Pomacanthus annularis(Juv):***

Classification: Actinopterygii | Perciformes | Pomacanthidae.
Description: Habitats coastal rocky coral reef areas and caves. Feeds on Sponges, Tunicates... etc. Juveniles settle in very shallow inshore habitats with short filamentous algae growth on rock or dead coral substrates. Feeds on sponges and tunicates. Undergoes a complete color transformation from the juvenile to adult stage. Max length: 45.0 cm. Distribution: Indo – west Pacific waters. IUCN Red List Status: Least Concern (LC)

40. ***Leiognathus daura:***

Classification: Actinopterygii | Perciformes | Leiognathidae.
Description: Found in shallow waters, predominantly over muddy bottoms. Usually occurs in schools. Feeds on polychaetes, bivalves, small crustaceans and sponges. Max length: 14.0 cm. Distribution: Indo-West Pacific: Gulf of Aden, along the coasts of India and Sri Lanka; including Pakistan, eastwards to the Philippines. IUCN Red List Status: Not evaluated.

III. Diversity of crabs and Lobsters in the Mithapur reef

1. ***Atergatis integerrimus:***

Common Name: Red Egg Crab
Description: These are coral reef dwellers, being found under rocks or in crevices at low tide. The red egg crab can grow to large sizes (width of up to 10cm). These species are basically herbivorous, and should not be eaten.Distribution: Indo-West Pacific.

2. ***Calappa lophos:***

Common Name: common box crab.
Description: Found in Sandy-muddy area. Reef-associated organism. Burrows body on soft and mud substrates. Distribution: Indo-Pacific and Atlantic Ocean: Japan to Southeast Asia, Australia to Sri Lanka.

3. ***Doclea rissoni:***

Common Name: Spider crab.

4. ***Eriphia smithii:***

Common Name: Rough red-eyed crab.
Description: Inhabits reefs. Subtropical and tropical climates. Distribution: Indo-Pacific.

5. ***Etisus laevimanus:***

Common Name: Smooth spooner.
Description: Occurs from the intertidal zone to a depth of about 20 m. Benthic. Inhabits reefs especially on disturbed reef flats. Subtropical and tropical climates. Distribution-Indo-West Pacific: South Africa to Hawaii. Max length: 8.0 cm.

6. ***Grapsus albolineatus:***

Common Name: mottled Sally-light-foot.
Description: Found out of the water, on rocks in the splash zone and in the infra-tidal zone. Max length: 5.0 cm. Distribution: Indo-West Pacific.

7. ***Pilumnus sp.:***

Common Name: Hairy crab.

8. ***Thalamita crenata:***

Common Name: Crenate swimming crab, wide front swim crab. Description: Inhabits shallow non-reef habitat with soft substrates. Prefers areas near mangroves or with muddy-rocky substrates. Max length: 8.0 cm. Distribution: Indo-Pacific: Cocos Islands to Hawaii.

9. ***Ocypode platytarsis:***

Common Name: Stalked eyed Ghost Crab.
Description: This is the largest on Indian Shore Crab and can be distinguished by the pale yellow carapace and the stridulating organ consists of row of tubercles on the inner palm.

10. ***Portunus pelagicus:***

Common Name: Flower crab, blue crab, blue swimmer crab, blue manna crab or sand crab.
Description: Inhabits sandy to sandy-muddy substrates in areas near reefs, mangroves, and sea grass and algal beds. They feed on various organisms such as bivalves, fish and, to a lesser extent, macro algae. They are excellent swimmers. Distribution: Atlantic Ocean and throughout Indo-West Pacific.

11. ***Petrolisthes sp.:***

Common Name: Marine porcelain crabs, Squat Lobster.
Description: Porcelain crabs are small, usually with body widths of less than 15 millimetres. Porcelain crabs are quite fragile animals, and will often shed their limbs to escape predators, hence their name. The lost appendage can grow back over several molts.

12. ***Panulirus polyphagus:***

Common Name: Mud spiny lobster.
Description: It is found on muddy substrates and sometimes on rocky bottoms near river mouths in turbid water. Max length: 40.0 cm. Distribution: Indo-West Pacific: from the coasts of Pakistan and India to Vietnam, the Philippines, Indonesia, Northwest Australia and the Gulf of Papua.

IV. Diversity of other reef associated fauna of the Mithapur Reef

1. ***Stichodactyla mertensii:***

Common Name: Merten's carpet sea anemone.
Description: Regarded as the largest sea anemone with a diameter of over 1 m. It contains obligate symbiotic zooxanthellae, and can serve as a host anemone to 17 separate fish species, the majority of which are anemone fish, with one damselfish.

2. ***Pelagia noctiluca:***

Common Name: Purple striped jelly.
Description: A holoplanktonic, oceanic and semi-cosmopolitan species inhabiting offshore warm waters; non symbiotic but often appears in high numbers. Feeds on salps, doliolids, larvaceans, hydromedusae, ctenophores, chaetognaths, planktonic crustaceans and fish eggs. Max length: 9.0 cm.

3. ***Cassiopea sp.:***

Common Name: Upside-Down Jelly Fish.
Description: Found in shallow mangrove swamps, mudflats, and turtle grass flats, where it lives usually upside-down on the bottom. There may be numerous individuals with varying shades of white, blue, green and brown.

4. ***Thysanostoma sp.:***

Common Name: Barrel Jelly Fish.
Description: Found in open waters over coral reef or in lagoon after a storm.

5. ***Holothuria pardalis:***

Common Name: Leopard Sea Cucumber.

6. ***Cephea sp.:***

Common Name: Cauliflower or Crowned Jelly Fish. Description: Found mostly in open waters above coral reef. Max length: 14.0 cm. Distribution: Red Sea to Polynesia.

7. ***Salmacis bicolor:***

Common Name: Bicolor Urchin.

8. ***Zoanthids:***

Common Name: Zoanthids.
Description: They are commonly found in coral reefs, the deep sea and many other marine environments around the world. Zoanthids feed both by photosynthesis, aided by the zooxanthellae they contain, and by capturing plankton and particulate matter. Zoanthids can eat meaty foods, such as lancefish, brine shrimp, krill and bloodworms.

9. ***Porpita Sp.:***

Common Name: Blue button.
Description: Feeds on small animals the lives on two dimensional ecosystems. Known from surface or near surface water layers, including porpitids and the halopelagic Sargassum fauna. The blue button has a single mouth located beneath the float which is used for both the intake of nutrients as well as the expulsion of wastes. Distribution: Found in tropical waters from California to the tropical Pacific, the Atlantic and Indian oceans.

10. ***Pelamis platurus:***

Common Name: Yellow belly Sea Snake or Pelagic Sea Snake.
Description: The yellow belly is the most widely distributed sea snake and is capable of living and giving birth entirely in the open sea (it is totally pelagic). A species of sea snake found in tropical oceanic waters around the world. The yellow-bellied sea snake is about 10 times more venomous than the Egyptian cobra (Naja naje) but it delivers a much smaller quantity of venom. Distribution: Tropical oceanic waters except Alaska south to southern California and Red Sea.

V. Seaweeds of Mithapur Reef

1. ***Chaetomorpha crassa:***

Common Name: Hair-shaped green algae, Sea Spaghetti.
Description: The thalli consist of un-branched filaments forming loose clumps entangled with other algal species; the clumps are bright green with some greenish white portions. Distribution: Ireland, Europe, Atlantic Islands, Central America ,Caribbean Islands, South America, Africa, Indian Ocean Islands, Asia, Australia and New Zealand, Pacific Islands. IUCN Red List Status: Least Concern.

2. ***Colpomenia sp:***

Description: a small brown alga, bladder-like, hollow and membranous.

3. ***Dictyota dichotoma:***

Common Name: Divided Net Weed, Brown Fan Weed.
Description: Thallus flat and leaf-like, ronds thin and translucent, olive to yellow-brown, fronds thin and translucent, olive to yellow-brown, occasionally with a bluish iridescent. Distribution: Widely distributed and common.

4. ***Chamaedoris sp.:***

Description: Thallus composed on one or more stipitate capitula, to 10 cm tall. It favors areas of strong water motion and is generally found in sandy, low visibility habitats.

5. ***Caulerpa taxifolia:***

Common Name: –. Description: Has stem which spreads horizontally just above the seafloor, and from this stem grow vertical fern-like pinnae, whose blades are flat like yew, alga produces a large amount of a single chemical that is toxic to fish. Distribution: Indian Ocean.

6. ***Cystoseira indica:***

Description: Typically found in the intertidal zone at the water's edge at a mean distance from sea level of 0 meters (-1 feet). Distribution: South-west Asia.

7. ***Cotryocladia leptopoda:***

Description: Thallus 8−20(−30) cm in height, deep to light red, arising from a discoid holdfast. Epilithic in the intertidal and sub-tidal to 14 m depth. Distribution: Northern and western Australia; Red Sea; Indian Ocean; Indonesia; Japan.

8. ***Champia sp:***

Description: Thallus with a discoid holdfast and erect or prostrate fronds.

9. ***Halymenia venusta:***

Common Name: —. Description: Thallus variable in size and shape, flat, sometimes hardly divided, forming large flat fronds up to 30 cm or more, or divided into several lobes, tough, 500 μ thick. Color: Light to deep red or darker with age. Distribution: Africa, Indian Ocean Islands, South-west Asia.

10. ***Hypnea musciformis:***

Common Name: Hook weed.
Description: Clumps or masses of loosely intertwined, cylindrical branches, firm, cartilaginous, highly branched. Usually red, but can be yellowish brown in high light environments or nutrient poor waters. Distribution: Mediterranean, Philippines, Indian Ocean, Caribbean to Uruguay.

11. ***Padina gymnospora:***

Common Name: –. Description: Usally the blades are 10-12 cm long and broad, but plants with 15 cm long and to 20 cm broad blades may be found. Thalli are olive-brown in colour. Distribution: Atlantic Ocean, Indian Ocean, Pacific Ocean.

12. ***Gastroclonium iyengarii:***

Common Name: —.Description: Color varies from red to pink or purple, older parts dark brown, younger parts light green to light red. Easily recognized due to erect shoot bearing large number of linear oblong articulated structure in tufts near the extremeties of the shoots bearing them. Distribution: South-west Asia.

13. ***Hydroclathrus clathratus:***

Common Name: Sponge Seaweed.
Description: Light brown or yellowish brown, characteristically net-like due to numerous perforations which range from 0.5 to 12.0mmin diameter; in between the holes, the fleshy strands have enrolled margins and vary from 0.5 to 2.5 mm in thickness. Thalli form extensive mats. Used for human consumption. Distribution: Atlantic Ocean, Indian Ocean, Pacific Ocean.

14. ***Halymenia porphyroides:***

Description: Thallus is gelatinous, slick, to 5(-48) cm high, to 6(-41) cm wide, pink to rose-red. Habitat on rocks or coral fragments on sand plains; 5-20 m deep. Distribution: Central America, Gujarat.

15. ***Galaxaura sp:***

Description: Plants erect, dichotomously branched; branches terete to flattened, glabrous or covered with photosynthetic hairs, calcified, articulated or non-articulated, multiaxial. Distribution: Mostly tropical to subtropical, a few species in temperate waters, low tide line to deep sub tidal.

16. ***Halimeda tuna:***

Description: The thallus is erect upto 9 cm tall, greenish to cream when dried. Segments are overlapping and are either spreading or compact; branched segments are moderately calcified. Distribution: Gujarat, Maharashtra, Lakshadweep.

17. ***Sargassum johnstonii:***

Common Name: Gulf weed.
Description: A group of brown algae whose initial development is along tropical shorelines, but which later break free and drift free in the open ocean where they reproduce vegetatively. Distribution: South-west Asia, Central America, North America.

18. ***Sargassum linearifolium:***

Common Name: Gulf weed.
Description: dark brown, 10–50 cm long, with a simple stipe 1–3 (–6) cm long, more or less terete, 2–3 mm in diameter, with rounded branch residues, bearing apically and radially 2–4 (–6) primary branches. Distribution: Australia and New Zealand, South-west Asia, Africa.

19. ***Padina tetrastromatica:***

Common Name: –. Description: Thallus irregularly cleft into narrow lobes in mature plants. Color: Yellowish brown becoming olive green when dried. Distribution: Gujarat, Malvan, Ratnagiri, (Maharashtra), Goa, Karwar, Honawar, Bhatkal, (Karnataka) Lakshadweep. IUCN Red List Status: Least Concern

20. ***Udotea indica:***

Common Name: Mermaid's Fan.
Description: Plants, erect, slightly calcified, very stiff. Blade cuneate to rounded, margin entire, lobed or lacerate, surface conspicuously zonate and markedly radially striated, dark to whitish green because of the calcification. Distribution: Africa, South-west Asia, South-east Asia, Pacific Islands.

21. ***Sebdenia polydactyla:***

Description: Thalli are erect from crustose bases and are tubular to bladelike in habit. The texture of many of the species is soft and flaccid, some being gelatinous. Distribution: South America, Gujarat.

22. ***Solieria robusta:***

Common Name: Blubber weed.
Description: Bunch of thick, succulent cylindrical 'stems' (about 1cm wide to about 15cm long) with side branches. There is a distinctive constriction at the base of each side branch. The tips are tapered to a point. Colours range from maroon, red, black, brownish and sometimes even greenish. Distribution: Australia and New Zealand, Africa, Asia, Pacific Islands.

23. ***Ulva reticulate:***

Common Name: Sea lettuce.
Description: The plant is attached to a substratum

throughout its life by hold fast, holdfast is a disc formed from primary cells of elongated, compact and strong nature. The layers of the cells dilate in some parts of thallus and function as air bladder. Distribution: South America, Indian Ocean Islands, Africa, South-west Asia, Asia, South-east Asia, Australia and New Zealand, Antarctic and the sub-Antarctic islands.

24. ***Spatoglossum sp:***

Description: Thalli erect, arising from a matted rhizoidal holdfast, up to 80 cm long, complanate, divided into sub-dichotomous to sub-palmate segments, 0.5-5 cm broad. Hair tufts scattered with hairs arising from a depression in thallus. Distribution: Widely distributed in tropical and temperate waters of Caribbean Sea, South America, New Zealand, Australia, Japan, French Atlantic Coast, Mediterranean Sea and Morocco.

25. ***Scinaia moniliformis:***

Description: Segments very regular, utricles 21-45 μm, polygonal in surface view. Distribution: Indian Ocean Islands, Africa, South-west Asia, Asia, South-east Asia, Australia and New Zealand.

26. ***Rhodymenia sp:***

Description: Thallus with erect or prostrate, usually stipitate fronds, arising from a basal disc or stolons, blades flattened, cartilaginous, simple or divided dichotomously, palmately or irregularly, sometimes with marginal or apical proliferations, occasionally perforate.

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Silent Stranglers:
Eradication of mimosa in Kaziranga National Park, Assam

Living at the Edge:
Rapid survey for the endangered Ladakh urial (*Ovis vignei vignei*) in Leh district of Ladakh Trans-Himalaya

Search for Spectacle:
A conservation survey of the Phayre's leaf monkey (*Tranchypithecus phayrei*) in Assam and Mizoram

Sighting Storks:
Status and distribution of Greater adjutant storks (*Leptoptilos dubius*) in the Ganga and Kosi river floodplains near Bhagalpur, Bihar

Bait and Watch:
Popularization of alternatives to dolphin oil among fishermen for the conservation of the Ganges river dolphin (*Plantanista gangetica*) in Bihar

No Mast Kalandar:
The beginning to the end of dancing with bears

Awaiting Arribadda:
Protection of Olive Ridley turtles (*Lepidochelys olivacea*) and their nesting habitats at Rushikuliya rookery, Orissa

Living with Giants:
Understanding human-elephant conflict in Maharashtra and adjoining areas

Crane Capital:
Conservation strategy for Sarus Crane (*Grus antigone*) habitat in Etawah and Mainpuri Districts, Uttar Pradesh

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Support provided to leopards involved in conflict related cases in Maharashtra

India at the International Whaling commission:
A policy document on India's involvement in the IWC 1981-2003

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Establishing the presence of hangul outside Dachigam National Park, Jammu & Kashmir

Bear Necessities:
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B. CONSERVATION ACTION REPORTS

Beyond the Ban:
A census of Shahtoosh workers in Jammu & Kashmir

Biodiversity, Livelihoods and the Law:
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A rapid assessment of the Pir Panjal markhor in Jammu & Kashmir distribution, status and threats

The Ground Beneath the Waves : (2 Volumes)
Post-tsunami impact assessment of wildlife and their habitats in India

Walking the Bears:
Rehabilitation of Asiatic black bears in Arunachal Pradesh

Mountain Migrants:
Survey of Tibetan Antelope (*Pantholops hodgsonii*) and Wild Yak (*Bos grunniens*) in Ladakh, Jammu & Kashmir, India

Predator Alert:
Attacks on humans by leopard and Asiatic black bear in the Kashmir valley – Analysis of case studies and spatial patterns of elevated conflict

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The campaign to save Vhali, the Whale Shark (*Rhincondon Typus*) in Gujarat

Tiger Country
Helping Save Bhutan's Natural Heritage

C. CONSERVATION REFERENCE SERIES

Wildlife Law:
A ready reckoner - A guide to the Wildlife (Protection) Act 1972

Back to the Wild:
Studies in wildlife rehabilitation

Right of Passage:
Elephant corridors of India

Poisons and the Pachyderm:
Responding to poisoning in Asian elephants – A field guide

Commentaries on Wildlife Law:
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Pakke Pachyderms:
Ecology and conservation of Asian elephants in Kameng elephant reserve, Arunachal Pradesh

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Conserving the forest and wildlife of the Bodoland Territorial Council

Canopies and Corridors:
Conserving the forest of Garo Hills with elephant and gibbon as flagships

D. OTHERS

Wrap up the trade:
An international campaign to save the endangered Tibetan Antelope

Tiger Bridge:
Nine days on a bend of the Nauranala

Emergency Relief Network Digest 2005 – 2006

Emergency Relief Network Digest 2006 – 2007

Action Tiger:
Tiger action plans of 12 tiger range countries

National Bear Conservation and Welfare Action Plan 2012

CONSERVATION ACTION SERIES

In the first effort of its kind, the Gujarat Forest Department, the Wildlife Trust of India (WTI) and Tata Chemicals Limited (TCL) stepped forward to conserve the coral reef at Mithapur and initiated the 'Coral Recovery Programme' in 2008. Twenty two live coral fragments were transported from Lakshadweep by ship, train and road and transplanted in Mithapur, in an experimental transportation and transplantation of extinct species '*Acropora humilis*' in Gujarat. This is the first time that a 1200 kilometre long transplantation of corals took place in India. This live coral transportation attempt challenged the belief that corals are delicate and would not survive the long distance transportation. The hard work and the innovative attempt made by WTI's West Coast Marine team at the Mithapur reef was acknowledged by the Tata Innovista- Dare to Try Award in the year 2014.

In a pioneering effort to bring in community based management and promote awareness, WTI initiated the 'Coral Rescue Programme' and conducted the 'Beach Cleaning Programme' periodically along Mithapur coast with Gujarat Forest Department, TCL volunteers, Indian Navy, Coast Guard, local fishermen community and school children. A one of it's kind 'coral garden' containing a variety of corals is being planned at Mithapur, which will be useful not only for education and tourism but also restoration of the reef.

Based on these conservation initiatives and awareness programmes, Mithapur reef's coral population has increased over the last five years. Post the successful long distance transportation and transplantation, it is now proven that '*Acropora*' corals can survive long distance transportation and can be introduced to Gujarat waters, with a few more mitigation measures to ensure their long-term survival. The prospects of coral restoration are further enhanced by observation of coral spawning in Mithapur.

Coral reefs are unexplored and germinal in India, and every year the team is discovering new species in the reef, and the generous support received from Tata Chemicals has gone a long way to make such discoveries happen.

Wildlife Trust of India
www.wti.org.in

FOREST DEPARTMENT GOVT. OF GUJARAT

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