CHAPTER 4

BIOTIC THREATS:

4.1) Algal Overgrowth

4.1.1 Introduction

One of the major biotic threats prevailing in the GoK is the growth of algae. Although algae are common inhabitants of coral reef, overgrowth of fleshy macro algae may be problematic to native coral colonies. Corals in GoK are already under high pressure from sedimentation, deforestation and industrialization, and such overgrowing macro algae further increases the pressure on these coral colonies.

Algae are usually common inhabitants of the reef ecosystem. They contribute substantially by supporting reef building, and many calcareous algae act as building blocks in creating the calcium carbonate structure of the reef over many years. "Outbreak" is a word used whenever any usually harmless species starts becoming a threat to another co-existing species. For example, *Acanthaster planci* outbreaks are very common in many parts of the world (Chesher, 1969; Branham et al., 1971; Glynn, 1973; Seymour and Bradbury, 1999). This species, while usually minimally harmful, can cause substantial damage to corals in high numbers (Endean and Cameron, 1990).

Algae are common inhabitants of the reefs and they contribute to reef building activity in many ways (Yonge, 1963; Dubinsky, 1990; Sorokin, 1993; Hallock, 1997). One of the most important contributions is the activity by unicellular microscopic algae zooxanthallae. Zooxanthallae are an important symbiont that live in the tissue cells of coral polyps. They provide nutrition, reduce wastes produced by the polyp, and help in the construction of calcareous exoskeleton

(Goreau and Goreau, 1959). Survival of polyps becomes difficult without zooxanthallae, and polyps may not be able to survive an extended period of time without them. Additionally, calcareous macro algae growing on reefs provide a substantial framework for the reef (Littler, 1976). Therefore, algae are a very important biota of the reef, and the balance between algae and corals maintains the biotic system of the reef.

The advances in human civilization have led to many changes in the natural environment. One such change is the phenomenon of global warming. Global warming has contributed towards disturbing the fragile balance between corals and algae. It has resulted in an increase in the average sea-surface temperature. Secondary to these effects, algal growth has increased worldwide. This overgrowth of algae, when exceeds the equilibrium between corals and algae, can become a threat to coral colonies (Glynn, 1993; Hughes et al., 2003, 2007). Although it has been said that this coral algal phase shift may be a local phenomenon and may not be a threat at the global level (Bruno et al., 2009), localized disturbance in the balance can cause major ecological problems in a specific region.

There are nearly 700 to 1000 different varieties of macro algae growing in tropical coastal regions worldwide (Sorokin, 1993). Depending upon the species, algae can be seasonal or perennial. The most common season for algal growth is winter. In the GoK, the algal season is from October to March, which is the post monsoon season. Thus, the water consists of high nutrients and low temperatures, and there is adequate exposure to sunlight, all the right ingredients for rapid growth of fleshy macro algae.

4.1.2 Study Area

The study area, Paga reef, is located on the southern margin of the GoK, Gujarat, India (22°29'45" N to 22°26'47" N and 69°12'12" E to 69°15'30" E). It is an offshore submerged reef with daily tidal exposure. It is also a part of the Marine National Park of Gujarat, and is therefore sheltered from anthropogenic pressures. It can be anticipated that the best corals in the GoK may be found on Paga reef, as it is away from the shore and therefore less popular for tourist and recreational activities. Moreover, the Paga reef does not have any islands in its vicinity, and therefore is less popular for fishing activities. There are also no major industries in the surrounding areas. Another important feature is that it is a submerged patch reef, which holds around four metres of water during high tides. Its location in the outskirts of the lower border of the GoK also makes it a preferred coral habitat (Bahuguna et al., 2010).

4.1.3 Methodology

Archived satellite data was traced for understanding the sequence of events leading to algal overgrowth in recent decades. The incidence of high algal growth first became evident in satellite images back in 1997, just before the global bleaching event in 1998. Following this, significant anomalies were detected in satellite images of 2002, and 2008, which showed a correlation between algal overgrowth and temperature. The image taken in 2008 is particularly relevant to the field observations conducted in this study.

Geographic and atmosphere correction was applied to all three years of data (please refer to section 3.4.2). The data was then differentiated into various reef classes to understand the distribution of the underlying substances. Initially, images were processed by unsupervised classification, followed by contextual editing to omit the spectral mixing of various classes. The final maps were generated with six different classes, namely, Reef Front, Sand Patch, Algal Ridge, Algae over Reef, Pools, and Reef Flat. Area statistics were generated for all classes, and comparative graphs were generated to understand the phenomena of algal overgrowth over the reef.

The second stage of the study was to determine the factors causing high algal growth. In order to achieve this, data of the SST from NOAA-AVHRR and NESDIS was gathered from the last 20 years. From this data, the pixel representing the GoK was identified and a temperature chart prepared for the recorded 20 years.

For SST, NOAA satellite data was used from its two sensors MODIS and AVHRR. These sensors provide SST data three hours after daily data capture. The specifications of the sensors used for SST as well as earth imagery are given in the **Table 4.1.1**.

4.1.4 Results and Discussion

The field visit was designed to allow generation of the spectral signatures of various live coral communities, and therefore, April was chosen as the ideal time for the field visit due to the availability of very low tide. Prior to the filed trip, maps were generated from previous satellite data. The most significant detail noticed on the maps was the presence of high algal growth in the reef's northern region. It was assumed that this algal overgrowth was portrayed on the satellite images because the image was taken during the peak algal season, and that during the field visit, there would be less algal growth and the coral population would be clearly visible.

During the field observations, the large area covered by flashy algae was immediately visible as the reef started getting exposed during low tide. The algal ridge was completely covered by a diversity of species of the genus *Ulva*. Upon closer inspection of the site, it was evident that a large portion of reef flat was also covered by these fleshy algae. Though the pools and reef front region continued to have flourishing coral colonies living in healthy conditions, it seemed that immediate action may be necessary to determine the causes, and assess the severity of, the algal overgrowth in the area. The field data and Global Positioning System (GPS) locations were collected for future reference and past correlations of the reef.

Due to such observations of algal overgrowth in reef areas, on return to base, laboratory tracing and interpretation of old data was conducted. The images from the years 1997, 2002, and 2008, which portrayed the largest algal cover, were identified for the study and the classification and interpretation of these images was carried out.

Classified images of all the three years were correlated and statistics for all the reef classes were generated. The following observations were noted for the three years of the study.

4.1.4.1 Year 1997

This image was taken in January, during the middle of the algal growth season. The rapid growth rate of the algae was evident by the observation that there was growth covering most of the algal ridge area, and continuing growth towards the reef flat region. The reef flat adjoining the algal ridge is especially at risk of algal inundation. The pattern of algal growth has been observed as spreading in from the North-West arm towards the centre region of the reef. The North-East area also had a prominent patch of algae on its reef flat region. The tide pools did not have a high amount of algae in them, but a big spreading patch was seen in the centre of the reef flat region. **Figure 4.1.1** shows the classified image of Paga reef from the year 1997.

4.1.4.2 Year 2002

This image was taken in March, the peak of the algal season. The image was taken during very low tide and therefore provided a more comprehensive view of the reef front. In this image, algae were found to have increased by seven percent, dominating parts of the reef flat region, while corals decreased in the reef flat region by ten percent. As it is an image taken during low tide, the sand patches and reef front regions are better exposed, and give a clearer image of the reef. As a result, the percentage area covered by the sand patches and reef front is increased. **Figure 4.1.2** shows the classified image of Paga reef from the year 2002.

4.1.4.3 Year 2008

This image was taken in May, which is typically the beginning of the non-algal season as it marks the onset of the pre-monsoon months. The sea is rough and SST is high. The image is taken during mid to low tide time, exposing a substantial portion of the reef area. As this image was taken at the start of summer, algal growth in this image is less in comparison to the 2002 image taken in March. However, a substantial amount of algae is still present in the central portion of the reef flat, and small patches can also be seen on the North-East of the reef. **Figure 4.1.3** shows the classified image of Paga reef from the year 2008.

Together with the satellite imagery, SST data was also acquired from 1996 to 2008. As mentioned previously, the first significant anomaly of algal overgrowth was seen in the year 1997, just a year before the global coral bleaching event hit many reefs around the world (Hoegh-Guldberg, 1999; Wilkinson 2004). Numerous parts of the Western Indian Ocean also experienced coral mortality on a large scale (Wilkinson et al., 1999; Sheppard 2003). It is noted that the mean temperature of the summer months of years 1998, 2002 and 2008 was considerably high, corresponding with the high amounts of algae. It is observed that for 2002 and 2007, the summer months show higher temperatures than usual, whereas in 1997, the temperature is approximately near the average mean temperature for summer months in the GoK. **Figure 4.1.4** shows the graph of SST for the GoK in the summer months.

Global warming has resulted in many adverse changes within the marine environment. The entire Gulf region is showing the effects of high turbidity, high salinity, high nutrient flow and high temperatures caused by global climate change (Vivekanandan et al., 2009). Corals are especially vulnerable to these conditions, and high temperatures inevitably lead to their bleaching (Glynn, 1993). On the other hand, high temperatures provide a favorable environment for the growth of fleshy marine algae like *U. fasciata* and *U. lactuca*, which grow rapidly over large areas (Jha et al., 2009). These overlying algae block sunlight and nutrition from reaching bleached coral colonies, resulting in further damage and eventually death of the colonies (Hughes, 1994). Over time, this can led to a phase shift from a coral-dominated to an algae-dominated habitat. Analysis of the Paga reef from 1997 to 2009 shows that, in comparison to corals, algae are growing at a considerably faster rate. The field observations documented in the form of **Plate 4.1.1** show the condition of reefs on the ground. The reef, previously home to many healthy growing corals, now has its majority of live corals limited to the reef front region only. Colonies were observed growing well in the shallow tidal pools, however the reef flat region was largely covered by fleshy algae and dead coral boulders. In certain areas, coral boulders were covered by a thin veneer of fine sediment. All these observations led to the conclusion that, reefs initially affected by sedimentation, were now being threatened by algal overgrowth. Various other species of algae were also observed at the reef front but they were not found to be harmful or overgrowing on the reef.

4.1.5 Conclusions

The interpretation of previous satellite images and SST data shows that the amount of algae growing over the reef is increasing, and the algal season is also expanding. Although a complete phase shift may not be evident due to variation in the seasonality of the algae, a clear increase in overgrowth of algae is apparent. As algal growth depends on a combination of factors, including temperature, sunlight, turbidity, salinity and nutrients, it is inappropriate to link algal overgrowth directly to the temperature increase only. However, the results from this study confirm a clear co-relation between algal growth and temperature. Thus, higher temperatures in summer months have a significant positive impact on algal growth.

In turn, these increased algae can grow over the coral colonies, which are already under threat from sedimentation. Algal overgrowth covering these coral polyps removes the potential for the recovery of these corals. If the extent of this phenomena increases, it will result in the loss of a large area of coral cover. Thus, remote sensing was used in the study to examine the correlation between the past history of the reef and the present situation.

In the case where previous field data is not available, analysis of satellite images can provide a good portrayal of the conditions prevailing in the past. Such analysis can also allow construction of an image of the future scenario, and hence help prevent further adverse effects by proper assessment and advanced planning.

The study also shows how changes in the environment can disturb the ecological balance. Previous studies have reported near-complete phase shifts in other reef regions of the world (Endean and Stablum, 1973; Smith et al., 1981; Done, 1992; Hughes, 1994; Rogers and Miller, 2006). Although this present analysis on Paga reef does not show such an extent of phase shift, it is clear that coral mortality is progressing at a rapid rate as a result.

Therefore, field observations and satellite data analysis show that climate change processes have led to an increased algal cover on Paga reef. It is also known that such devastating changes to coral reef habitats are occurring at other reef sites around the globe (Connell, 1997; Done, 1992; Knowlton, 1992;

Hughes, 1994; McManus and Polsenberg, 2004). Urgent action may be required to reverse or slow down this process.

Table 4.1.1 Specification of the sensors used for Sea Surface Temperature and Earth imagery

Sr. No.	Satellite	Sensor	Operational period	Spatial Resolution	Temporal Resolution	Radiometric Resolution	Spectral Resolution
1	NASA Aqua and Terra	MODIS	1985- July2003 current	9 km 18 km 54 km	Daily 8 days	10 bits	5 bands
2	IRS Series	LISS IV	2004 onwards	5.8 m	24 days	8 bits	3 bands
		LISS III	1996 onwards	23.5 m	24 days	8 bits	4 bands

Figure 4.1.1 Classified map of Paga reef: Year 1997

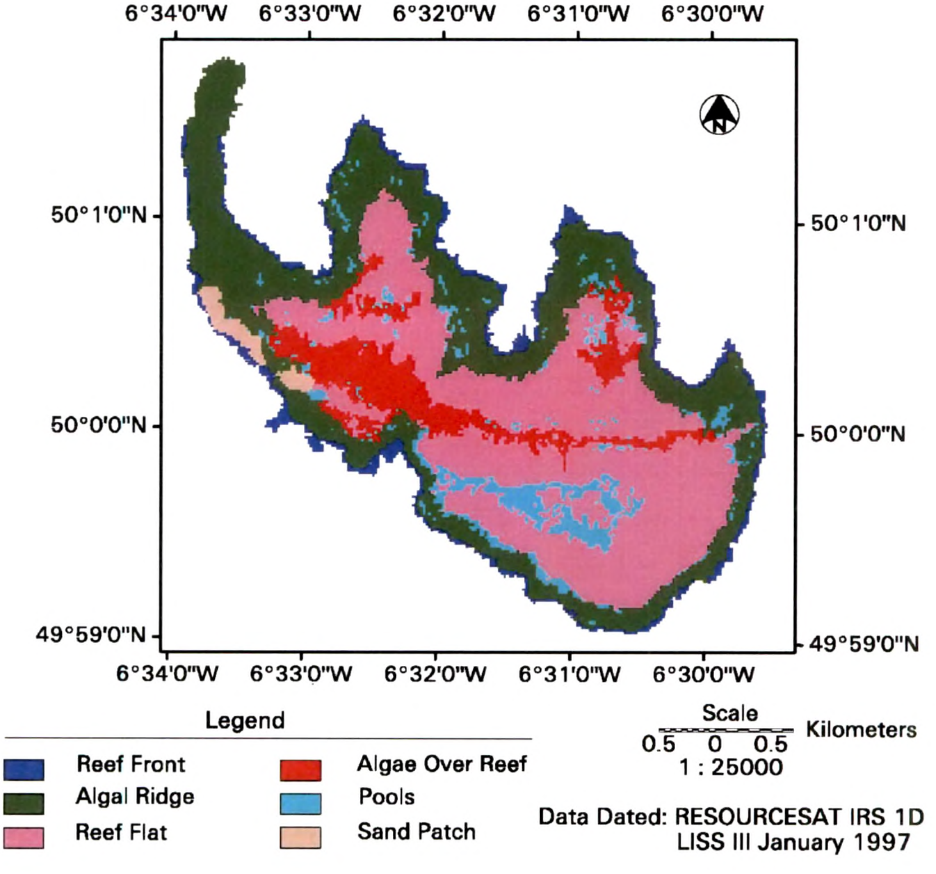


Figure 4.1.2 Classified map of Paga reef: Year 2002

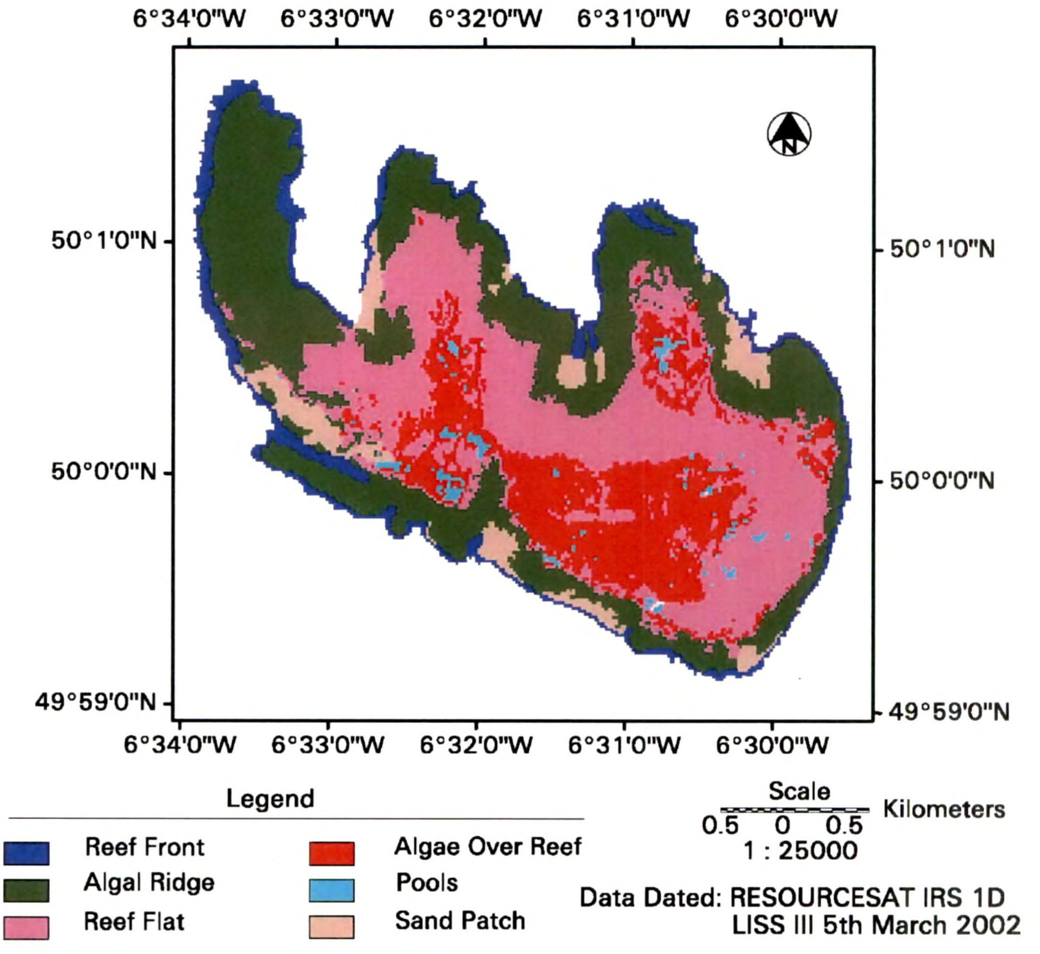


Figure 4.1.3 Classified map of Paga reef: Year 2008

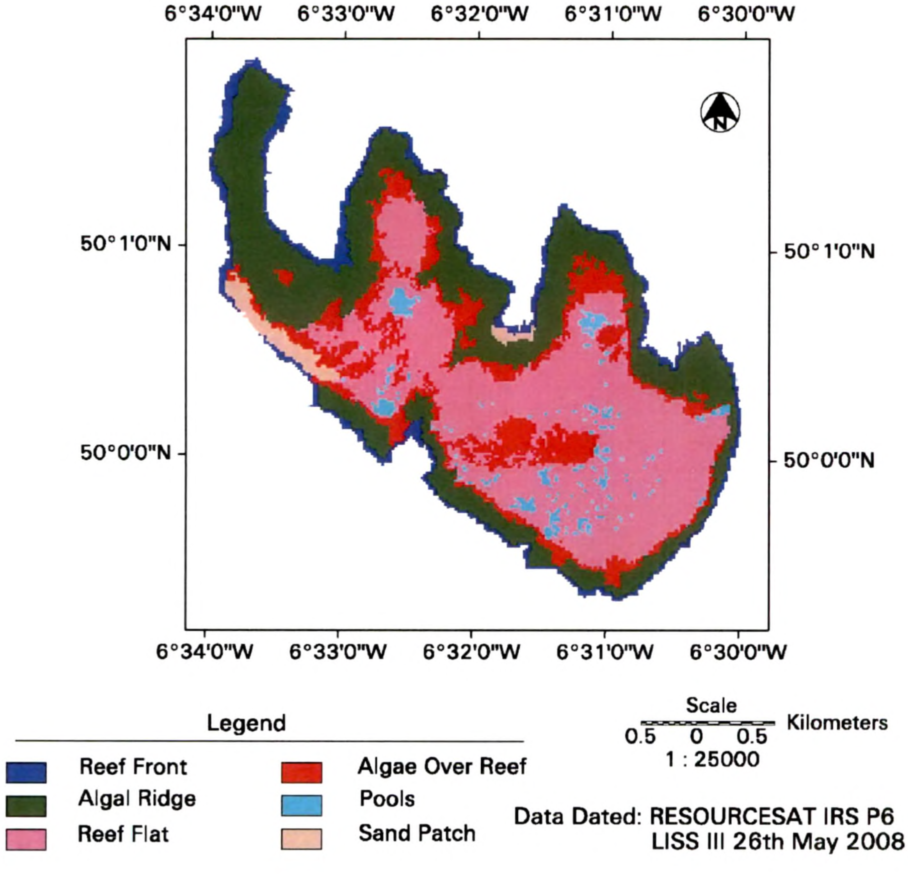


Figure 4.1.4 Graph showing Sea Surface Temperature of summer months from 1996 to 2008 for the Gulf of Kachchh (the median line is showing the mean SST for the GoK)

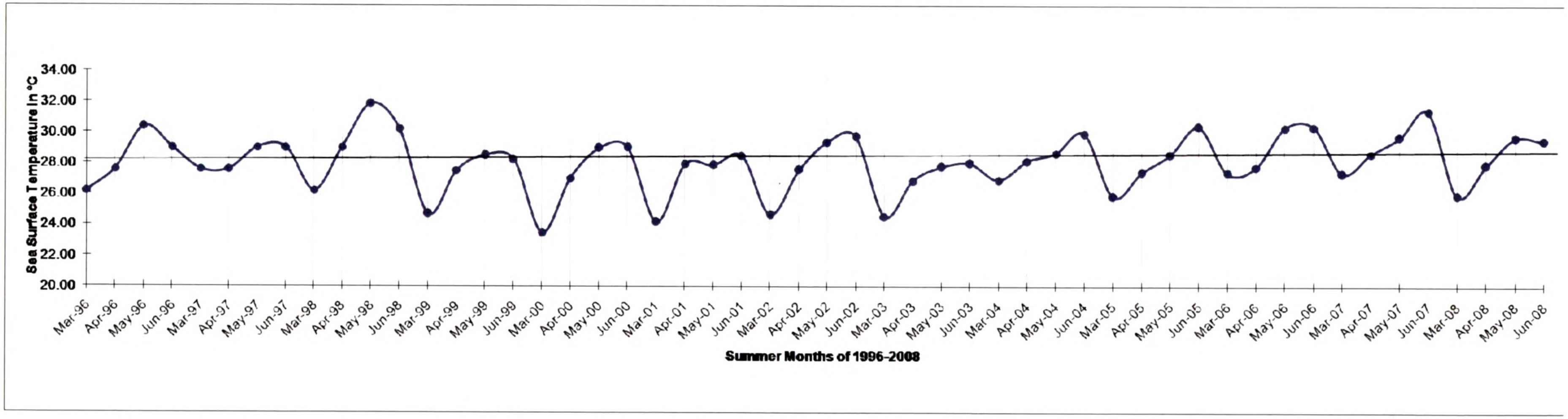
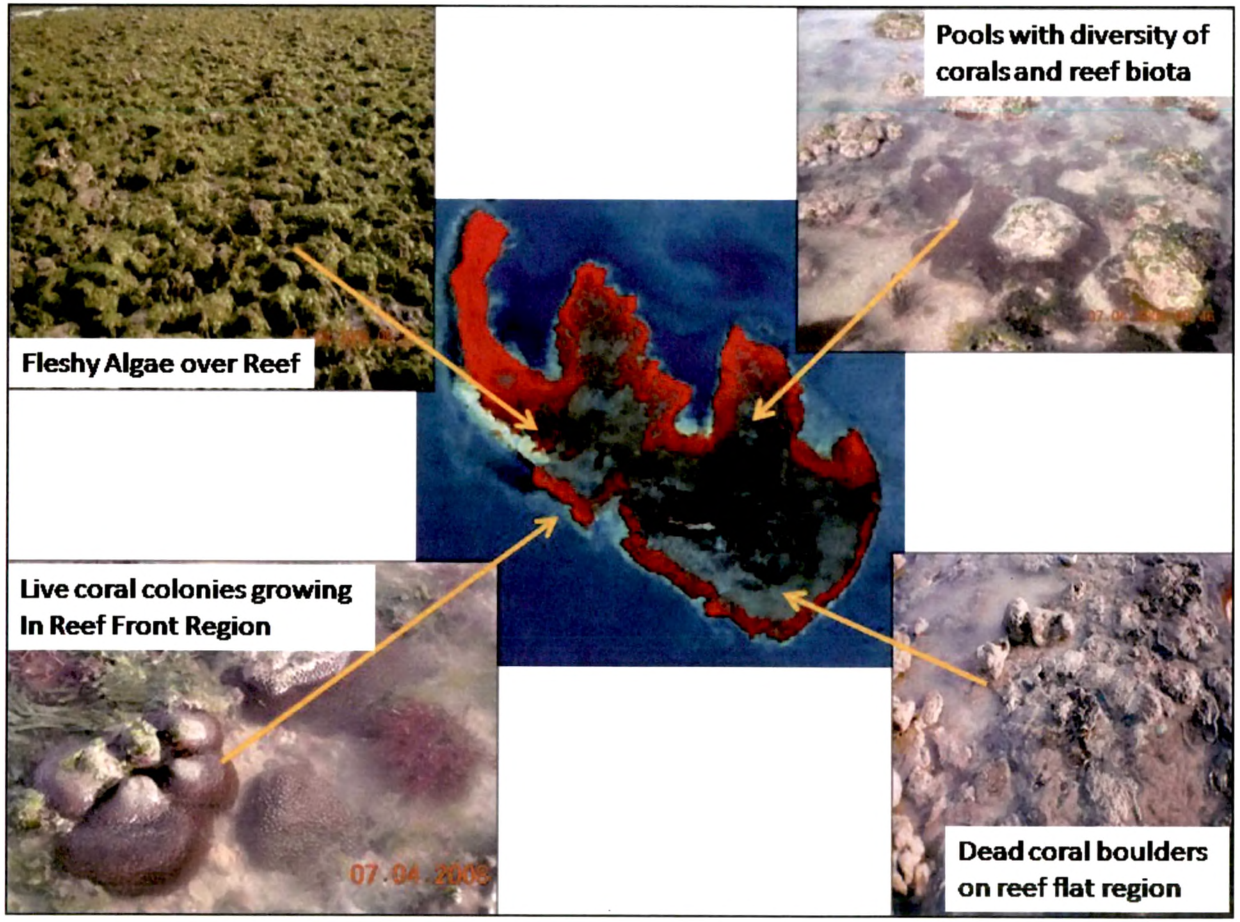


Plate 4.1.1 Differential Reef Structures as seen on the ground and on Satellite image



CHAPTER 4
BIOTIC THREATS:
4.2) Impact of Zoanthid- *Palythoa*

4.2.1 Introduction

Palythoa has its distribution in the Caribbean Sea, Florida and Western Indian Ocean reefs, but has not been recorded in the GoK. The GoK is one of the four major coral reef regions of India. Although there are minimal records of the genus *Palythoa* from the Indian coastline, a report of the genus was mentioned in 1909 by James Hornell in his work on Marine Zoology of Okha Mandal. This record has only one photograph of the species with its name and location mentioned in a plate (Hornell, 1909). After 1909, no other literature mentions the presence of *Palythoa* from either the GoK or other parts of coastal Gujarat. Some literature cites it as a species of coral, which is actually misleading. *Palythoa* has been very often misunderstood for coral due to its mat-like appearance over the reef flat regions. In many places, especially in aquarium stores, it is sold as a "starter coral", as its rapid growth of upto 2.5 millimetre/day and adaptability to harsh conditions makes its growth in aquarium tanks very easy (Suchanek and Green, 1981). Hence, mystery surrounds this genus, and this is the first study from the Indian coastline to examine the species in more depth.

4.2.2 Study sites

In this study, the first sighting of *Palythoa* occurred in February 2008. It was observed on the coast of Dwarka near the lighthouse. The first sight observation was an accidental encounter of the species, without any prior information about it. As there is very little evidence in the literature available for this species from the Indian coast, *Palythoa* was considered to be some species of coral, due to its similarity in appearance with Hermatypic corals. Widespread colonies of the species were noted, and photographs were taken to correctly identify the species. Extensive research failed to identify this species (Veron, 2000). After further analysis, it was clear that this species belonged to the genus *Palythoa*, from Phylum Coelenterata, Class Anthozoa, Order Zoantharia, and Family Sphenopidae (Reimer et al., 2007). Review of the literature showed this to be a very common inhabitant of the reef. In subsequent visits, more information was gathered on this genus, including distribution, morphology, habitat and effects on neighboring biota.

Although *Palythoa* is considered to be a silent inhabitant in most areas of the world, it can be notoriously conspicuous sometimes due to its inherent property of producing **Palytoxin**. It has been found to be competing for space with other reef inhabitants, including corals, sponges and other Zoanthids. During the survey, it was found out that there were two different colonies of two slightly different species. They were *Palythoa tuberculosa* and *Palythoa mutuki*. Both the species have a wide distribution along the

Dwarka coast (Bhattji et al., 2010), and later, it was also found to be present on other reefs of the GoK, including Bural Chank, Paga and Narara reefs.

On the Saurashtra coast, *Palythoa* has been observed at Dwarka, Narara and Bural Chank reef **(Figure 4.2.1)**. The location around Dwarka is a rocky shore outside the Marine National Park **(Plate 4.2.1)**, whereas for the other two locations, the reefs are within the Marine National Park. Around the intertidal regions of Dwarka's lighthouse (22° 14' 35" N – 68° 57' 17" E), an area of 500 metres by 100 metres is covered by various intertidal organisms. These include various sponges, cnidarians, molluscans, arthropods, echinoderms, fishes and a variety of genera of algae. Among them, large colonies of *Palythoa* have been observed growing on rocks and in shallow water pools **(Plate 4.2.1)**. The growth rate of the colonies was observed to be very high.

4.2.3 Observation

Palythoa is a very versatile genus. More than 193 species have been reported (Fautin, 2006), and due to its heavy sand encrustation (Mueller and Haywick, 1995), as well as large inter-specific variations in morphology, species diversity, identification and taxonomy within this group is still under discussion amongst scientists worldwide (Muirhead and Ryland, 1985; Ryland and Muirhead, 1993; Burnett et al., 1994). It is possible that many zoanthid species are invalid due to an inadequate description (Burnett et al., 1997) and many *Palythoa* species may well be among them.

4.2.3.1 Classification with characters

Palythoa is a very common aquarium animal, although it is considered good "starter coral" and often misclassified with other scleractinian corals. A detailed characteristic till the Subclass Zoantharia /Hexacorallina is well known. The characteristic features of order, suborder, family, genus and species are given in detail below:

Domain: Eukaryota

Kingdom: Animalia

Phylum: Coelenterate (Cnidaria)

Class: Anthozoa

Subclass: Hexacorallia (Zoantharia)

Order: Zoantheria

Family: Sphenopidae

Genus: *Palythoa*

Species 1: *tuberculosa*

Species 2: *mutuki*

Order: Zoantharia – Colonial anemone like polyps with one siphonoglyph. There is no basal disc but they attach themselves by inserting their pointed aboral pole into the substratum.

Suborder: Brachycnemia – Mostly zooxanthellate, 5th mesentery incomplete from dorsal side, non epizoic on other living organisms.

Family: Sphenopidae – Encrusted with sand or other particles often visible upon close examination, outer column surface rough to touch.

Genus: *Palythoa* – Inhabits shallow reef areas with bright lighting conditions. It prefers moderate to strong currents, hence is found in areas of reef crest and reef fronts. This genus is fairly resistant to high turbidity, high nitrates, phosphates and poor water quality conditions, allowing them to grow well in canals, harbors and intertidal areas with a high sediment load. Characteristically, there is an overgrowth of *Palythoa* on rocks and dead reef areas, but it can also overgrow neighboring invertebrates including scleractinian corals (Suchanek & Green, 1981). Its overgrowth and subsequent homicide of the native colony occurs with the help of an allelochemical (neurotoxin) known as 'Palytoxin'. This Palytoxin is used in many pharmaceutical research as it is described as the most potent non-protein marine toxin (Mueller and Haywick, 1995). This toxin is used by the organism to protect itself from predators and to acquire sufficient space on the reefs (Suchanek and Green, 1981). *Palythoa* also contains zooxanthallae in its epidermal tissue. Therefore its distribution is strongly light-dependent (Mueller and Haywick, 1995). It is sensitive to increases in temperature, as it is generally the first one to show temperature-induced bleaching, and so can act as an early bleaching indicator for corals (Kemp et al., 2006). Despite of this, it is very common in zones of high sediment deposition

(Haywick and Mueller, 1997). This genus has been identified as a sediment assimilator as it stores fine sediments in its mesogloea tissue (Muller & Haywick, 1995). The purpose of sediment assimilation is for tissue strengthening, allowing the *Palythoa* to have greater rigidity and therefore become more resistant to waves and currents of reef crest. *Palythoa* acquires its nutrition via two methods – one is with the help of zooxanthellae and the other is capture of live prey with the help of its tentacles (Amada, 1970). The nervous system of the *Palythoa* consists of the primitive nerve net type. The *Palythoa* can reproduce both asexually and sexually. *Palythoa* has a high reproductive rate and is very aggressive in nature. The growth rate of *Palythoa* varies according to the defence mechanism of other competent species. Asexual reproduction is through colony fission which happens all year round. Sexual reproduction is believed to occur between April and May (Acosta et al., 2005). It is hermaphroditic and broadcast spawn.

There are two species of the genus *Palythoa* existing in this area. They are *P. tuberculosa* and *P. mutuki*. The characteristic features of both are as follows.

4.2.3.1.1 *Palythoa tuberculosa*

P. tuberculosa are colonial animals, forming large light yellow to brown colonies, with tentacles open day and night. Covering the mouth is a ring of tentacles which is brown in color. The colonies are rough to touch, and all the polyps are embedded into a well developed coenenchyme storing the sediment particles into it. Polyp size is >5 mm, and they are often open during the daytime (Reimer, 2010) **(Plate 4.2.2)**.

4.2.3.1.2 *Palythoa mutuki*

While this is also a colonial species, *P. mutuki* form smaller colonies with larger polyps. The polyps are dark brown in colour, with green oral disks. Colonies are composed of several polyps living close to each other, but are loosely attached to each other by coenenchyme. Polyp size is 8-10 mm, with polyps often opening during the daytime (Reimer, 2010) **(Plate 4.2.2)**.

Both *P. tuberculosa* and *P. mutuki* are present in nearby surroundings and compete with each other for space **(Plate 4.2.3)**. Both species release one of the most potent non-protein poisons, Palytoxin, in their body secretions, as do all other species of the genus *Palythoa.* An additional important differentiating feature of the species is the presence of coenenchyme.

Palythoa is a colonial animal and it reproduces by asexual and sexual reproduction, which is described below.

4.2.3.1.3 Asexual reproduction

The majority of the *Palythoa* colonies reproduce asexually by binary fission (Fautin, 2002; Acosta and González, 2007). In Cnidaria, new colonies can be formed asexually through several mechanisms, including polyp bail-out (Sammarco, 1982), coral polyp expulsion

(Kramarsky et al., 1997), fragmentation (Highsmith, 1982), asexually produced planulae (Fautin, 2002), and colony fission (Pearse, 2002) among others. Fission is the primary mode of asexual reproduction in zoanthids (Tanner, 1999), and plays an important role in population size (Tanner, 1999), population dynamics (Acosta et al., 2005), and population structure in several species (Karlson, 1991).

4.2.3.1.4 Sexual reproduction

Past studies report that mass spawning of the egg and sperm occurs at night in July, within five days following a full moon. This indicates that spawning occurs in summer, with high tides during full moon resulting in higher chances of dispersal of the eggs and sperm. The literature also reveals that such events are sometimes closely related to the time of spawning of other scleractinian corals. (Shiroma and Reimer, 2010)

4.2.4 Results and Discussion

Palythoa was first observed at the Dwarka intertidal areas in February 2008. Later, it was also found along the Bural Chank and Narara Reefs of the GoK. Small colonies were observed in the month of April 2008, which was believed to be the initial stage of colony development. As there is little natural control over *Palythoa*, it could rapidly spread over other areas of coral reef habitat. Keeping in mind its faster growth rate and its ability to overgrow on natural coral community, there is an immediate need to study its distribution on the other sites of Bural Chank reef as well as other reefs of the Marine National Park.

The identification of *Palythoa* was carried out in consultation with Mr. M. I. Patel, Coral expert of Gujarat and Dr. J. D. Reimer of Japan. The two species that were confirmed after discussion are *P. tuberculosa* and *P. mutuki*.

Both these species of *Palythoa* were observed to be growing in close association with each other. Both were first observed to be growing on the rocky shore of Dwarka (22° 14' 35" N- 68° 57' 17" E). This rocky stretch of around 500 × 100 metres is occupied by many colonies, both small and large, of both species of *Palythoa*. The extent of smaller colonies varies from 2 to 4 inches, and for large colonies, this rises to 1 to 2 metres, with distribution of approximately 25 polyps per 1 square inch. At many locations, both the species were observed to be in competition with each other for space.

Palythoa is present in a larger extent in the intertidal areas of Dwarka that is located outside the Gulf, while only a small amount is present on the reefs. Those colonies present on the reefs may be considered as starter colonies.

An important question that may be raised is the reason why *Palythoa* remained undiscovered until recently. Additionally, the reason why it did not enter the Gulf despite being so close to the location is another common question. Both of these occurrences can be explained by the hydrodynamics of the region, and the flow of the currents in the area. Dwarka is located outside of the Gulf on the lower margin, and falls on the southern side of the entry point of the Gulf. As seen in the **Figure 4.2.1** the flow of the water current enters the Gulf from the northern margin and leaves the Gulf from the southern margin. Due to these phenomena, the flow of the current does not allow water from Dwarka that is directly attached to the Arabian Sea, to go towards the southern margin of the GoK, where all the reefs are located. The free-floating larvae of the genus *Palythoa* can swim long distances and thus, traveling the distance of the 20-60 kilometres is fairly easy for them. However, because they float with the water currents, the hydrodynamics of the Gulf does not allow them to reach the reefs.

The reason this genus was considered for this study was due to its aggressive nature and its competition with all the organisms within the vicinity. The genus had gone unnoticed for many years, and the damage that has been done has also escaped knowledge. This study builds on previous literature that shows that *Palythoa* is a very aggressive intruder of reefs. It has harmed reefs worldwide (Suchanek and Green, 1981). The main mechanisms of harm have been through competition for space, and hostility towards any other species that come towards it. It also shows high inter-specific competition. The competition of *Palythoa* with scleractinian corals was observed to be at only selected locations in Dwarka. However, it is highly likely that they may become a potential threat for the entire coral reef region. Previously, they had not entered the coral dominated islands situated in the sheltered environments of the Gulf. However, presently, a few small colonies of the *Palythoa* have been observed, at Bural Chank (Bhattji et al., 2010) and Narara (Dave, 2011). Despite their small size, these colonies possess the ability to cause substantial damage to corals, which are already exposed to many other biotic and abiotic threats.

There are no reports in the literature regarding the presence of *Palythoa* in Indian waters, except for one report in 1909 by James Hornell in "Report to the government of Baroda on the marine zoology of Okhamandal in Kattiawar". In the last few decades, no other author or agency has mentioned this genus, and no other description of this genus has been found during a comprehensive literature review. Hence, it is concluded that the observations from this study provide a new record of zoanthids in this region. Contemporary technology and precise photographic evidence has been incorporated with appropriate investigations to confirm the organism is indeed *Palythoa*. This is the first report to do so, as no scientific work has been done to confirm its presence in this region after 1909. Therefore, identification and scientific information about the genus is from various foreign authors and a variety of articles about their taxonomy, ecology, toxicity, and competition were used to study the organism.

The distribution of *Palythoa* is highly species dependent. For example, *P. mutuki* prefers low water movements and wave actions, and therefore occupies back reefs, lagoons and inner intertidal reef areas. In contrast, *P. tuberculosa* is found to exist in areas of high water currents and wave actions, near outer reef flats, reef crest and reef slope.

The rocky surface is the preferred location for the settlement of *Palythoa* larvae, but they can also grow on dead reef and any hard substratum. As it is an intertidal organism, many other organisms also live in the same area. These include a variety of Sponges, Zoanthus, sclerectinian corals, and various algae such as Caulerupa, Hypnea, Scinaia, Sargassum, Acanthophora, and Amphiroa.

Palythoa occupies large colonies on the rocky intertidal areas of Dwarka. An attempt was made to survey it with the help of remote sensing. However, due to the coarse resolution of the sensor, it was difficult to get an accurate remote sensing comparison. In order to understand its habitat structure, satellite images of the area were obtained and studied. The observations reveal that Dwarka is located outside the Gulf on the Saurashtra coast in the Arabian Sea. Hydrodynamics of the area show that the majority of the water entering the Gulf is from the northern coast. Hence, there is very little influence from the southern margin. This is possibly one of the major causes for the localized distribution of the species. However, the presence of *Palythoa* only in the Dwarka region raises the question for reasons behind its limited distribution. As outlined above, possible causes of these phenomena are the effects of high turbidity, high salinity, and habitat preferences of the species. As previously discussed, *Palythoa* polyps are resistant to high turbidity, but the settlement of larva is altogether a different phenomenon. When polyps release their eggs and sperm into surrounding sea water, fertilization takes place in the sea water, and the first stage development is the Planula larvae. This larva is a free floating form, which swims freely in the water until it finds suitable substratum to establish a new colony. Once it has found an appropriate location, the larva settles there and divides asexually to form a small colony. This colony is then stationary, and grows within its own habitat. The settlement of larva is highly dependent on the condition of the substratum, and hence a suitable substratum must be selected carefully. This whole process is very important for the establishment of a new colony and widespread distribution of the species. Larvae are very delicate and cannot withstand adverse environmental conditions such as high turbidity and salinity. Moreover, they prefer only hard substratum, and cannot settle on the soft moving substratum. The GoK reefs have been facing a problem of sedimentation for many decades, and therefore have little hard substratum directly exposed for larval settlement. This makes it very difficult for the growth of the *Palythoa* species to be established inside the Gulf.

Another important point for the settlement of a new colony is the amount of competition engaged with more resistant species. Hard coral species living in the highly turbid environment of the GoK are more resistant and have better potential to survive and settle in the reef habitat than *Palythoa*. All these factors have contributed to keep *Palythoa* out of the GoK. Although they have been observed after almost a century, *Palythoa* have succeeded in entering into a reef habitat. As result, they are a direct competitive threat to established corals, and are an obvious concern for coral conservationists.

Small colonies of *Palythoa* have also been observed at Bural Chank and Narara reefs of the Marine National Park **(Plate 4.2.4)**.

The *Palythoa* species create a tough and rigid colony of members which are highly territorial. They overgrow all the organisms that come into competition with the colony (Suchanek and Green, 1981). The powerful toxin, Palytoxin, is the reason for its superiority (Bastidas and Bone, 1996; Mendonça-Neto and Gama, 2009). It has also been observed that inter species competition is also very high within this genus. Both the species *P. tuberculosa* and *P. mutuki* are in competition for space at the Dwarka intertidal area **(Plate 4.2.3)**. The literature reveals that *Palythoa* has proved to be a threat to various other reef organisms including corals (Bastidas and Bone, 1996; Mendonça-Neto and Gama, 2009). Until recently, it was misunderstood as coral, and therefore minimal attention was paid to the risk it posed. Now that it is known that it acts as a direct threat to corals **(Plate 4.2.4)**, and is present inside Marine National Park boundaries, special care should be taken to protect the valuable ecosystem of corals. *Palythoa* is also an active predator on zooplanktons. In the coral reef ecosystem, they feed mainly on the settling larvae of various coral species. The coral larvae come near the reefs to settle after the initial floating movement. *Palythoa* is an active feeder at this time and can contribute significantly in reducing the number of larvae (Fabricius and Metzner, 2004).

Because of the presence of Palytoxin in the mucus produced by the polyps, it is almost impossible to have a good biological control over *Palythoa*. However, turtles of certain species still manage to feed on these organisms.

Hawksbill turtles (Leon and Bjorndal 2002; Stamper et al., 2007) are thought to be able to digest these non protein molecules. The structure of Palytoxin, though not yet confirmed, is a complex multi carbon chain (Ciminiello et al., 2011), that is a variant of another toxin in a found in a different genus of *Palythoa* (Moore and Bartolini, 1981). The proposed structure of the Palytoxin till date has been given in **Figure 4.2.2.**

Therefore, due to the little biological and ecological control possible over *Palythoa*, the species can prove to be a major threat to reefs and their biota.

Figure 4.2.1 Location map of the areas of *Palythoa* habitat, along with the hydrodynamics of the Gulf of Kachchh

Figure 4.2.2 Chemical structure of Palytoxin (adapted from Ciminiello et al., 2011)

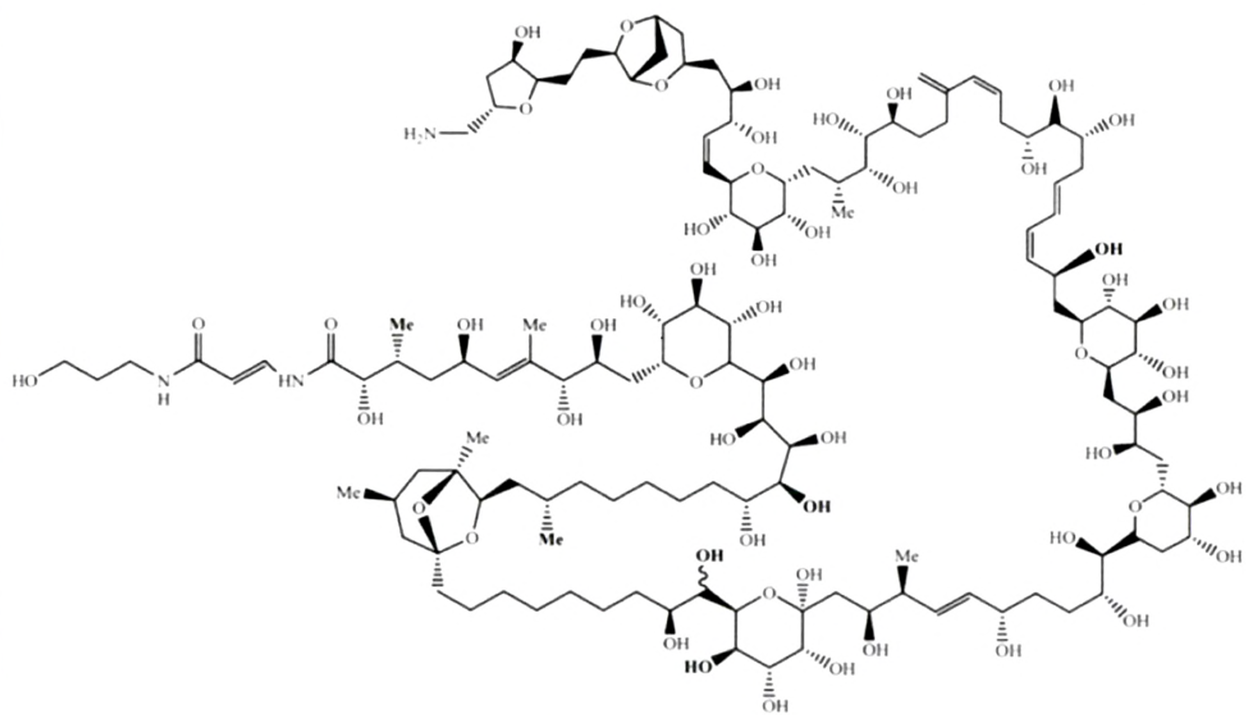


Plate 4.2.1 Habitat of *Palythoa*

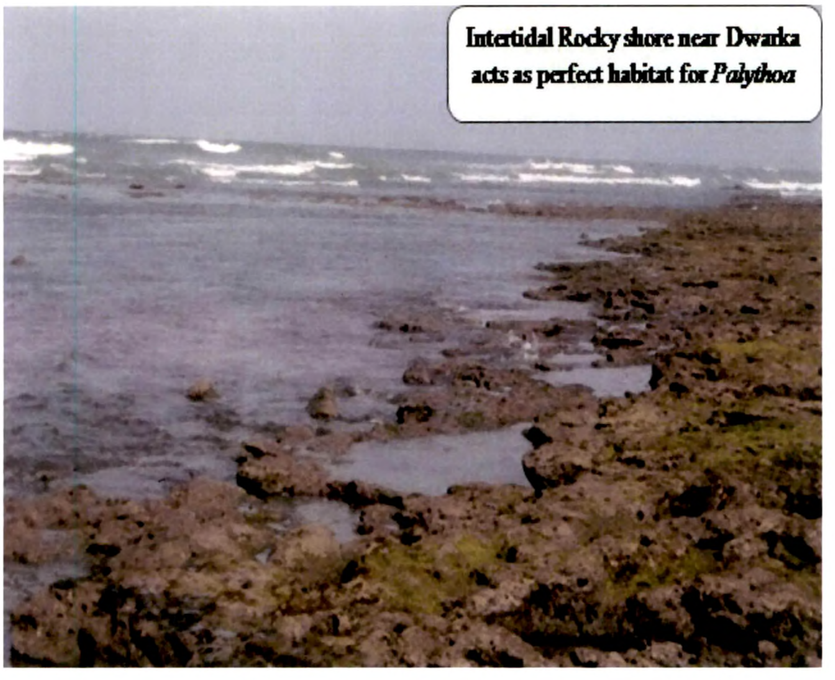
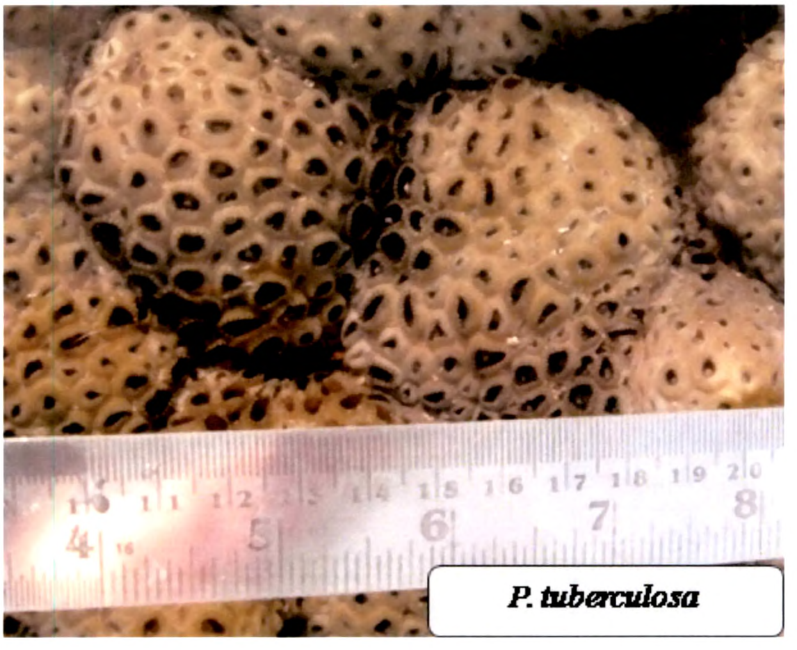


Plate 4.2.2 *P. tuberculosa* and *P. mutuki*



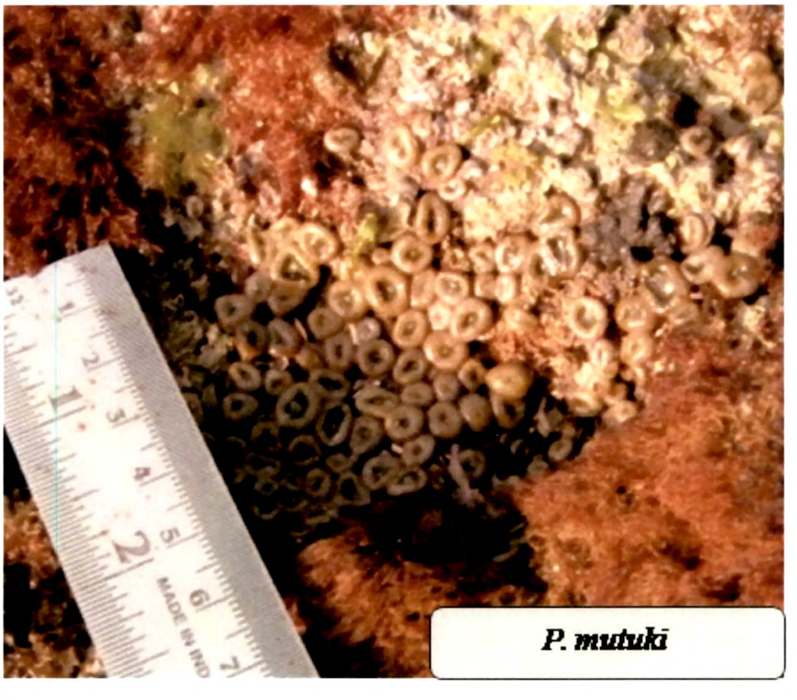


Plate 4.2.3 *P. tuberculosa* overgrowing polyps of *P. mutuki*

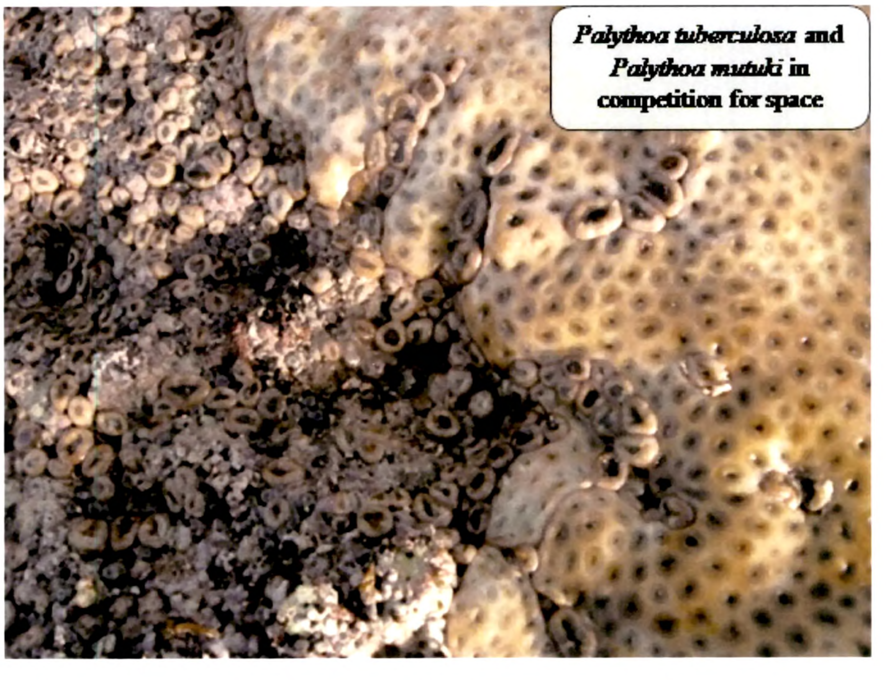


Plate 4.2.4 *P. tuberculosa* overgrowing live corals