CHAPTER 3 DIVERSITY OF ZOANTHIDS

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3.1 INTRODUCTION

Dana (1846) explained for the first time as possessing leather like external feature with no corallum within and radiated margins of the disk are the most striking peculiarities of the Family Zoanthidae. However, the description was inclusive of the genus termed *Zoantha*, *Isaura* and *Palythoa* and only one family was described. The first identification characters taken into consideration by Dana, 1846, were by their mode of budding and growth. As described in his work, the form of the colonies was similar to that described recently by Reimer *et al.*, (2006). Four species of Genus *Isaura,* five of Genus *Zoantha* and ten of Genus *Palythoa*; of which except two species *Z. sociata* and *P. caesia*, all others have been modified. The rest species have either been modified updated using recent taxonomic accounts.

Zoanthids are conspicuous representatives in inter-tidal regions, commonly found on reefs, rocky coastal substratum as well as infra-littoral zones of the tropical regions (Sebens, 1982; Ryland and Babcock, 1991). The organisms possess two rows of tentacles, are typically colonial, with a single ventral siphonoglyph and detritus encrustation in the mesoglea of some representatives of this family (Fujii and Reimer, 2011). The order comprises diverse families and various genera, among them *Isaurus, Palythoa, Protopalythoa*, and *Zoanthus*, which can be found in agitated as well as calm waters as polyps typically colonial and genera *Acrozoanthus, Parazoanthus* and *Epizoanthus* are commonly found associated with sponges, hydroids, gorgonians and polychaetes (Ryland and Muirhead, 1993). Major Zoanthids have been identified and studied from Indo-Pacific regions and Caribbean regions (Reimer *et al.*, 2006, 2008, 2012; Burnett *et al.*, 1997) (Table 3.1)

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3.2 IDENTIFICATION OF ZOANTHIDS

Morphologically Zoanthid taxonomy is characteristically based on polyp structure and coenenchyme characteristics **(Fig. 3.1)** described by Pax (1910), after Dana (1846). Adding to it the sphincter muscle anatomy and colour differentiation by Lwowsky (1913), the tentacle number to the identification character by Herberts (1972), the taxonomy was re-described. After this classification, not much work on the identification and classification was carried out. Inclusion of the nematocyst type and their distribution amongst the Zoanthid species, descriptions were given by Ryland and Lancaster (2003) and Fautin (2009). During this period extensive studies were carried out specifically on Zoanthids by Reimer and his co-workers from Japan (Reimer, 2004; 2006a; 2006b; *et al.*, in 2008; 2009). Later, a dichotomous key was prepared by Reimer (2010) on the Zoanthids of Okinawa, which is now useful for the general identification of these Zoanthids. Also, other keys were generated with respected to the study sites and publish by him and his co-workers from the tropical regions of the world. Burnett *et al.* (1997) produced a key to Zoanthids of Great Barrier Reef and Torres Strait describing 8 different non breeding groups; Cortes (2009) described from Costa Rica; Fautin (2003) described the hexacorallians of the world inclusive of the Zoanthids. All the research groups have emphasized on the difficulty in identifying *Zoanthus* species based on morphology alone and therefore molecular techniques are being utilized for the proper phylogenetic classification since then. Thus, depending on various authors, the descriptions were based on different characters, maintaining the major characters of mesentery and septa common. The taxonomy thus being in chaos and no complete list could be generated.

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Previous studies have described the presence of zoanthids in the Indian coast (Rao *et al*., 1989; Babu *et al*., 1997; Lakshmi *et al*., 2004; Parmeswaram *et al*., 2001, 2005; Ali, 2010; Kaladharan *et al*., 2011) but only for biochemical studies and physiological processes. Zoanthids were seen to increase in the past decade and covered almost entire intertidal zone (Pandya *et al*., 2014). Therefore zoanthids were studied as key species. Ecological assessment of their interactions with other macro benthic flora and fauna was studied.

Morphological changes are being induced in this group as these organisms are light dependent (Reimer *et al*., 2006; Burnett *et al*., 1997; Todd, 2008; Otaki *et al.* 2012). The colour card technique has been used for Scleractinian corals to examine and assess the bleaching, however has not been tested on other zooxanthellate anthozoans like zoanthids (Hibino *et al*., 2013). This proves to be an effective tool for the assessment of zoanthid and their colour morphs (Plate: 3.11).

As per Reimer (personal communication), zoanthid showing similar characteristics to a Genus but not exhibiting typical characteristics of that species, were termed using *aff.* (*Latin: Affinis*) And *cf.(Latin: conferre)* to ease the identification process.

3.2.1 SPECIES IDENTIFICATION AND DOCUMENTATION:

The identification to genus or species level was based on the descriptions of external characters: macroscopic morphology inclusive of number of tentacles, height and diameter of polyps; colour patterns of tentacles, oral disk, column, and

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coenenchyme; and internal characters using histological techniques.(Table 3.2, 3.3)

3.3 ZOOXANTHELLATE ZOANTHID SPECIES

Taxonomic account of Zoanthids has been mystified due to increased levels of morphological variation with and between the species. The following description is on the Zoanthids observed at the Saurashtra coast, followed by their colour morphs and morphotypes.

3.3.1 FAMILY SPHENOPIDAE

This family comprises of Genus *Palythoa, Protopalythoa* and*Sphenopus* known to be spread worldwide with numerous species. Colonies may be of solitary polyps or polyps embedded in a thick coenenchyme (Plate: 3.6A, B, C). The solitary species is Genus *Sphenopidae* and was not observed in the present study. However there is ambiguity between the presences of *Protopalythoa spp.* as it may be the *Palyth*oa sp. variant.

3.3.1.1 Genus *Palythoa* (Pax, 1900)

There are 107 species of Genus *Palythoa* previously described in the literature (Hibino *et al.*, 2014). Many species of Palythoa were described in the twentieth century, primarily by Pax (30 species described between 1908 and 1957) and Carlgren (20 species described between 1900 and 1952) as both of them examined specimen from expeditions to various parts of the world e.g., West Africa, Australia. However, it is likely that the true number of species is much lower due to high levels of morphological variation within species and inadvertent re-

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descriptions (Burnett *et al.*, 1997; Reimer *et al.*, 2004). Besides Ryland and Lancaster (2003), there has been no major taxonomic revision of this group since the first half of the twentieth century. *Palythoa* was the only genus observed along the entire study area and a few colonies showed characteristics similar to the Genus *Protopalythoa* which has its distribution in the Caribbean Sea, Florida and Western Indian Ocean reefs. There has 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. Although there are minimal records of the genus *Palythoa* from the Indian coastline, a report of the genus was mentioned by James Hornell (1909) in his work on Marine Zoology of Okha Mandal. After this no other literature mentions the presence of *Palythoa* from either the GoK or other parts of coastal Gujarat. The first sighting of *Palythoa mutuki* and *Palythoa tuberculosa* after Hornell was made by Bhattji *et al.*, (2010) along the Dwarka coast. The next reports were by, Dave (2011), Pandya *et al.* (2013), Adhavan *et al.*, (2014) along the Saurashtra Coast at four sites and Gulf of Kachchh. *Palythoa* colonies are seen to be dominant in the supra to mid littoral zones. The polyps are immersed in particle impregnated coenenchyme giving overall beige to pale yellow appearance, although the polyps are themselves are often darker. Colonies are often convex in shape and rarely exceed 30cm diameter. *Palythoa* is tolerant to change in the water currents and exhibits tolerance towards turbidity and high nutrient levels, therefore these organisms grow in tide pools intertidal areas with a high sediment load (Bhattji *et al.*, 2011).

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Palythoa morphs- *Palythoa tuberculosa, P. caesia, P. mutuki, P. heliodiscus, Palythoasp.*

1. ***Palythoa tuberculosa Klunzinger 1877***

(Plate 3.7: A, B)

Palythoa tuberculosa (Esper, 1805), initially *Alcyonium tuberculosum* from Tranquebar (now Tharangambadi) (Hibino *et al.*, 2013), India was described as colonies with a leather-like surface and yellowish-brown coloration. *P. tuberculosa* are colonial animals, forming large light yellow to brown colonies, with tentacles open day and night. After Esper, Ehrenberg in 1834, described species similar to that from the Red Sea viz., *P. flavoviridis* and *P. argus*. To the aforesaid descriptions and records, Klunzinger (1877) again described *P. tuberculosa* and synonymised the two species. Klunzinger's (1877) description showed that *P. tuberculosa* inhabited the upper intertidal zone with colonies 5–20 mm in thickness and showing uneven, tan surface. The following were the measurements described in his records: 30–40 tentacles, 1–6 mm height and 5–7 mm diameter, however, the type of organisms studied were not described as preserved, live or dried. *P. tuberculosa* is currently the most used nomenclature for species from Indo-Pacific region including those from Red Sea (Erhardt and Knop, 2005; Polak *et al.*, 2011), Oman (Erhardt and Knop, 2005), the Maldives (Erhardt and Knop, 2005), India (Esper, 1805), New Caledonia (Sinniger, 2006), Singapore (Reimer and Todd, 2009), Palau (Erhardt and Knop, 2005), Taiwan (Reimer *et al.*,2011), Japan (Yamazato *et al.*, 1973; Reimer *et al.*, 2006b, c, 2007b), Hawaii (Hoover, 1999), and the Galapagos (Reimer and Hickman, 2009).

Polyps "immersae", just extending above the well developed coenenchyme. Oral disks often closed during the day time with coenenchyme white to dark brown and

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generally uniform in color. Covering the mouth is a ring of tentacles which is brown in colour. The colonies are rough to touch, and all the polyps are embedded into a well developed coenenchyme storing the sediment particles into it.

P. tuberculosa appears to have two major growth forms viz. “massive encrusting” and other being “small and rounded”. The colony and polyp colours are tan or brown, although patchy bleaching is sometimes observed in larger *P. tuberculosa* colonies. Oral disks were observed to be closed during the low tides.

The massive encrusting form is found to take up huge areas of rocky intertidal zone and the small rounded colonies are approximately 30cm in diameter. The “small and rounded” colonies were found at all sites but in a greater amount at Dwarka coast and massive encrusting were found mainly at Veraval and Sutrapada.

2. ***Palythoa caesia*:**

   ***(Plate 3.*7: C)**

Palythoa caesia was first described from Fiji by Dana (1846) as having ‘immersae’, dark brown colonies with uneven surfaces, and many tentacles (the number was not specified). This binomen is most commonly applied in Australia (Burnett *et al.*, 1994, 1997), and has also been used in the Indian Ocean (Burnett, 2002), Papua New Guinea (Erhardt and Knop, 2005), Guam (Paulay *et al.*, 2003), and Hawaii (Hoover, 1999).

Colonies convex; color umber; polyps when contracted exhibit 4-6 lines broad; disks umber coloured except the centre which is pale grayish violet; tentacles very numerous in two series, umber coloured. Overall, *P. caesia* has more number of

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tentacles than *P. tuberculosa* as described in Hibino *et al.* 2013. High-density aggregations were observed at Dwarka and Sutrapada.

Recent research also indicates P. caesia Dana 1846 and *P. tuberculosa* are same species and therefore P. caesia may be *P. tuberculosa* from Dwarka coast, *P. tuberculosa* was originally described from India.

3. ***Palythoa mutuki* (Haddon and Shackleton, 1891); *Carlgren, 1937***

   (Plate 3.8A)

Polyps "liberae" in form (Ryland and Lancaster (2003) and Reimer *et al.* (2006c), Colonies are composed of several polyps living close to each other, but are loosely attached to each other by coenenchyme (stoloniferous), up to 40 mm in length Polyp size is 8-10 mm, Oral disks green or brown, diameter up to 30 mm, oral disk color green or brown. Mesentery number ranges from 45 to 74. Shares the same microenvironment as *Zoanthus sansibaricus*.

Described from Japan, Great Barrier Reef Taiwan, New Caledonia, India and Galapagos, Ogasawara Islands (Reimer *et al*. 2011; Reimer *et al.*, 2006; Reimer *et al*. 2011; Sinniger *et al*, 2006; Reimer and Hickman, 2009).

4. ***Palythoa* cf. *mutuki* Carlgren 1937**

   (Plate 3.8 B)

Polyps "liberae". Oral disk up to 30 mm diameter, green. Radii visible (white or pale brown). Small colonies upto 50 polyps. Closely related to *P. mutuki*.

5. ***Palythoa aff. heliodiscus*Ryland and Lancaster, 2003**

   (Plate 3.8 C)

Polyps *"liberae",* with brown external coloration and brown oral disks up to 2.0 cm in diameter. This species is characterized by its relatively plain oral disk, with

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clearly visible septae, Stoloniferous, and comparatively short tentacles to *P. mutuki* and upto 60 in number.

3.3.2 FAMILY ZOANTHIDAE

Family Zoanthidae is exceptional in exhibiting absence of sand encrustation in the mesoglea of the organism's body cavity. It comprises of three genera viz., *Zoanthus*, *Isaurus* and *Acrozoanthus* and are found both in shallow tropical and sub-tropical waters globally. However, *Acrozoanthus* was not been observed at the present study sites.

3.3.2.1 Genus *Zoanthus*
(Plate: 3.1—3.14)

Zoanthus shows asexual reproduction to a significant grade and forms extremely large colonies. Species of this genus are found from back reef areas to shallow sub littoral, although zonation of different species is evident. *Zoanthus* spp. is possessing brightly coloured, disk and tentacles often strongly contrasted with different patterns observed. Several different colour morphs of a species may be found neighboring each other. The disk may be variegated and mouth is often a different colour from the remainder. No sediment is incorporated during growth, making sectioning comparatively easy, however, due to its extremely soft body, the sectioning becomes quite tough .

Unlike *Isaurus* species polyps that usually have tentacles, *Zoanthus* polyps are uniformly smooth on outer surface. Often having brightly coloured oral disks although green and brown forms (similar to *Palythoa spp.*) have also been observed.

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Genus *Isaurus*- simple and solitary recumbent polyps forming small colonies, not showing budding.

Genus *Zoanthus*- small to large colonies, coenenchyme attached at the base or polyps attached through a dense coenenchyme.

The external surface of polyps and coenenchyme is mainly light to dark purple although pale green polyp colours are sometimes observed. *Zoanthus* spp. are found in locations with high wave current activity an high light levels attached to hard substrate usually large rocks but also occasionally dear hard corals.

Forms dense carpets in mid littoral zone and occurs as patches in infra-littoral zone.

At low sea temperatures *Zoanthus* polyps close their oral disk. Zoanthids have been known by different names at different places as in the Indo-pacific genus *Zoanthus vietnamensis* is known as *Zoanthus pulchellus* in the Caribbean region, and *Zoanthus sansibaricus* is known as *Zoanthus sociatus* (Table: 3.3).

Zoanthus morphs- *Zoanthus sansibaricus, Z. sociatus, Z. vietnamensis, Z. kuroshio*, etc. It is yet to be confirmed whether z. kuroshio and z. vietnamensis are separate species or morphotypes of one species (Reimer *et al.* 2006a).

1. ***Zoanthus sansibaricus (Carlgren, 1900)***

Z. sansibaricus was common among the intertidal area. It is known to be a "generalist" as described by Kamezaki *et al.*, 2013). *Zoanthus sansibaricus* is widespread in Indo-Pacific, Reimer and Hickman 2009. Particularly found in shallow intertidal areas. Forms large colonies with "liberae" polyps and free of the dense coenenchyme. External polyp light to dark purple, no markings, uniform in

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colour, possesses 48–60 brown or dark green tentacles. Wide variation in oral disk colour (e.g. red, blue, white, light to dark green, orange, brown, grey)(Plate 3.11). *Zoanthus sansibaricus* encompasses many different Morphotypes (Burnett *et al*. 1997; Hibino *et al*. 2013), Can form massive colonies (1.5m2) intermingles with colour, morph-types of same species.

2. ***Zoanthus aff. sociatus***

Polyps "liberae" and extend from poorly developed coenenchyme. Often polyps less crowded together than *Z. sansibaricus*. Larger in diameter towards oral opening than at base. External surface of polyps purple with white or pale striped vertical markings on upper half. 42-60 tentacles. Oral disk color may vary (orange, red, brown, pink, gray, blue), often with fluorescent green oral opening. Colonies vary widely in size (Plate 3.12)

Colonies of different color morphotypes were often observed interspersed with each other. The most commonly observed oral disk color morphotypes of *Z. gigantus* were orange and mint green.

3. ***Z. vietnamensis* (Pax and Mueller, 1957)**

Z. vietnamensis forms small colonies. Polyps up to 30mm in length, up to 20mm in diameter. Polyps "liberae'. Oral disk always pale to dark pink often with white oral opening. 55-64 tentacles. As described by Carlgren (1900) and Uchida (2001) has a blue/ purple oral disk with white and yellow mouth (Plate 3.13).

4. ***Zoanthus aff. kuroshio* Reimer and Ono, 2006**

Z. kuroshio was only found at one location, Sutrapada. Similar to *Z. vietnamensis, Z. kuroshio* with pale pink oral disk, 42-48 mesenteries. Polyps "immersae",

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embedded in coenenchyme. Polyps narrow in diameter from base to upwards (Plate 3.14).

3.3.2.2 Genus *Isaurus (Plate 3.10)*

Polyps may be with or without tubercules. Recumbent polyps i.e. closed during daytime and become open and upright at night. Body tubercules often in longitudinal series or not arranged properly. Tubercules brown, red, or white and white linings appear on the outer disk. No sand-encrustation, colonial forms were observed (less than 50 polyps) with "liberae" polyps. Polyp surface coloration mysterious and varies with environment (white, gray, brick red), often similar to surrounding environment. Polyps upto 3-5 cm in length colony. They are also similar to *Zoanthus* spp. Being wide spread from tropical to subtropical distribution.

1. ***Isaurus tuberculatus*(Gray 1828)**

Based on morphology and anatomy this species was identified. Widely distributed *Isaurus spp*. in the tropical and sub-tropical was unknown from the coasts of India until reported by Pandya *et al.*, 2014. Tubercles present and similar to polyp colour or white in colour.

The species is cryptic and occurs in very low numbers (Muirhead and Ryland 1985, Reimer *et al*. 2008). *Isaurus* spp. has been studied from Indo-Pacific and Atlantic. Three species of *Isaurus* genus have been documented from the tropical regions. Camouflaging the surrounding has also been observed in case of the *Isaurus* spp.

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2. *Isaurus* sp. or *Isaurus aff. maculatus*

Tubercules absent, rounded as compared to *I. tuberculatus*, and if present, not arranged in the longitudinal fashion. Base of polyps and coenenchyme often with white or pale in color.

Studies are still required at molecular level to identify whether these two are same species or different at molecular levels.

Identification as described was carried out using Histology (Plate: 3.2) and Scanning Electron Microscopy (Plates: 3.1) was done to assess the internal features.

Scanning Electron Microscopy revealed the amount of encrustation in the *Palythoaspp.* and *Zoanthus spp.* It was revealed that *Palythoa spp.* sediment encrustation ascompared to *Zoanthus spp.* was more*.* In particular with the *Palythoa spp., Palythoa tuberculosa*showed more encrustation in the body wall; whereas *Palythoa mutuki* showed more encrustation in the oral disk region than on the outer surface (Plate 3.1: A- Oral Disk of *Palythoa mutuki*; B-*Palythoa mutuki* Polyp showing encrustation, E: *Palythoa tuberculosa* polyp)

SEM images of *Zoantus sansibaricus* and *Isaurus tuberculatus* showed no encrustation in their polyps (Plate 3.1: C: *Isaurus tuberculatus, D: Zoanthus sansibaricus*).

Results of EDS (Plate 3.3- 3.6) demonstrated the inorganic content in *Zoanthus spp. and Palythoa spp*. The results of EDS are described below as per the study sites:

EDS analysis of zoanthids from Okha was not carried out as the availability of speceimen was less.

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Zoanthus sansibaricus collected from Veraval coast, showed trace amount of elements such as Aluminium, Silicon, Sulfur and Chlorine; whereas that from Sutrapada was found to contain Magnesium, Aluminium, Silicon, Sulfur and Chlorine. The presence of these inorganic metals signify the effect of industries in these areas. (Plate: I and II)

Palythoa tuberculosa and *Palythoa mutuki* collected from Dwarka depicted the presence of Aluminium and Silicon in more percentage than compared to other study sites as the nearby terrestrial region is enriched with Bauxites in the same area and Bauxite mining is a common practice, therefore the run off leading to sea carries elements like Aluminium. This may be due to the absence of industrial pollution in this area (Plate III and IV).

Palythoa mutuki collected from Veraval was observed to contain trace amount of Molybdenum; apart from the previously described elements; suggesting that it is able to trap the minute amounts of inorganic elements and thus can be inferred that it is a good survivor in the industrially impacted zone (Plate VI).

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Table 3. 1: Classification of Zoanthids

Kingdom	Animalia
Phylum	Cnidaria
Class	Anthozoa
Sub-class	Ceriantharia Octocorallia Hexacorallia
Order	Zoanthinaria
Suborder	Brachycnemina Macrocnemina
Family	Zoanthidae (Genus: *Zoanthus, Isaurus*) Sphenopidae (Genus: *Palythoa*) Neozoanthidae Epizoanthidae Parazoanthidae

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Table 3. 2: The characteristics visible for the identification of Zoanthids for commeners (Source: Reef magazine)

1	Lack or presence of surface tentacles and their shape (verrucae (short tentacles) papillae (bumps and warts), etc.); soft on touch
2	lack or presence of uncovered zones between tentacles of upper oral surface and margins
3	lack or presence of marginal tentacles
4	relative stiffness of base
5	Potentially the ability of animal to trap prey by infolding, or if a prey capture response is present at all.
9	mode of reproduction (laceration, fission, budding or other)
7	Degree of coloniality - large colonies, small colonies, isolated individuals.

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Table 3. 3: Identification Key for the Zoanthid species observed in Gujarat

1	Polyps sand-encrusted	Go to 2, 3
1A	Polyps not sand-encrusted	Go to 2A, 3, 4, 4A
2	Polyps are embedded into coenenchyme ("immersae)	Go to 5, 6
2A	Polyps are not embedded into coenenchyme	Go to 3, 4, 4A
3A	Polyps free and clear of coenenchyme ("liberae")	Go to 12, 13, 14, 15
4	Closed polyps have large white striped pattern and mouth is green in color	Go to 10, 11
4A	Closed polyps display only minor markings or no obvious markings at all	Go to 12
5	Polyps barely free of coenenchyme ("immersae"); Colony colour varies from pale cream to brown and from polyps immersed in coenenchyme to polyps protruding from coenenchyme.	*Palythoa tuberculosa*
6	Polyps colonial, completely immersed in a thick coenenchyme when closed. Colonies may be small and ovoid with large polyps, or very large with small, densely packed polyps	*Palythoa caesia*
7	Polyps may be unitary or interconnected but are not embedded into the coenechyme, tentacles appear straight, alternating up and down	*Palythoa mutuki* (Indo-Pacific) *Palythoa grandiflora* (Caribbean)
8	Polyps free and clear of coenenchyme ("liberae") with patterns in oral disk; Colonies not found intertidally usually at depths >5m in areas with low light stoloniferous large oral disk with visible septae, generally have short tentacles >60 in number	*Palythoa heliodiscus*
9	Intertidal. Disk green or brown, often with contrasting light coloured mouth and hypostome. Often semi-closed in direct sunlight, with triangular appearance. Polyps trumpet shaped when closed	*Protopalythoa spp.*
10	Polyps barely free of coenenchyme	*Zoanthus kuroshio*

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	("immersae") Polyps embedded ('immersae') in well developed coenenchyme oral disk, pink, white or light purple or green in colour	
11	A radial pattern, often a variation of pink or purple with a white mouth in oral disk. Polyps immersed in thick coenenchyme. Intertidal on exposed reef crests. Colonies forming extensive rubbery mats.	*Zoanthus pulchellus* (Caribbean) *Zoanthus vietnamensis* (Indo-Pacific)
12	Polyps bright green with blue and cream markings on oral disk; oral diameter are approximately 5mm.	*Zoanthus aff. sociatus;*
13	Polyps with no vertical stripes on outside surface, various colour in oral disk; Oral disk may be of a variety of colours (Red, orange, yellow, green, blue, white, brown) sometimes with elaborate patterns outer surface of polyps darker.	*Zoanthus sansibaricus* (Indo-Pacific) *Zoanthus sociatus* (Caribbean)
14	Closed polyps have large white striped pattern and mouth is green in color.	*Zoanthus aff. gigantus* (Indo-Pacific) *Zoanthus solanderi* (Caribbean)
15	Colonies small (less than 50 polyps), polyps up to 2 or 3 cm in length; Polyps large (to 70 mm), joined at base. Colonies usually with only a few polyps. Body wall with large tubercules usually arranged in longitudinal series. Intertidal and sub-littoral zones	*Isaurus tuberculatus*

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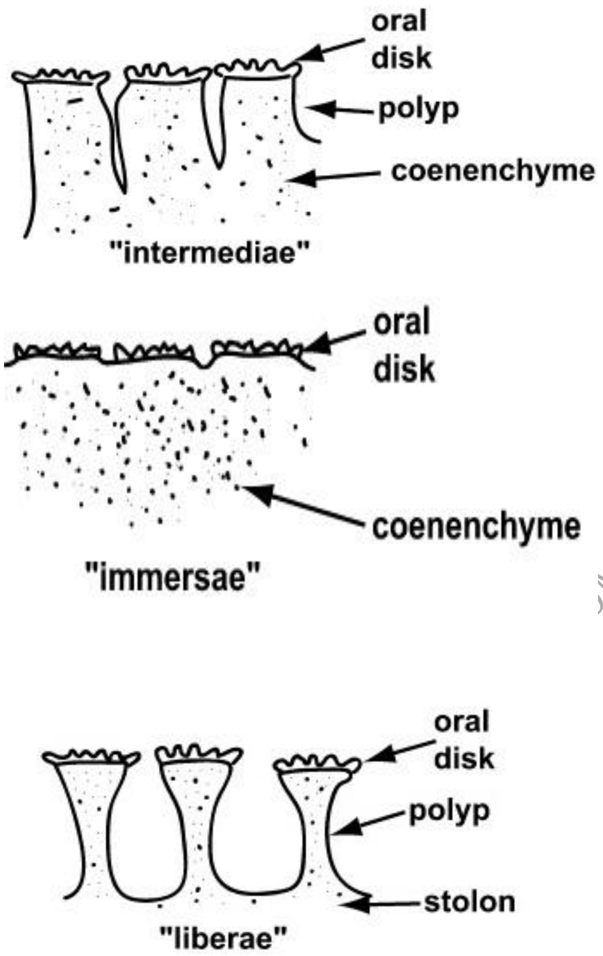

Figure 3. 1: Colony of polyp structure of zoanthids (Source: Reimer *et al.*, 2006)

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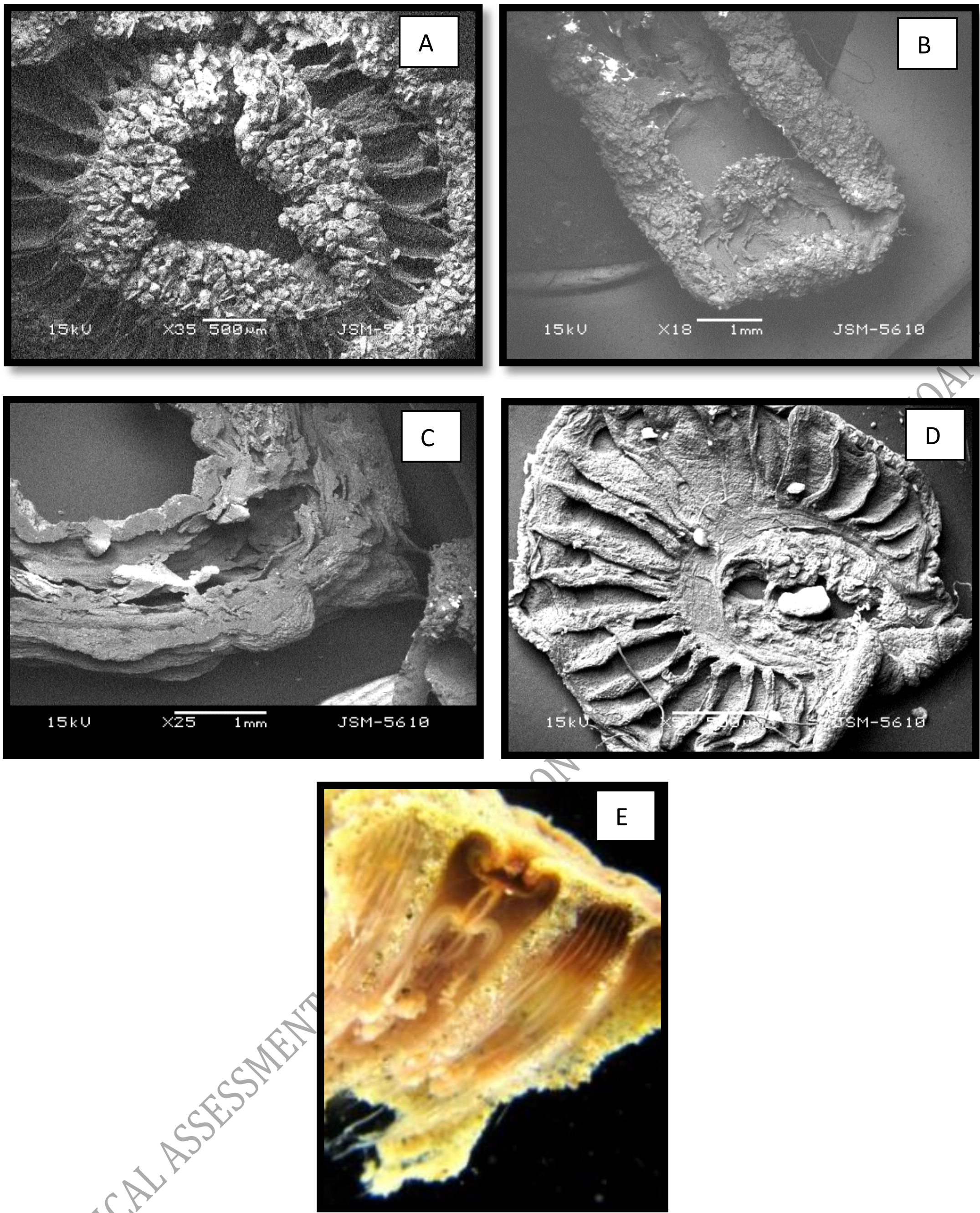


Plate 3. 1:A,B,C,D: Scanning Electron Microscopy images of *Palythoa mutuki, Isaurus tuberculatus and Zoanthus sansibaricus; E: Palythoa tuberculosa*showing encrustation in polyp walls

ECOLOGICAL ASSESSMENT

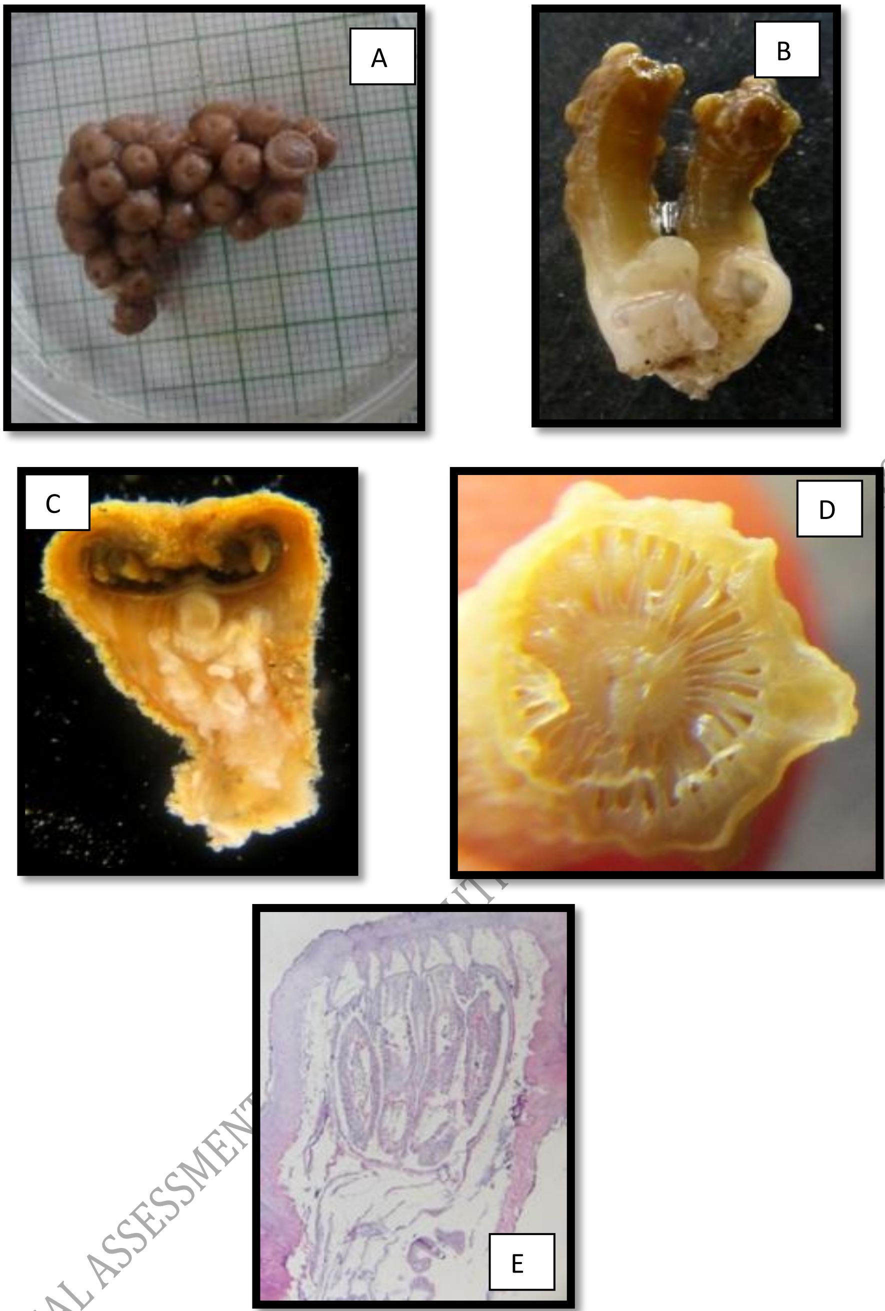


Plate 3. 2: ***A: Zoanthus sansibaricus colony; B: Isaurus tuberculatus polyps, C: L.S of Zoanthus sansibaricus; C: T. S. of Isaurus tuberculatus showing tubercle; D: Zoanthus sansibaricus colony; E: L.S. of Isaurus tuberculatus.***

Plate 3. 3: EDS of *Zoanthus sansibaricus* at Veraval

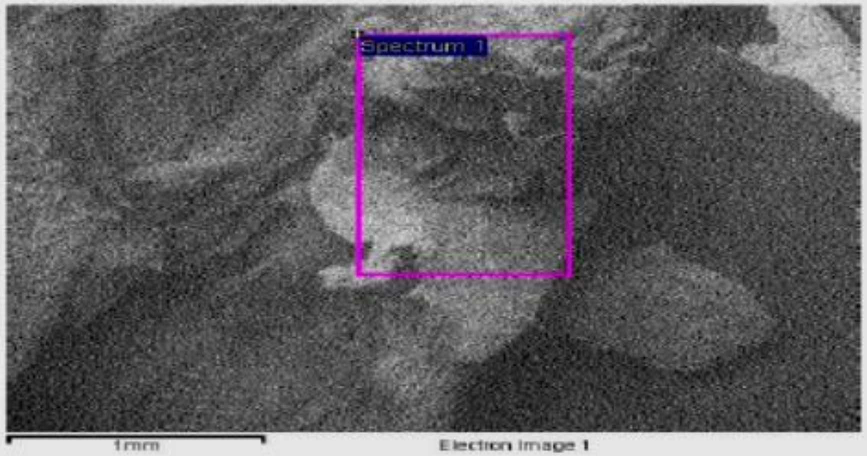
Spectrum processing :
No peaks omitted

Processing option : All elements analyzed (Normalised)
Number of iterations = 6

Standard :
C CaCO3 1-Jun-1999 12:00 AM
O SiO2 1-Jun-1999 12:00 AM
Na Albite 1-Jun-1999 12:00 AM
Mg MgO 1-Jun-1999 12:00 AM
Al Al2O3 1-Jun-1999 12:00 AM
Si SiO2 1-Jun-1999 12:00 AM
S FeS2 1-Jun-1999 12:00 AM
Cl KCl 1-Jun-1999 12:00 AM
Ca Wollastonite 1-Jun-1999 12:00 AM

Element	Weight %	Atomic %
C K	50.69	60.99
O K	36.06	32.57
Na K	1.63	1.02
Mg K	1.17	0.70
Al K	2.00	1.07
Si K	2.06	1.06
S K	1.42	0.64
Cl K	3.31	1.35
Ca K	1.65	0.59
Totals	100.00	

Comment: *Zoanthus sansibaricus* Veraval



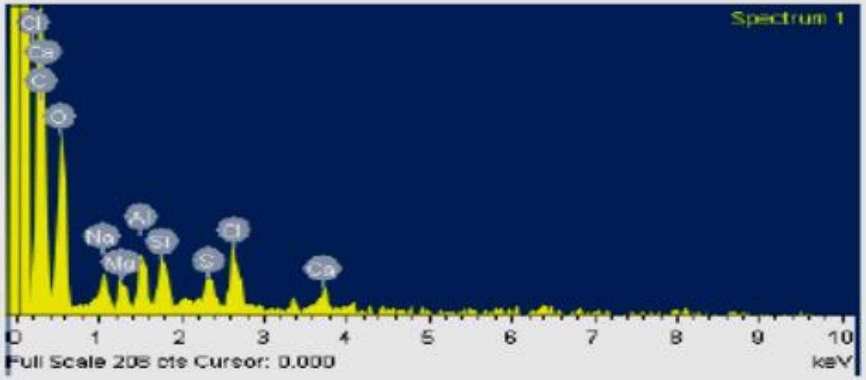


Plate 3. 4: EDS of *Zoanthus sansibaricus* at Sutrapada

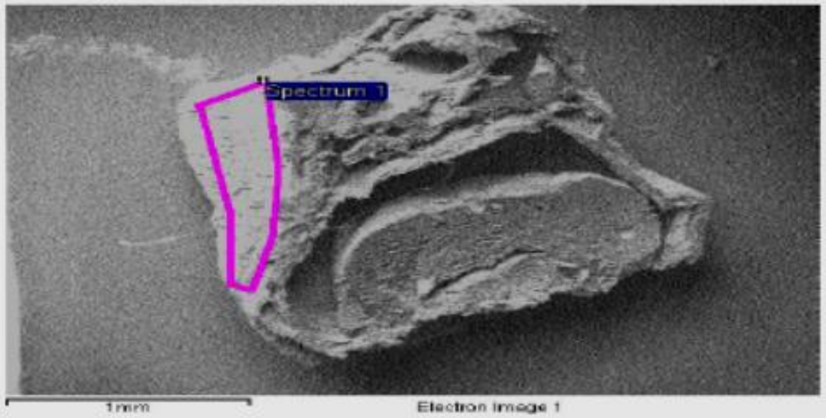
Spectrum processing :
No peaks omitted

Processing option : All elements analyzed (Normalised)
Number of iterations = 5

Standard :
C CaCO3 1-Jun-1999 12:00 AM
O SiO2 1-Jun-1999 12:00 AM
Mg MgO 1-Jun-1999 12:00 AM
Al Al2O3 1-Jun-1999 12:00 AM
Si SiO2 1-Jun-1999 12:00 AM
S FeS2 1-Jun-1999 12:00 AM
Cl KCl 1-Jun-1999 12:00 AM
K MAD-10 Feldspar 1-Jun-1999 12:00 AM
Ca Wollastonite 1-Jun-1999 12:00 AM
Fe Fe 1-Jun-1999 12:00 AM

Element	Weight%	Atomic%
C K	44.85	59.86
O K	28.19	28.25
Mg K	1.02	0.67
Al K	4.51	2.68
Si K	4.34	2.48
S K	1.66	0.83
Cl K	1.35	0.61
K K	1.57	0.64
Ca K	3.45	1.38
Fe K	9.06	2.60
Totals	100.00	

Comment: *Zoanthuds sansibaricus*: Sutrapada



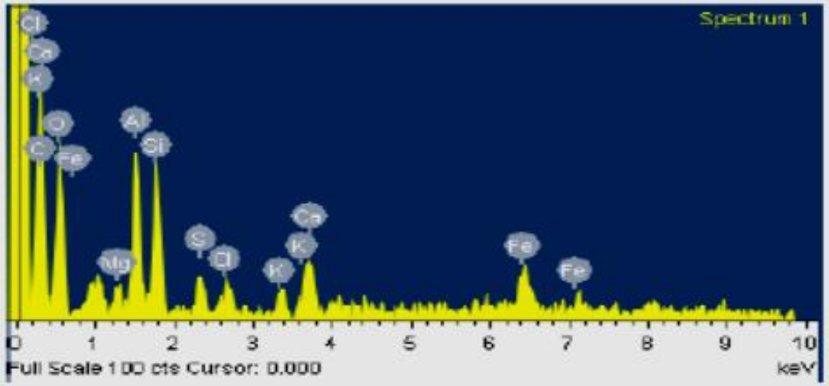


Plate 3. 5: EDS of *Palythoa mutuki* at Dwarka

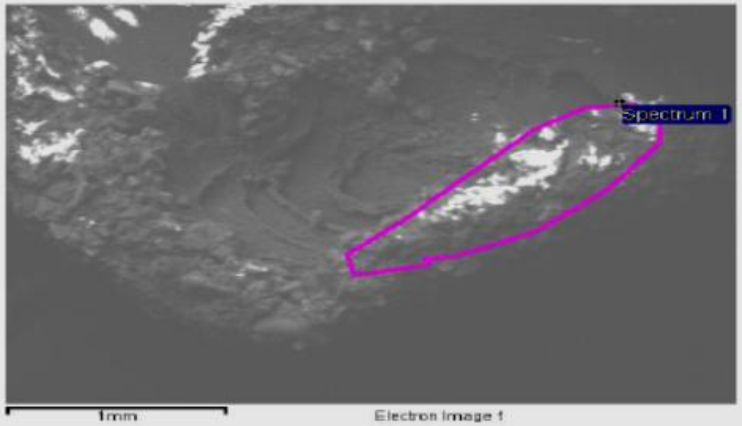
Spectrum processing :
Peak possibly omitted : 2.310 keV

Processing option : Oxygen by stoichiometry (Normalised)
Number of iterations = 6

Standard :
C CaCO3 1-Jun-1999 12:00 AM
Na Albite 1-Jun-1999 12:00 AM
Al Al2O3 1-Jun-1999 12:00 AM
Si SiO2 1-Jun-1999 12:00 AM
Ca Wollastonite 1-Jun-1999 12:00 AM

Element	Weigh t%	Atomic %	Compd %	Formul a
C K	22.06	28.53	80.83	CO2
Na K	0.87	0.59	1.18	Na2O
Al K	1.70	0.98	3.21	Al2O3
Si K	6.10	3.37	13.05	SiO2
Ca K	1.24	0.48	1.74	CaO
O	68.03	66.05		
Totals	100.0 0			

Comment: *Palythoa mutuki*:Dwarka



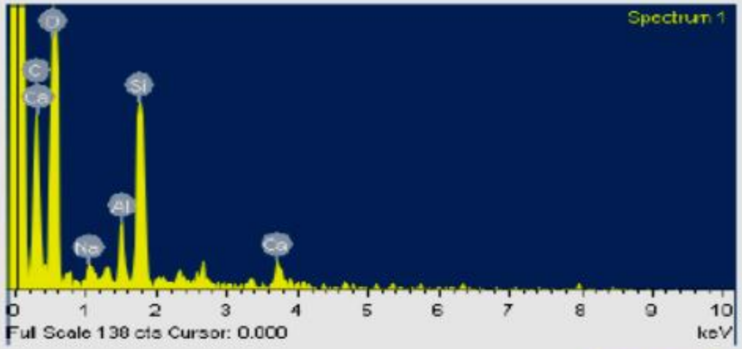


Plate 3. 6: EDS of *Palythoa tuberculosa* at Dwarka

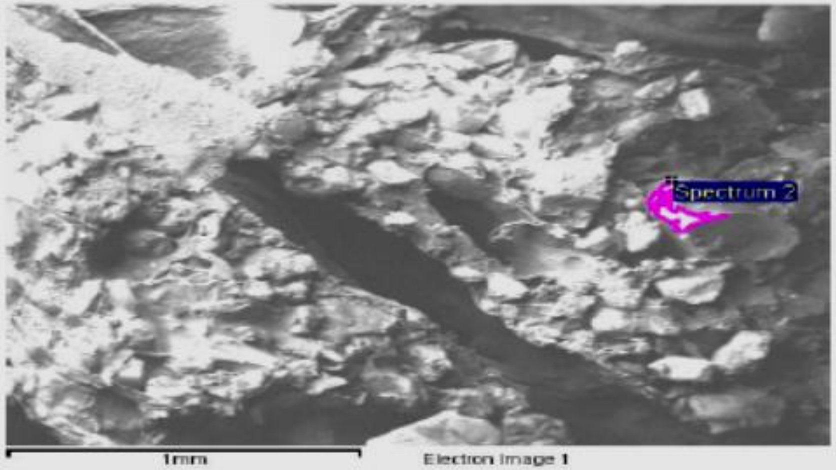
Spectrum processing :
No peaks omitted

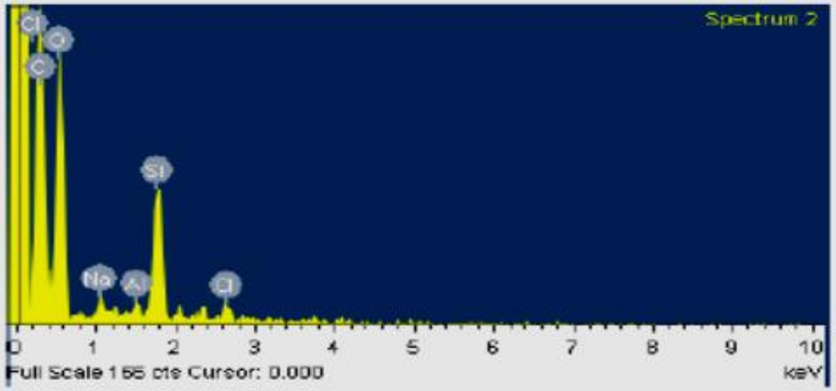
Processing option : Oxygen by stoichiometry (Normalised)
Number of iterations = 6

Standard :
C CaCO3 1-Jun-1999 12:00 AM
Na Albite 1-Jun-1999 12:00 AM
Al Al2O3 1-Jun-1999 12:00 AM
Si SiO2 1-Jun-1999 12:00 AM
Cl KCl 1-Jun-1999 12:00 AM

Element	Weight%	Atomic %	Compd %	Formula
C K	24.69	31.01	90.47	CO_2
Na K	0.68	0.45	0.92	Na_2O
Al K	0.29	0.16	0.54	Al_2O_3
Si K	3.50	1.88	7.49	SiO_2
Cl K	0.58	0.25	0.00	
O	70.26	66.25		
Totals	100.00			

Comment: *Palythoa tuberculosa*: Dwarka





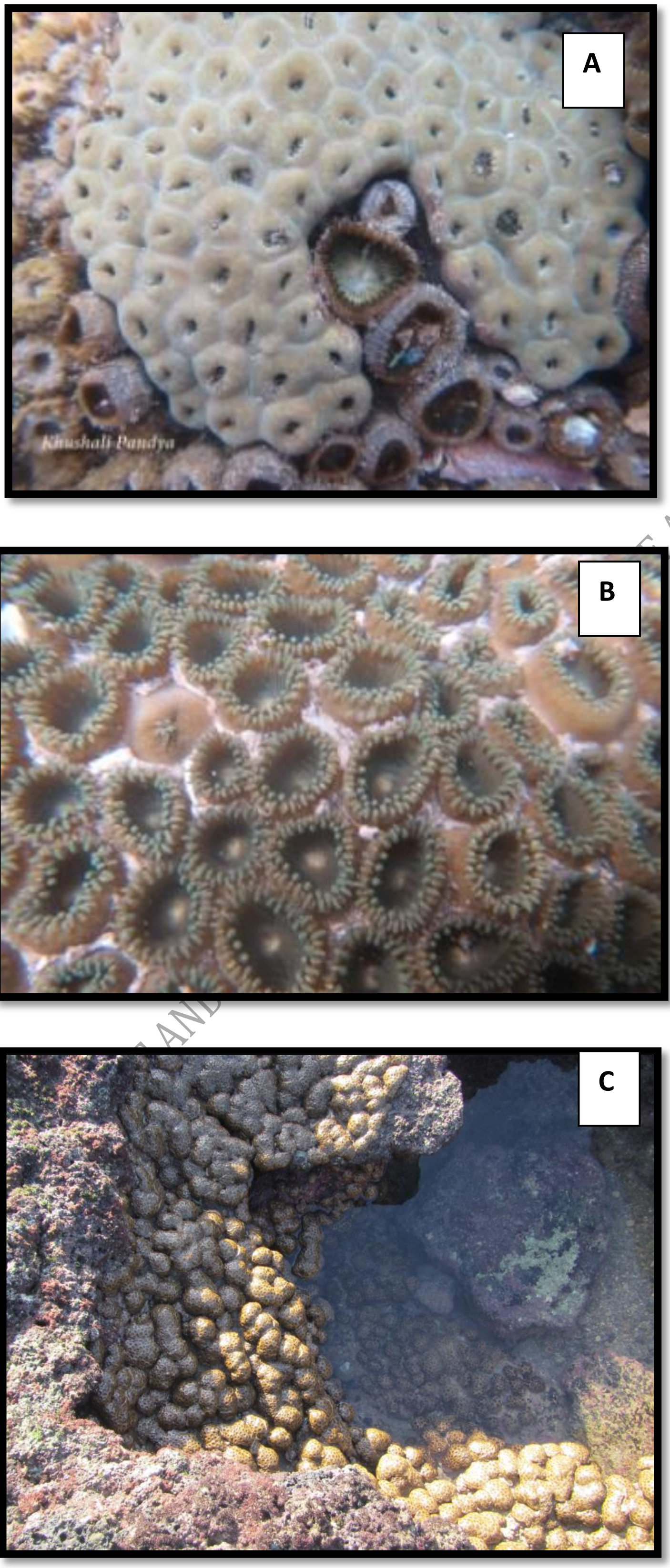


Plate 3. 7: A, B: Colonies of *Palythoa tuberculosa and C: Palythoa caesia*

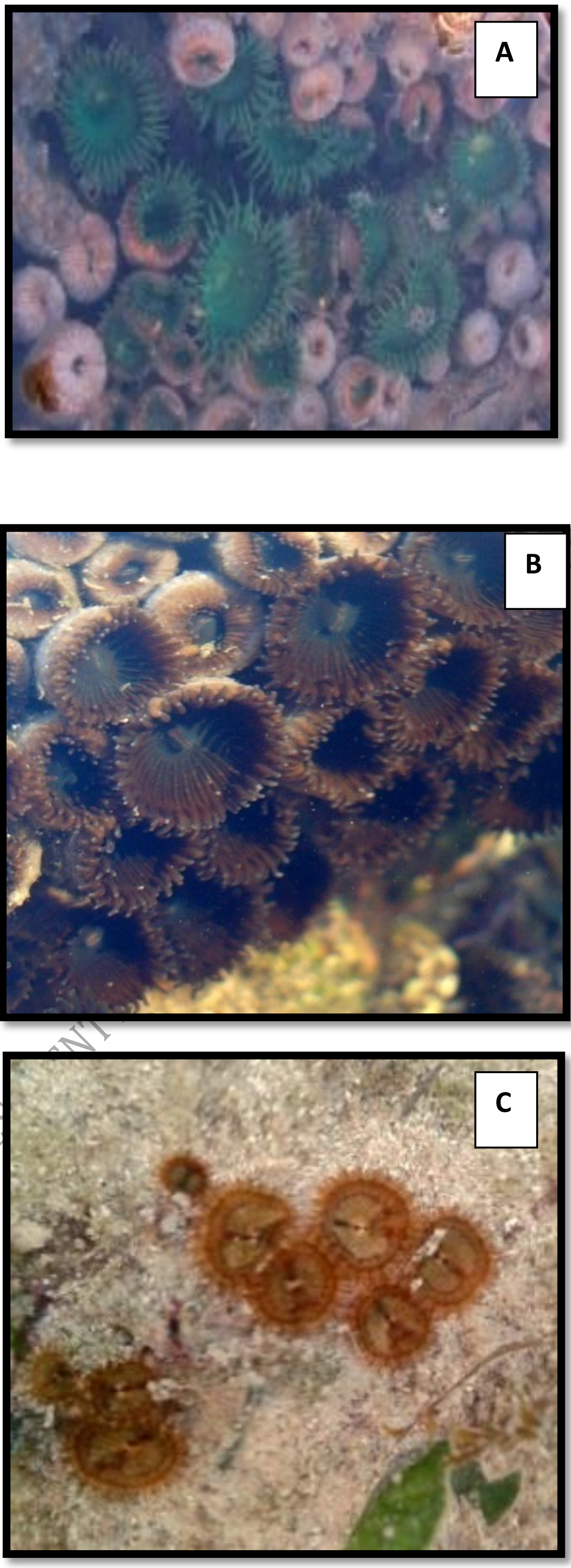


Plate 3. 8: A and B: Palythoa mutuki polyps and colony; C: Palythoa heliodiscus

ECOLOGICAL ASSES
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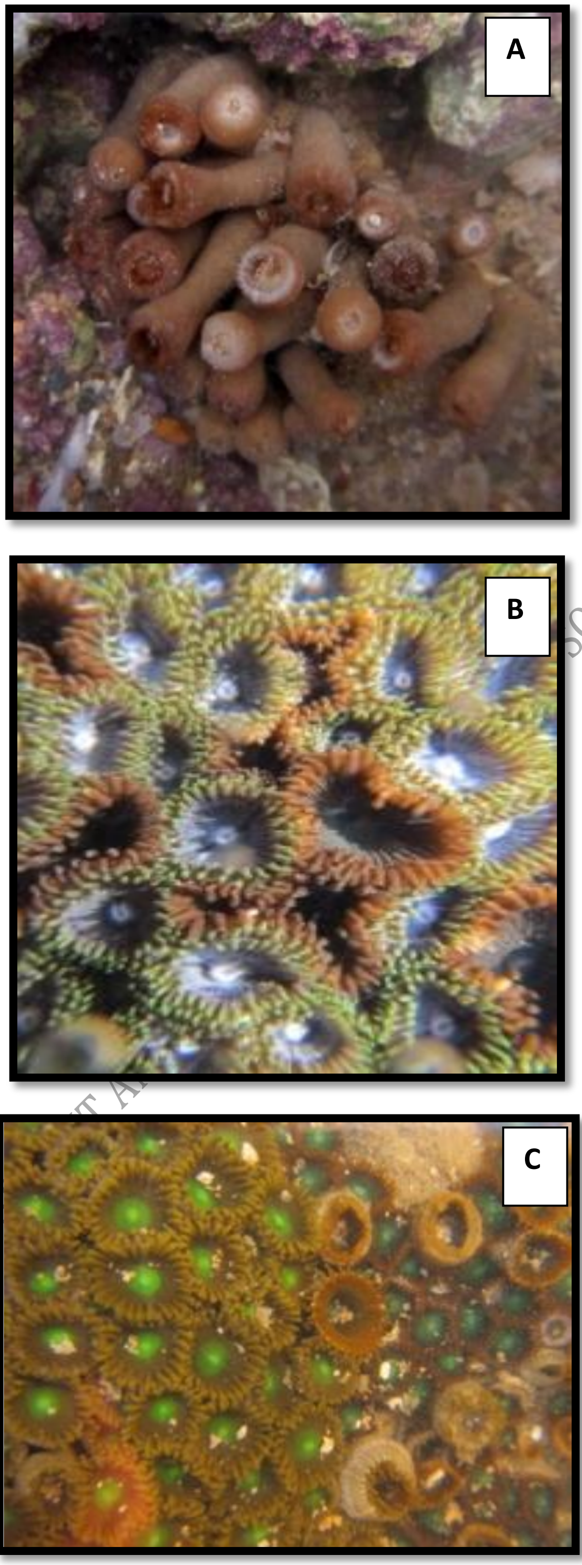

Plate 3. 9: A: Stoloniferous polyps of *Palythoa mutuki*; B and C: *Zoanthus sansibaricus* colony

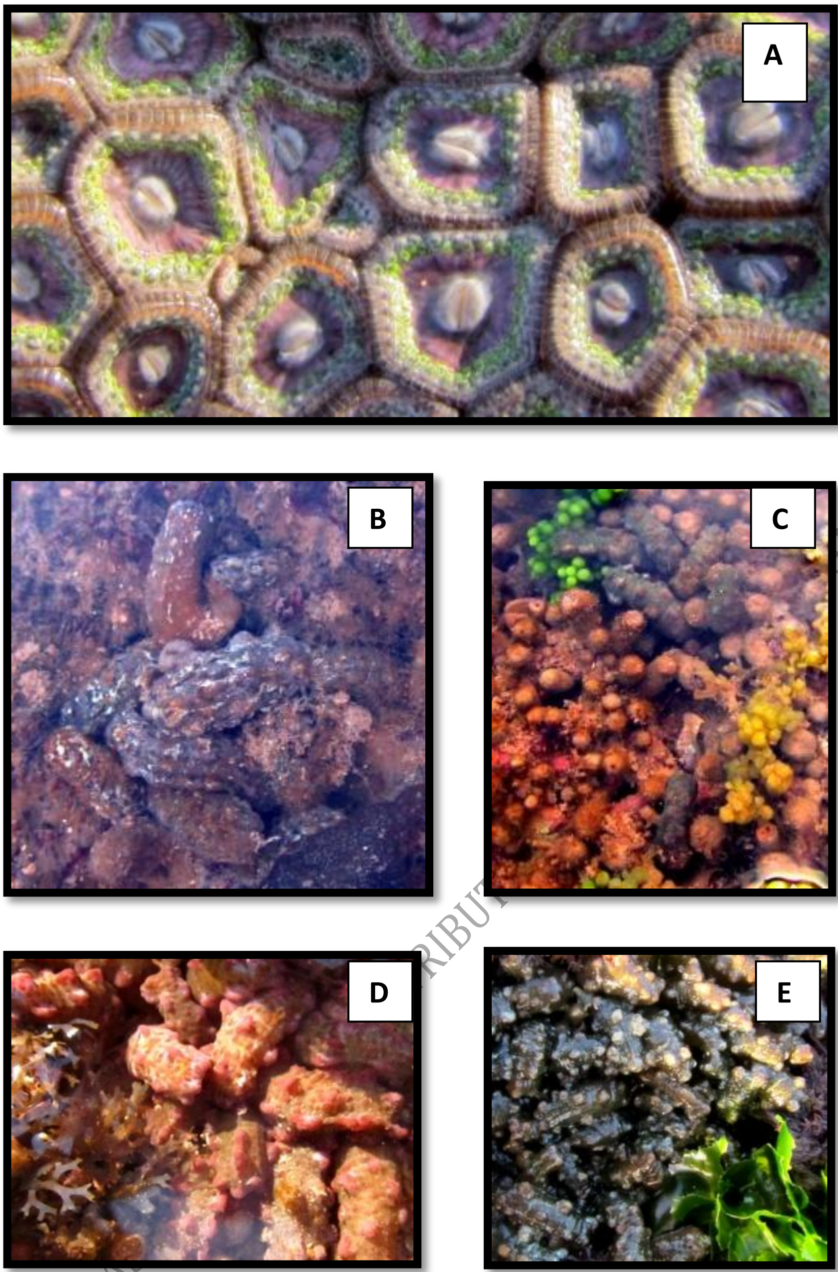

Plate 3. 10: A: *Zoanthus vietnamensis*, B - E*: Isaurus tuberculatus* and its variants

Table 3. 4:Colour Morphs of *Zoanthus sansibaricus*

1	Location	Veraval
	Number of tentacles	54 – 60
	Colour of tentacles	Light brown to brown
	Manubrium	White
	Oral disk	Brown, orange rim in inner side
	Directives	Invisible
	Outer disk	Yellow to light brown
2	Location	Veraval
	Number of tentacles	42 – 48
	Colour of tentacles	Greenish brown with green patch in the middle
	Manubrium	Light grey
	Oral disk	Green, grey at the base of the tentacles
	Directives	Both the directives absent
	Outer disk	Light brown
3	Location	Narara
	Number of tentacles	48 – 54
	Colour of tentacles	Light brown to light green
	Manubrium	White
	Oral disk	White greyish brown radiating outwards, continuous rim absent
	Directives	Both the directives absent
	Outer disk	White brown parallel strips
4	Location	Sutrapada
	Number of tentacles	48 – 54
	Colour of tentacles	Light brown
	Manubrium	White
	Oral disk	Light blue near the manubrium, brown towards the tentacles
	Directives	Both the directives visible in some polyps
	Outer disk	Light brown
5	Location	Sutrapada
	Number of tentacles	48 – 54
	Colour of tentacles	Light brown
	Manubrium	White with blue streak
	Oral disk	Cyan blue to brown from centre to radially outward
	Directives	Both the directives absent
	Outer disk	Yellowish white

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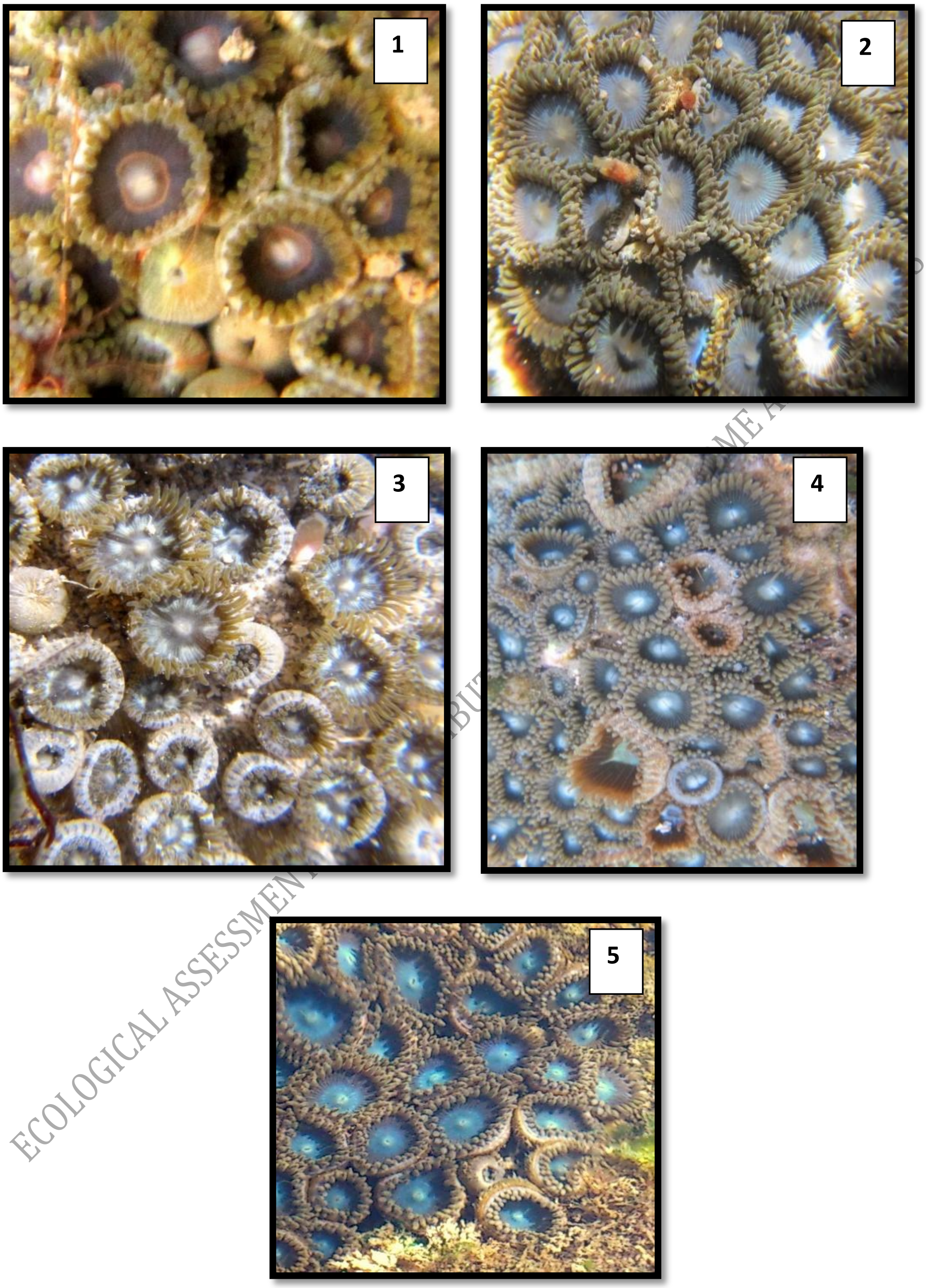
Plate 3. 11: Colour morphs of *Zoanthus sansibaricus*



6	Location	Sutrapada
	Number of tentacles	48 – 54
	Colour of tentacles	Light Grey brown
	Manubrium	White
	Oral disk	Light grey to white, fluorescent green rim visible in some polyps
	Directives	Directives not visible
	Outer disk	Brown grey
7	Location	Sutrapada
	Number of tentacles	48 – 54
	Colour of tentacles	Greyish brown
	Manubrium	Light blue
	Oral disk	Light grey near manubrium, light blue and dark blue parallel radially outwards, green bands visible in some polyps
	Directives	Dorsal and Ventral Directives visible in some polyps
8	Location	Sutrapada
	Number of tentacles	48 – 54
	Colour of tentacles	Light brown to olive green
	Manubrium	White
	Oral disk	White grey with green rim
	Directives	Both the directives visible
	Outer disk	Light brown
9	Location	Sutrapada
	Number of tentacles	48 – 54
	Colour of tentacles	Olive green to fluorescent green
	Manubrium	White
	Oral disk	White to off white with grey rim near manubrium
	Directives	Dorsal and ventral directives present
	Outer disk	Light brown
10	Location	Sutrapada
	Number of tentacles	54 – 60
	Colour of tentacles	Green
	Manubrium	Green
	Oral disk	Cyan blue to brown from centre to radially outward
	Directives	Both the directives absent
	Outer disk	Grey, white at distal end

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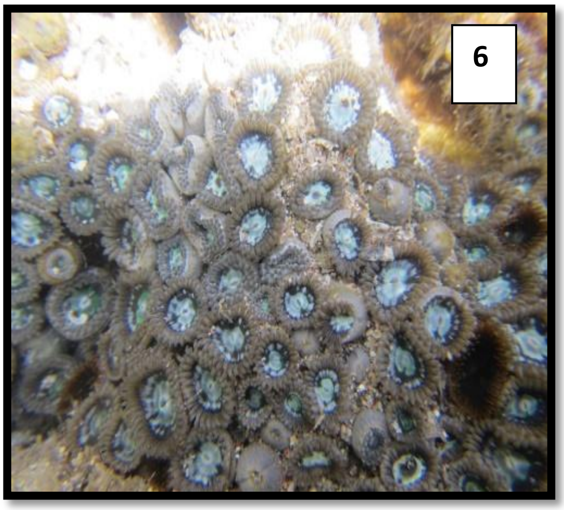
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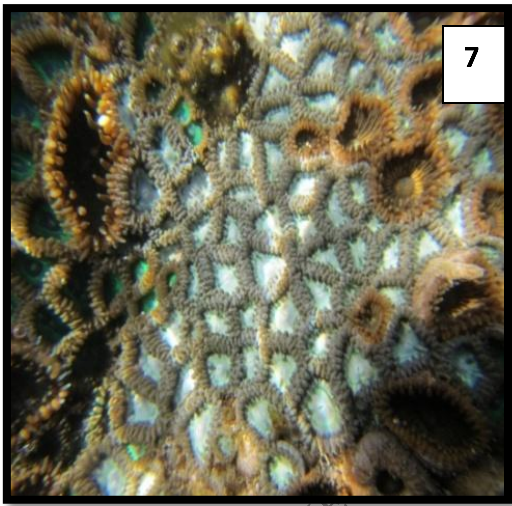
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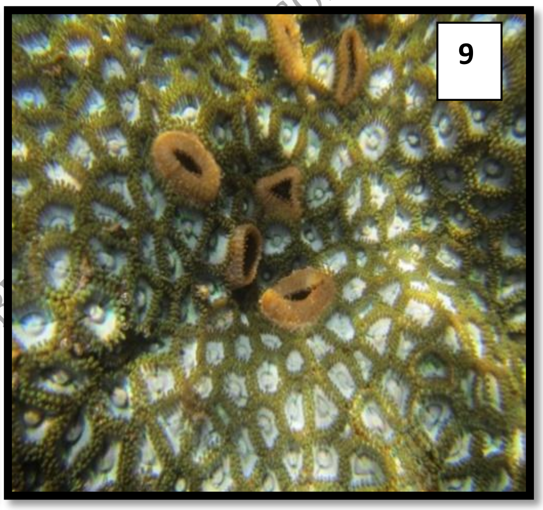
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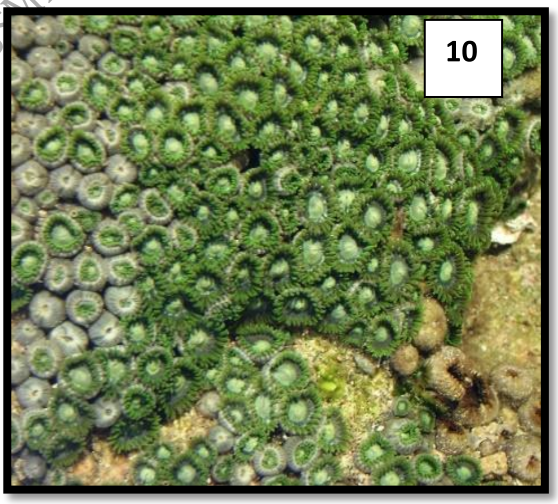
10

11	Location	Sutrapada
	Number of tentacles	48 – 54
	Colour of tentacles	Fluorescent green
	Manubrium	White
	Oral disk	Dark brown to grey, green rim near the manubrium Light brown at the centre
	Directives	Both the directives not visible
	Outer disk	Not visible
12	Location	Sutrapada
	Number of tentacles	54 – 60
	Colour of tentacles	Greenish brown
	Manubrium	Light Green
	Oral disk	Green, grey at the base of the tentacles
	Directives	Partially visible in some polyps
	Outer disk	yellow
13	Location	Sutrapada
	Number of tentacles	48 – 54
	Colour of tentacles	Greyish brown
	Manubrium	1. White
		2. Greyish brown
	Oral disk	1. Light grey, fluorescent green rim extending upto base of tentacles
		2. Grey with bluish green rim
	Directives	1. Dorsal directive visible in some polyps
		2. Both the directives absent
14	Location	Dwarka
	Number of tentacles	42 – 48
	Colour of tentacles	Light brown to olive green
	Manubrium	Light brown
	Oral disk	Fluorescent green at the centre, brown grey radially outward
	Directives present / absent	Directives not visible
	Outer disk	Grey brown
15	Location	Veraval
	Number of tentacles	54 – 60
	Colour of tentacles	light brown to greenish, whitish grey at the base
	Manubrium	White grey with fluorescent green streak
	Oral disk	Grey white at the centre, fluorescent green disk, green near the base of the tentacles
	Directives	Partially visible in some polyps
	Outer disk	Orange transition into yellow towards distal end

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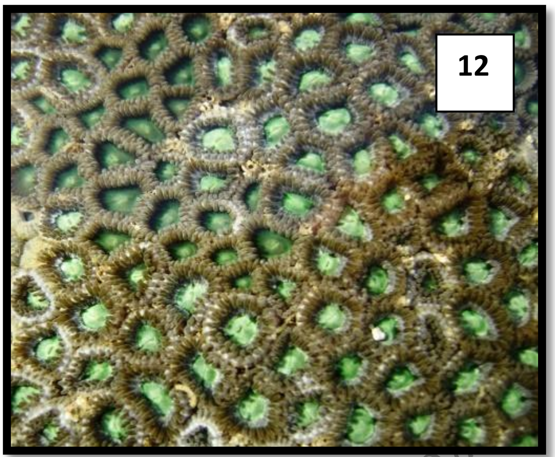
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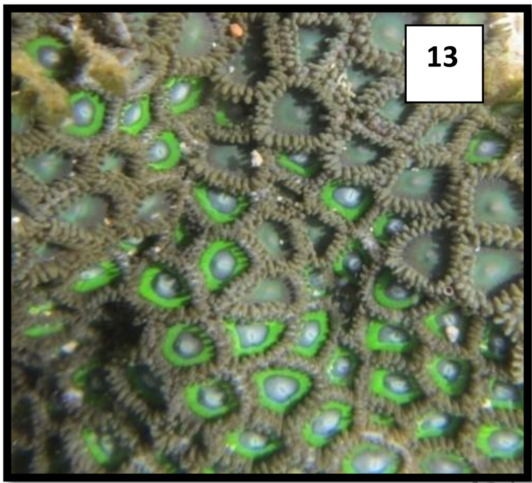
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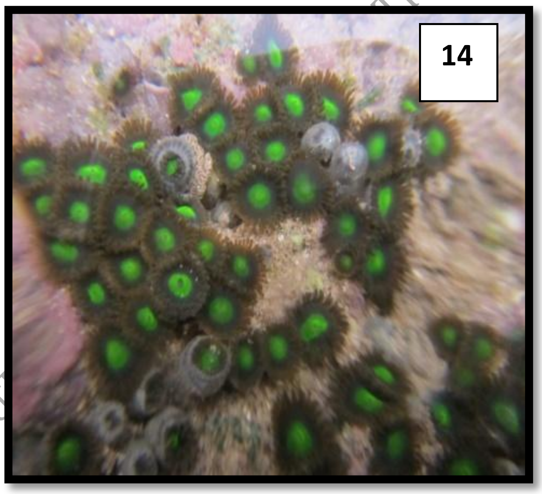
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16	Location	Veraval
	Number of tentacles	42 – 54
	Colour of tentacles	Light brown to greenish
	Manubrium	Fluorescent green
	Oral disk	Light green near the manubrium, brown towards the tentacle
	Directives	Invisible
	Outer disk	Light brown
17	Outer disk	Grey brown
	Location	Sutrapada
	Number of tentacles	48 – 54
	Colour of tentacles	Olive green
	Manubrium	White to fluorescent green
	Oral disk	Grey with green rim
	Directives present / absent	Directives not visible
	Outer disk	Greyish brown
18	Location	Sutrapada
	Number of tentacles	54-60
	Colour of tentacles	Brown
	Manubrium	Light green to yellow
	Oral disk	Outer Brown and green inside
	Directives	Invisible
	Outer disk	Light grey
19	Location	Veraval
	Number of tentacles	54 – 60
	Colour of tentacles	Light brown to brown
	Manubrium	White with fluorescent green streak
	Oral disk	Brown with thick rim of fluorescent green colour at inner side,white near the base of the tentacles
	Directives	Dorsal and Ventral Directives visible
	Outer disk	Light brown
20	Location	Dwarka
	Number of tentacles	48-54
	Colour of tentacles	Brown
	Manubrium	Light green
	Oral disk	Outer brown, white patterns and green ring present
	Directives	invisible
	Outer disk	Brown

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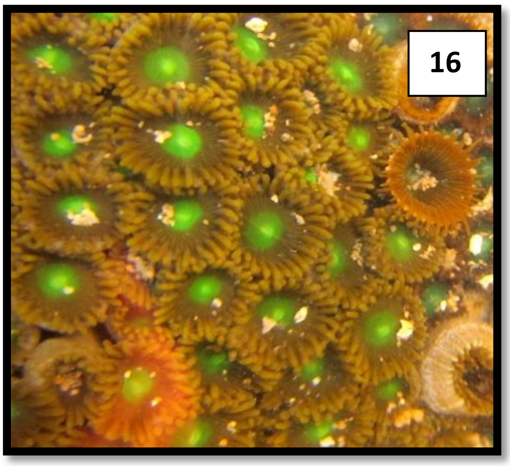

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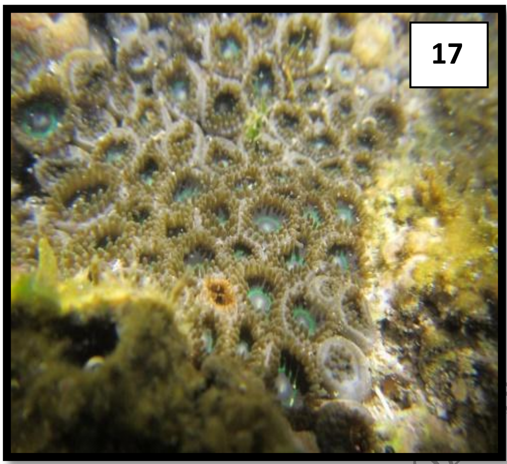

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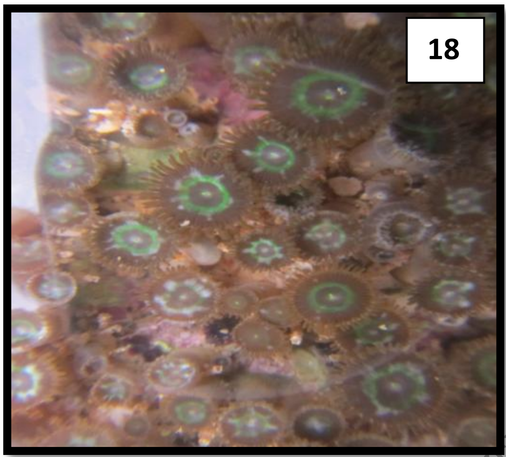

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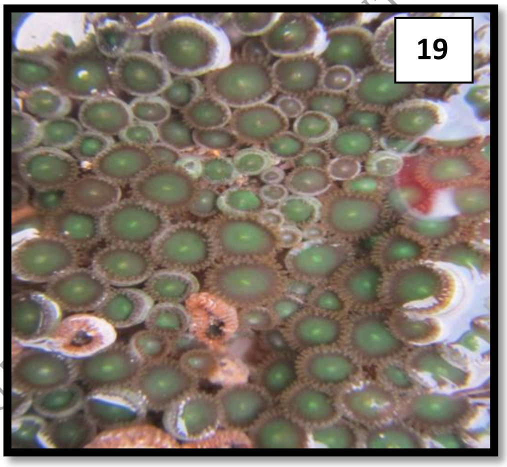

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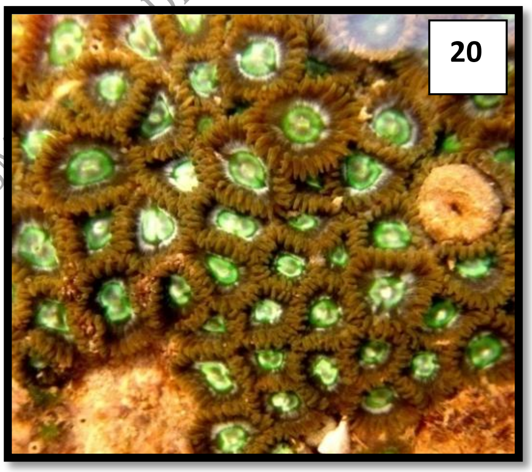

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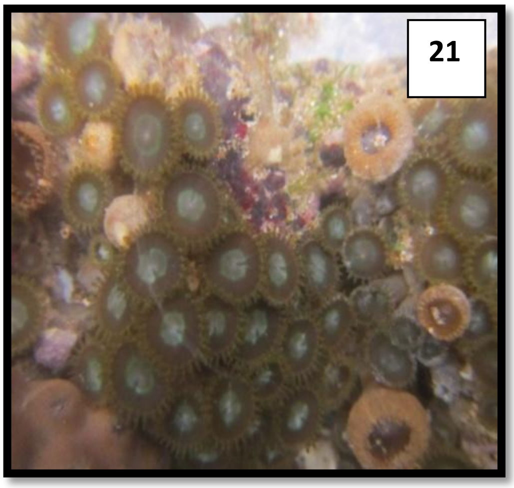
21	Location	Dwarka
	Number of tentacles	48-54
	Colour of tentacles	Olive green
	Manubrium	Light grey
	Oral disk	Brown outer, Green ring
	Directives	Invisible
	Outer disk	Grey
22	Location	Sutrapada
	Number of tentacles	48 – 54
	Colour of tentacles	Olive green
	Manubrium	Light brown
	Oral disk	Light brown at the centre, dark brown radially outward, orange rim near manubrium
	Directives present / absent	Both the directives not visible
	Outer disk	Not visible
23	Location	Dwarka
	Number of tentacles	42 – 48
	Colour of tentacles	Olive green to brown
	Manubrium	Fluorescent green
	Oral disk	Brown with orange stripes radially outward
	Directives present / absent	Directives not visible
	Outer disk	Olive green white parallel stripes

ECOLOGICAL ASSESSMENT AND DISTRIBUTION PATTERN OF SOME ANTHOZOANS



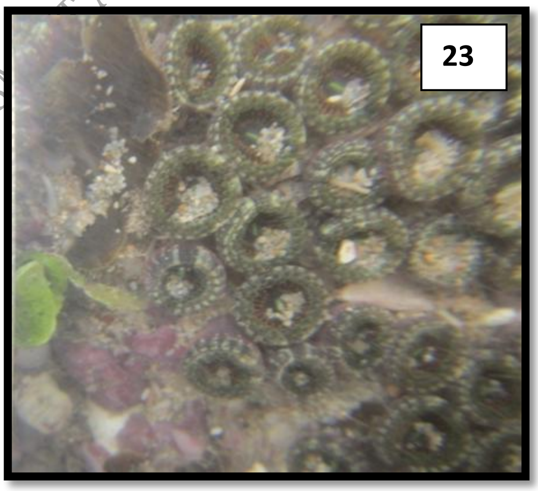


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Table 3. 5: Color Morphs of *Zoanthus aff. sociatus*

1	Location	Sutrapada
	Number of tentacles	42 – 48
	Colour of tentacles	Blue brown
	Manubrium	Light blue
	Oral disk	Light blue to blue-violet from centre to radially outward
	Directives present / absent	Both the directives not visible
	Outer disk	Grey
2	Location	Sutrapada
	Number of tentacles	36-48
	Colour of tentacles	Brown with green at distal end
	Manubrium	White with fluorescent green streak in the centre
	Oral disk	White near the manubrium, grey extending outward, green rim, white till the base of tentacles
	Directives present / absent	Visible
	Outer disk	Grey
3	Location	Sutrapada
	Number of tentacles	48 – 54
	Colour of tentacles	Blue brown
	Manubrium	Fluorescent green
	Oral disk	White grey oral disk with fluorescent green patches radially outward
	Directives present / absent	Both the directives present
	Outer disk	Light green
4	Location	Veraval
	Number of tentacles	48 - 54
	Colour of tentacles	Greenish brown
	Manubrium	Fluorescent green
	Oral disk	Fluorescent green with thick brown rim. Greyish white at the base of the tentacles
	Directives present / absent	Not visible
	Outer disk	White, light grey
5	Location	Sutrapada
	Number of tentacles	48 – 54
	Colour of tentacles	Olive green Brown at the base, green at the distal end
	Manubrium	White
	Oral disk	White grey with green rim
	Directives present / absent	Both the directives visible
	Outer disk	Light brown

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Plate 3. 12: Colour morphs of *Zoanthus aff. sociatus*

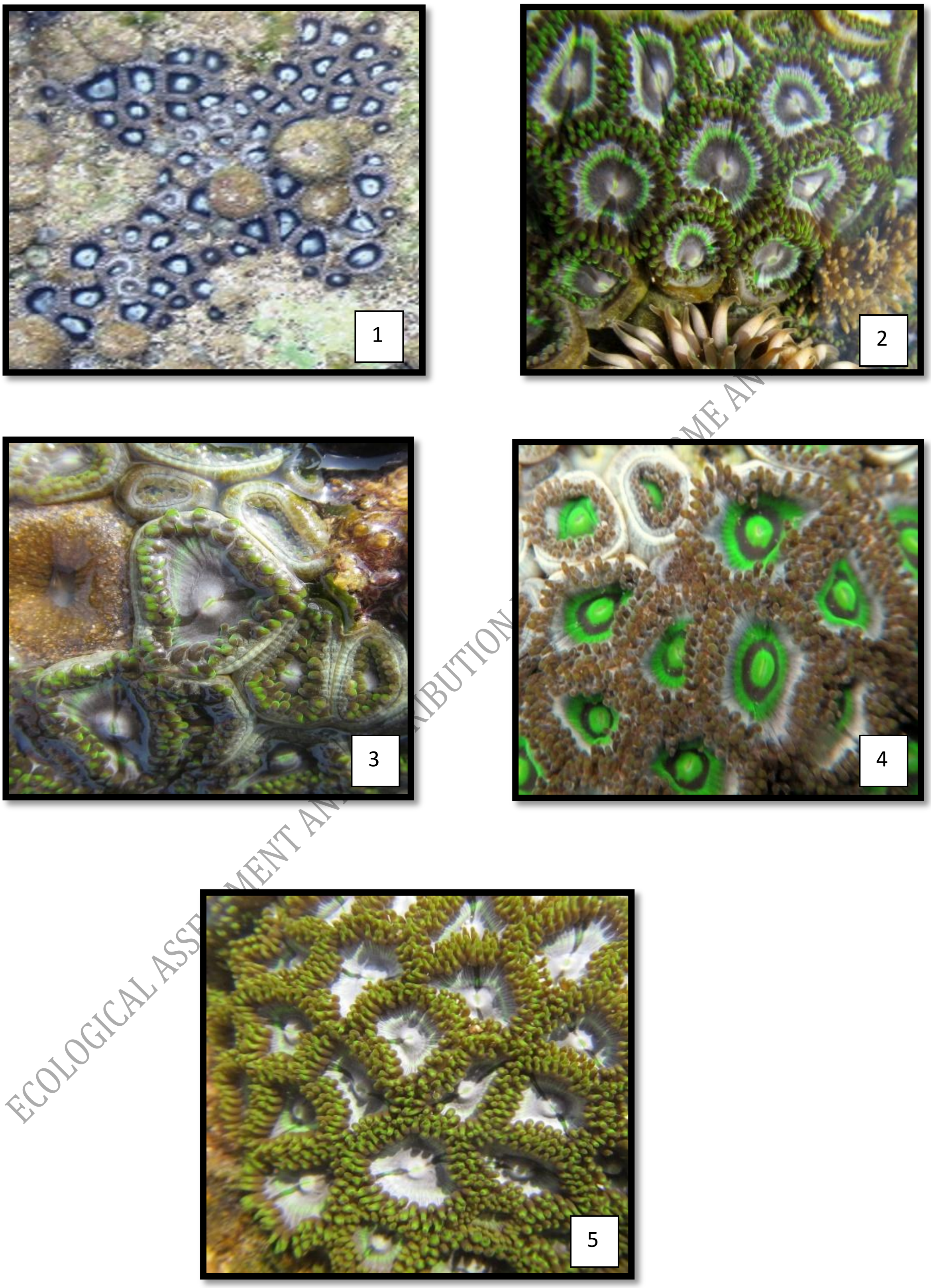

Table 3. 6: Colour morphs of *Z. vietnamensis*

1	Location	Sutrapada
	Number of tentacles	48 – 54
	Colour of tentacles	Green brown alternate bands
	Manubrium	White
	Oral disc	Pink and purple
	Directives	Visible
	Outer disc	Light grey
2	Location	Sutrapada
	Number of tentacles	48
	Colour of tentacles	Green brown
	Manubrium	White
	Oral disc	Light and dark pink to violetbanded
	Directive	Dorsal and ventral directives present in some polyps
	Outer disc	Grey
3	Location	Dwarka
	Number of tentacles	48 – 54
	Colour of tentacles	Green to fluorescent green
	Manubrium	White with brown slit
	Oral disc	Grey Brown
	Directives	Directives not visible
	Outer disc	Pink brown
4	Location	Veraval
	Number of tentacles	54 – 60
	Colour of tentacles	Light brown to green
	Manubrium	White
	Oral disc	Light violet, pinkish at the base of the tentacles
	Directives	Directives not visible
	Outer disc	Light brown
5	Location	Dwarka
	Number of tentacles	42 – 48
	Colour of tentacles	Olive green with fluorescent green tips
	Manubrium	Fluorescent green
	Oral disc	Grey brown
	Directives	Dorsal and ventral directives visible in some polyps
	Outer disc	Light brown

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Plate 3. 13: Colour morphs of *Z. vietnamensis*

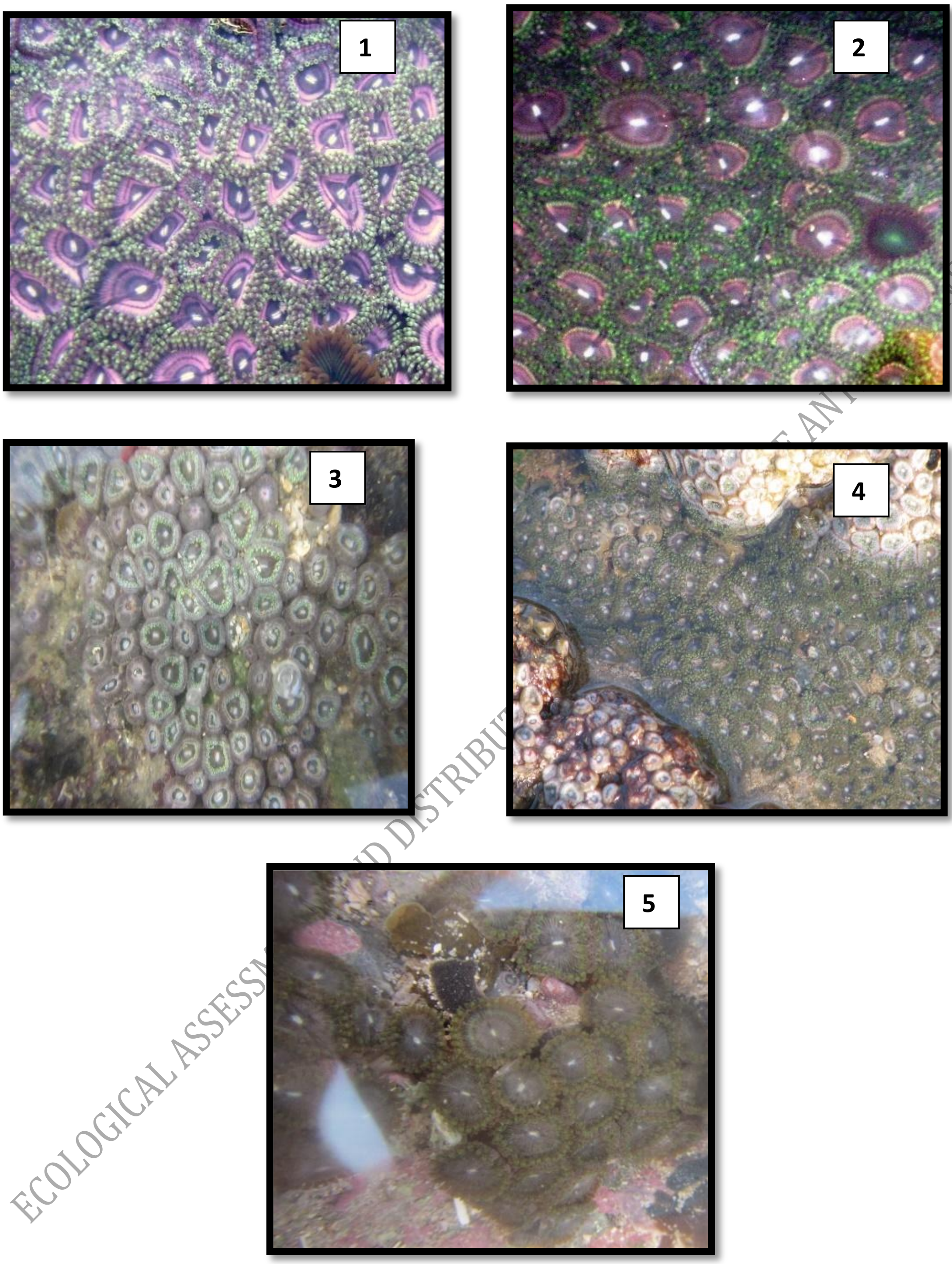
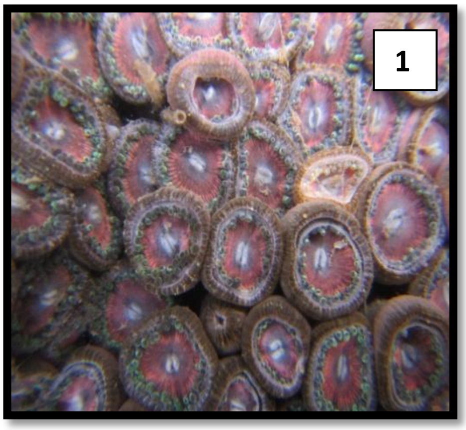


Table 3. 7: Color morphs of *Zoanthus kuroshio*

1	Location	Veraval
	Number of tentacles	48 – 54
	Colour of tentacles	Brown with green at the tips
	Manubrium	White with brownish grey slit
	Oral disc	Pinkish orange with grey near the manubrium
	Directives present / absent	Directives not visible
	Outer disc	Olive green to paly yellow
2	Location	Sutrapada
	Number of tentacles	48 – 54
	Colour of tentacles	Green brown alternate bands
	Manubrium	White with grey slit
	Oral disc	Grey, pinkish orange to white from the centre to radially outward
	Directives present / absent	Directives not visible
	Outer disc	Grey white alternate bands parallel to the tentacles

ECOLOGICAL ASSESSMENT AND DISTRIBUTION PATTERN OF SOME ANTHOZOANS

late 3. 14: Colour morphs of *Z. kuroshio*



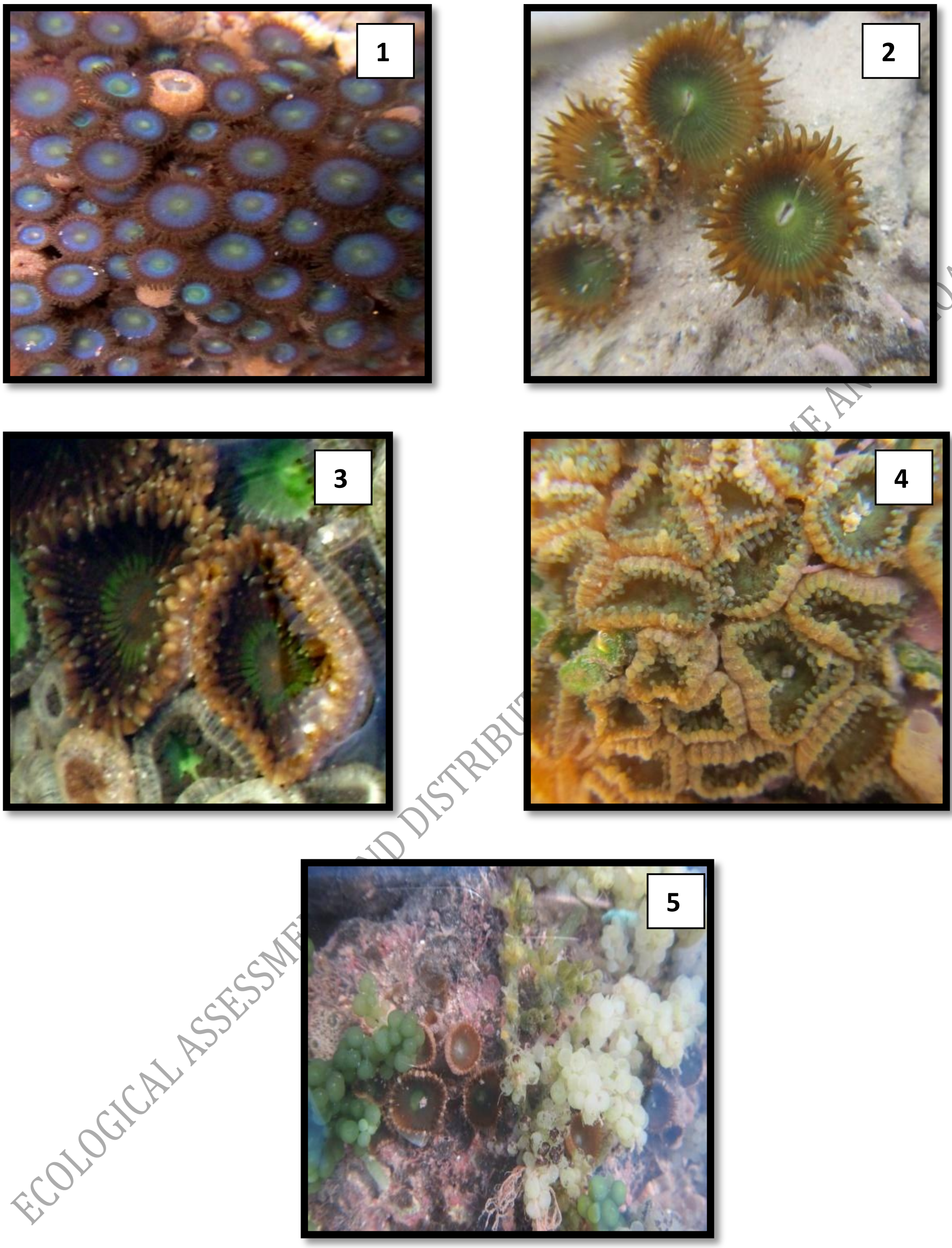
ECOLOGICAL ASSESSMENT AND DISTRIBUTION PATTERN OF SOME ANTHOZOANS

Table 3. 8: Colour morphs of *Palythoa mutuki, Palythao cf. mutuki and Palythoa heliodiscus*

1	Location	Sutrapada
	Number of tentacles	48 – 52
	Colour of tentacles	Brown
	Manubrium	Green
	Oral disc	Blue
	Directives present / absent	Directives not visible
	Outer disc	Brown
2	Location	Okha
	Number of tentacles	54 – 60
	Colour of tentacles	Brown olive green
	Manubrium	Light green
	Oral disc	Green
	Directives present / absent	Directives absent
	Outer disc	Light brown
3	Location	Okha
	Number of tentacles	42-48
	Colour of tentacles	Brown
	Manubrium	Brown
	Oral disc	Green
	Directives present / absent	Invisible
	Outer disc	Brown
4	Location	Okha
	Number of tentacles	36-42
	Colour of tentacles	Pale green and brown
	Manubrium	Yellow
	Oral disc	Yellow to Pale green
	Directives present / absent	Invisible
	Outer disc	Brown
5	Location	Dwarka
	Number of tentacles	48 – 54
	Colour of tentacles	Light brown
	Manubrium	Light pink
	Oral disc	Brown with green thick rim near manubrium
	Directives present / absent	Dorsal directive present in some polyps
	Outer disc	Light brown to orange

ECOLOGICAL ASSESSMENT AND DISTRIBUTION PATTERN OF SOME ANTHOZOANS

Plate 3. 15: Colour morphs of *Palythoa mutuki, Palythao cf. mutuki and Palythoa heliodiscus*



6	Location	Okha
	Number of tentacles	48 – 54
	Colour of tentacles	Olive green to brown
	Manubrium	Yellow with green slit
	Oral disc	Brown; lighter to darker shade from centre to radially outwards
	Directives present / absent	Dorsal directive present in some polyps
	Outer disc	Grey white
7	Location	Dwarka
	Number of tentacles	42-48
	Colour of tentacles	Light Brown
	Manubrium	Light Blue
	Oral disc	Brown, White, Light Blue
	Directives present / absent	Invisible
	Outer disc	Light Green to Yellow
8	Location	Okha
	Number of tentacles	42-48
	Colour of tentacles	Brown
	Manubrium	Brown
	Oral disc	Brown
	Directives present / absent	Invisible
	Outer disc	Brown

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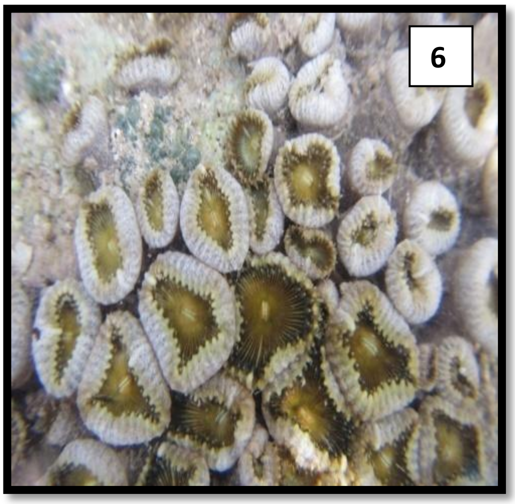

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