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First Record of Fauna *Palythoa tuberculosa* and Flora *Dictyosphaeria versluysii* and its comparison with *Dictyosphaeria cavernosa* at Andaman Waters, India

Vibha V. Ubare, P. M. Mohan* andP. Nagarjuna
Department of Ocean Studies and Marine Biology,
Pondicherry University, Brookshabad, Port Blair-744 112,
Andaman and Nicobar Islands, India.
**Email-pmmtu@yahoo. com*

Abstract

Zoanthids are benthic Cnidarians classified under the subclass Hexacorallia. Despite their worldwide distribution, they are still among the less studied organisms of the marine ecosystem. Even though they are widely distributed, their sensitive nature to other organisms and lack of a hard internal structure made this study a very cumbersome process. This is the first time *Palythoa tuberculosa,* Order Zoanthidea, Sub Order Brachycnemia, was recorded from the Andaman Sea, off Andaman Islands, India.

This survey also reported that *Dictyosphaeria versluysii*, a newly reported species of alga in the studied locations, was compared with *Dictyosphaeria cavernosa*, an already mentioned species of algae from Andaman Islands. Detailed observations and comparison of these species was carried out.

It was observed that in locations where *Dictyosphaeria versluysii* exist, *Palythoa tuberculosa* also occurs; however, this is not the case for *Dictyosphaeria cavernosa*. Similarly, the identified locations of *Dictyosphaeria cavernosa* has severely affected coral bleaching, this also supports the earlier findings of its distribution.

Keywords: *Palythoa tuberculosa*, *Dictyosphaeria versluysii*, *Dictyosphaeria cavernosa*, Andaman waters, India.

INTRODUCTION

The Andaman Sea is an enclosed basin, which is circumscribed by Burma and Malay Peninsula on the east and on the opposite site by the chain of Andaman-Nicobar Islands and Sumatra (Tikader et al. 1986). This chain of Andaman and Nicobar Islands is one of the biodiversity hotspots under the Indo-Burma Hotspot region. However, the marine biodiversity of these islands have not been studied in depth, even though it is unique. Untildate, many marine flora and fauna communities are taxonomically unexplored from these islands.

Zoanthidea is one of the Order of Sub Class Hexacorallia. Hexacorallia is specially known for stony corals (Order: Scleractina), black corals (Order: Antipatharia) and tube anemone (Order: Ceriantharia) but other than these, two more orders come under the subclass Hexacorallia i. e. Corallimorpharians (Order: Corallimorphia) and Zoanthids (Order: Zoanthidea) (Daly et al. 2003). Zoanthids are benthic anthozoans, characterized by having two rows of tentacles, one siphonoglyph and usually live a colonial way of life (Reimer and Hickman 2009; Irei et al. 2011; Reimer et al. 2011). Most zoanthids use sand and detritus material to cover their body, this enhances their body structure and makes it very difficult to perform sectioning and morphological examination of their internal tissues (like sphincter muscle and mesentery count) for taxonomic identification (Reimer and Todd2009). Due to its shrinking nature when close to a foreign object, there were difficulties in the study of their morphological characters, even after death, making it the least studied organism in the Phylum Cnidaria. However, its ability to secret a palytoxin has generated more interest in the study of this group.

The Order Zoanthidea comprises of two Sub Orders, Brachycnemia and Macrocnemia. The Sub Order Brachycnemia is distinguished from Macrocnemia by the status of the 5^{th} mesentery from the dorsal directive which is complete in Macrocnemia and incomplete in Brachycnemia (Reimer 2010; Reimer et al. 2011). According to Reimer et al. (2011), the Brachycnemia includes 3 families:

1) Sphenopidae-sand encrusted, colonial form
2) Neozoanthidae-monogeneric and monospecific, and
3) Zoanthidae-does not utilize encrustation

The Family Sphenopidae consists of the genera *Palythoa* and *Zoanthus*, which are quite common on coral reefs, and are popular items in the pet industry, as well as subjects for research into Palytoxin (*Palythoa*). Similar to many other coral reef-inhabiting invertebrates, both *Zoanthus* and *Palythoa* sp. possess symbiotic dinoflagellates (Order Suessiales) of the genus *Symbiodinium* (zooxanthellae) (Reimer et al. 2006b; Reimer 2008; Reimer and Todd 2009).

Historically, there is almost no information or record in the literature on Zoanthids or particularly for this species *P. tuberculosa* from Andaman waters. Therefore, this work has been considered as the first record with a detailed observation of the species *Palythoa tuberculosa.*

Similarly, several species and varieties of algae are present in the marine environment. They play an important role in the food chain as a primary producer. There are three types of algae: Green algae (Chlorophyta), Brown algae (Phaeophyta) and Red algae (Rhodophyta). The green algae are largely unicellular and have predominance of cholorophyll pigments, which gives them their green coloration (Skelton and South 2000). In green algae, the other pigments do not mask the chlorophyll. The simplest marine green algae are unicellular and planktonic, some species are epiphytes, i. e they live on other seaweeds and a few are endophytes, living within tissues.

The most familiar type of marine algae are those popularly known as seaweed. They serve as food, fertilizer, and are used for the industrial production of alginate, iodine

etc. However, the bubble model alga in this part of the study area, was not studied in detail.

MATERIALS AND METHODS

Study area

All specimens were collected during faunal and floral diversity survey, between December 2012 and March 2016. *P. tuberculosa* wascollected from Carbyns Cove (Fig. 1), Latitude 11° 38’ 43. 58 N and Longitude 92° 45’ 31. 72 E., and in Badabalu (Latitude 11° 30’ 36. 34 N and Longitude 92° 41’ 15. 41 E) and the algal specimen *Dictyosphaeria versluysii*, wascollected from two more stations over and above the earlier mentioned ones. These stations are Chidiyattapu (Latitude 11° 29’ 11. 71 N and Longitude 92° 42’ 43. 68 E) and Burmanallah (Latitude 11° 34’ 35. 50 N and Longitude 92° 44’ 38. 91 E). Among these four stations, the alga species, *Dictyosphaeria cavernosa*, wascollected only from Chidiyattapu. Before collection, all specimens were recorded as a photograph using Sony Cybershot Camera with Underwater Pack. The collected fauna was preserved in 70% ethanol while the algae were preserved in 4% formaldehyde. The morphological data for *P. tuberculosa* (Oral disk/ Polyp diameter, Colour of Polyp, etc.) were also measured and recorded. For the algal species, the transverse sections were studied under the Nikon Binocular Microscope (Model SMZ 1500 D).

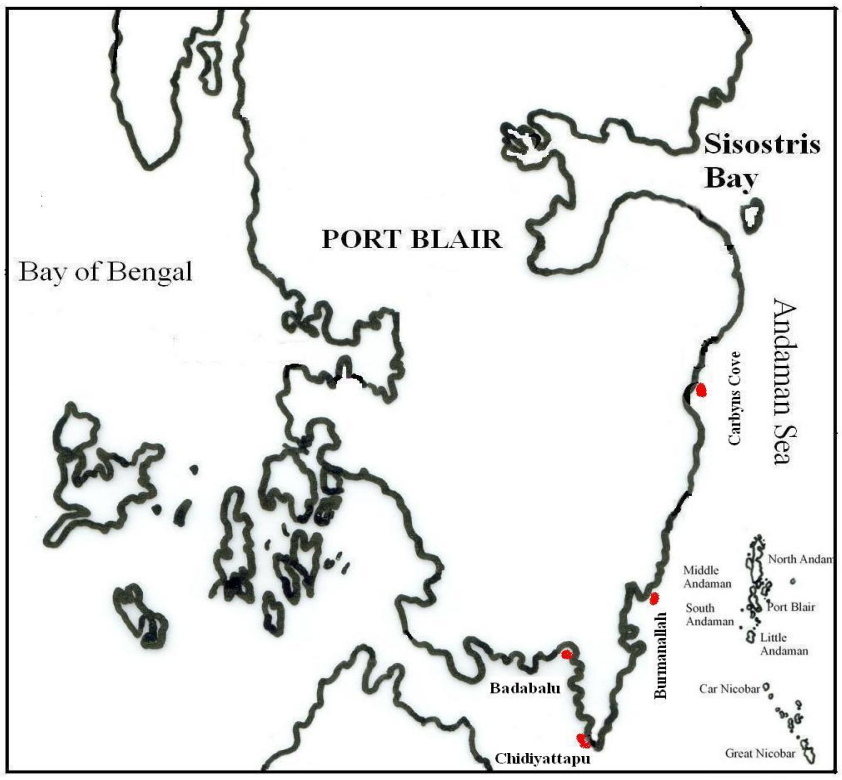

Figure 1: Study Area

The faunal specimens were identified and described based on the key of Walsh and Bowers (1971), Reimer (2007) and Reimer (2010) using morphological characters and photographic images.

RESULTS AND DISCUSSION

Systematics

Palythoatuberculosa (Esper, 1791)
Kingdom-Animalia Linnaeus, 1758
Phylum-Cnidaria Verrill, 1865
Class-Anthozoa, Ehrenberg, 1834
Subclass-Hexacorallia Haeckel, 1896
Order-Zoantharia Gray, 1832
Suborder-Brachycnemia Haddon & Shackleton, 1891
Family-Sphenopidae Hertwig, 1882
Genus-*Palythoa* Lamouroux, 1816
Palythoatuberculosa Esper, 1791(WoRMS 2016)

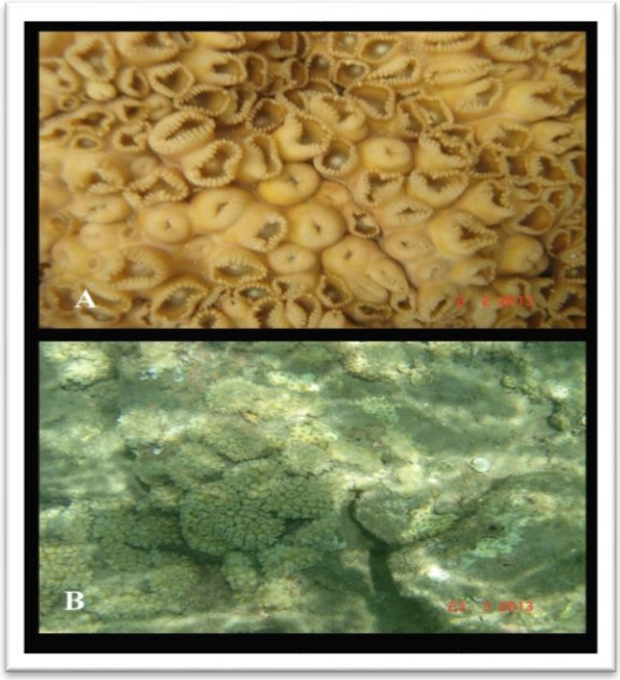

Figure 2-*Palythoa tuberculosa* (Esper, 1791) A. Closer view; B. Colony.

Material Examined-Station Carbyns Cove; 11° 38’ 43. 58 N 92° 45’ 31. 72 E, 2-3 m, coll. P. M. Mohan and VibhaV. Ubare, 2 February 2016.
Station Badabalu; 11° 30’ 36. 34 N 92° 41’ 15. 41 E, 4-5 m, coll. P. M. Mohan and VibhaV. Ubare, 23 March 2016.
The faunal specimens were collected during low tide, from a depth of 2-4 m. It was attached to a rock and depth of occurrence was noticed up to 5 m (Table 1).

Table 1: Morphological characters count of species *Palythoa tuberculosa* (Espar, 1791).

Morphological Characters	Count/Form
Depth	Intertidal to 5 m
Oral Disk Diameter	0. 8-1. 0 cm
Tentacle Count	29-33
Polyp and coenenchyme form	Immersae
Polyp colour	Sandalwood yellow
Oral disk colour	Dark brownish yellow

The algal specimens wee collected on the same study area and its systematic as follows:

Dictyosphaeria versluysii (Weber-van Bosse, 1905)
Kingdom-Plantae Haeckel, 1866
Phylum-Chlorophyta Pascher, 1914
Class-Ulvophyceae K. R. Mattox and K. D. Stewart, 1978
Order-Siphonocladales (Blackman & Tansley) Oltmanns (
Family-Siphonocladaceae Schmitz, 1879
Genus-*Dictyosphaeria* Decaisne, 1842
Dictyosphaeria versluysii Weber-van Bosse, 1905 (WoRMS, 2016)

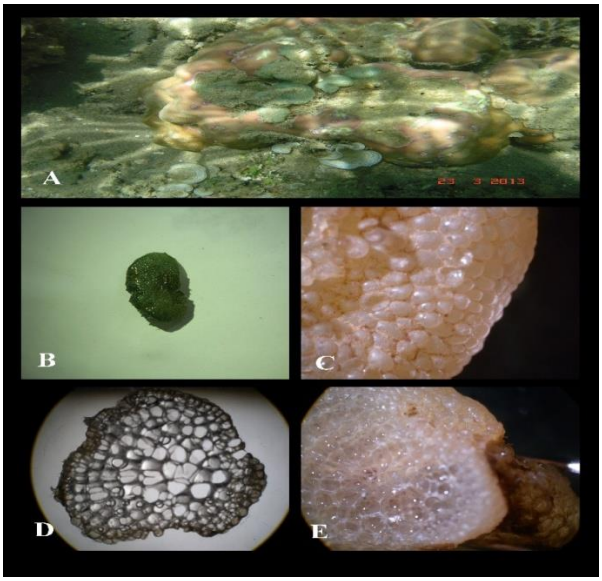

Figure 3. *Dictyosphaeria versluysii* (Weber van Bosse, 1905) A. *Dictyosphaeria versluysii* (Weber van Bosse, 1905) spreaded on corals; B. Individual specimen; C. Thallus microscopic view; D. Microscopic view of transverse section; E. Close up view of solid cross section.

Material Examined-Station Carbyns Cove; 11° 38’ 43. 58 N 92° 45’ 31. 72 E, Intertidal to 5 m coll., P. M. Mohan and VibhaV. Ubare, 25 December 2012 and 2 February 2016.
Station Burmanallah; 11° 34’ 35. 50 N 92° 44’ 38. 91 E, Intertidal to 2 m, coll. P. M. Mohan and VibhaV. Ubare, 12 February 2016.
Station Chidiyattapu; 11° 29’ 11. 71 N 92° 42’ 43. 68 E, Intertidal to 4 m, coll. P. M. Mohan and VibhaV. Ubare, 9 March 2016.
Station Badabalu; 11° 30’ 36. 34 N 92° 41’ 15. 41 E, Intertidal to 5 m coll. P. M. Mohan and VibhaV. Ubare, 23 March 2016.
The floral specimen was collected during low tide; it was attached to rocks and in between corals for up to 5 m.

Comparitive Material Examined
Dictyosphaeria cavernosa(Forsskål) Børgesen, 1932
Kingdom-Plantae Haeckel, 1866
Phylum-Chlorophyta Pascher, 1914
Class-Ulvophyceae K. R. Mattox & K. D. Stewart, 1978
Order-Siphonocladales (Blackman & Tansley) Oltmanns
Family-Siphonocladaceae, Schmitz, 1879
Genus-*Dictyosphaeria* Decaisne, 1842
Dictyosphaeria cavernosa(Forsskål) Børgesen, 1932 (WoRMS, 2016)

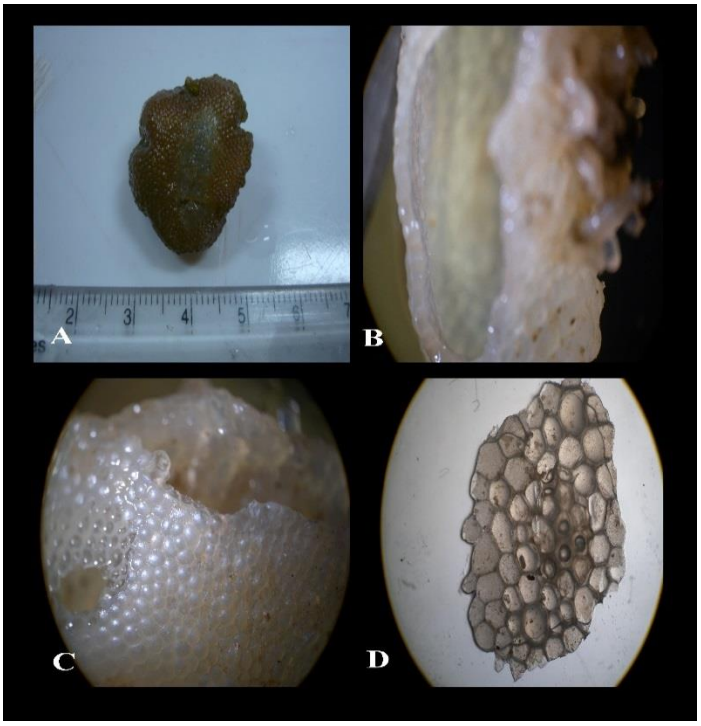

Figure 4. *Dictyosphaeria cavernosa*(Forsskål) Børgesen, 1932 A. Solitary species; B. Hallow inner view; C. Thallus Microscopic view; D. Microscopic view of transverse section

Material Examined-Station Chidiyattapu; 11° 29’ 11. 71 N 92° 42’ 43. 68 E, Intertidal to 4 m, coll. P. M. Mohan and VibhaV. Ubare, 9 March 2016.
The floral specimen was collected during low tide; it was attached to rocks and in between corals for up to 5 m
The faunal specimens was deposited in Zoological Survey of India, Regional Centre, Port Blair (ZSI/ANRC-10062, Dt. 11/03/2014) and floral specimens were deposited (*Dictyosphaeria versluysii (*BSI/ PB-30920-Dt. 05/03/2014) and *Dictyosphaeria cavernosa (*BSI/PB-30921 / Dt. 05/03/2014)) in Botanical Survey of India, Regional Centre, Port Blair.
The genus *Palythoa* is commonly called Moon Polyps, Sea Mats or Encrusting Anemone. The colony is present in a massive form with smaller and larger colonies easily observed. The largest colony measures 100 cm in length and 45 cm in width while the smaller colony is 3 cm in length and 2 cm in width. As described by Walsh and Bowers (1971), Reimer et al. (2006a), Reimer and Todd (2009) and Shiroma and Reimer (2010), polyps show “immersae” form. The coenenchyme is well developed. Their polyps are short and embedded in the coenenchyme, each polyp has a flat oral disc rimmed with tentacles which are very small. The colony is yellowish or sandal colored.
The floral species *Dictyosphaeria versluysii* is commonly called the Button weed. The thallus diameter is between 2. 5 to 5. 0 cm, it is solid and flattened, shows firm and tough texture and consists of large bubble-shaped cells. The rhizoids are short and generally unbranched. The transverse section (T. S) shows the primary cells, which are mainly angular on surface view and appears like a honeycomb.
Dictyosphaeria cavernosa is commonly called the Green Bubble Algae. It is an opportunistic green algae, which is invasive in overfished, high nutrient reef communities of the Hawaii Islands (Botany 2001).
The thallus is between 3. 5 to 6. 5 cm in diameter, saclike, hollow, and spherical. The texture of the thallus is firm, tough and consists of large bubble shaped cells, which are easily noticeable. The rhizoids are short, and unbranched. The primary cells are mainly angular and few are polyhedral in surface view, showing a honeycomb like appearance. It forms a small bubble of clusters on a hard surface but not like a weed or bush.

Habitat and Ecology
Commonly found in Coral reef ecosystems, *P. tuberculosa* can live in environments with strong currents or waves (Shiroma and Reimer 2010). *P. tuberculosa* exists in a wide variety of environments from shallow to deep (> 35 m) (Reimer et al. 2006b; Shiroma and Reimer 2010).
Dictyosphaeria versluysii is found in the calm, as well as in areas with strong wave action or current. The alga is attached to rocks or coral rubble associated with sand on shallow, calm reef flats, in tide pools and subtidally.
Dictyosphaeria cavernosa is found attached to rocks or coral rubble on shallow, calm reef flats and in tide pools.

Distribution

P. tuberculosa species is distributed worldwide, especially in shallow tropical and subtropical waters (Irei et al. 2011) of the Red sea, Maldives, South Africa, Japan and Taiwan.

The floral species *Dictyosphaeria versluysii* is found in the Atlantic Ocean, North America, Central America, Caribbean Islands, Western Atlantic, South America, Africa, Indian Ocean, South-West Asia, Australia, New Zealand, Hawaii Island, Pacific Ocean, Aldabra Islands, Chagos Archipelago, Indonesia, Kenya, Madagascar, Maldives, Mauritius, Mozambique, Reunion, Rodrigues Islands, Seychelles, Somalia, South Africa, Tanzania, and Thailand (WoRMS and Algaebase 2016).

Similarly, the species *Dictyosphaeria cavernosa* is distributed in Aldabra, Gulf of Mexico, Indian Ocean, Kenya, Madagascar, Mauritius, Mozambique, Red Sea, Reunion, Seychelles, Somalia, South Africa, Tanzania, Arabian Sea, Pacific Ocean, Hawaii islands, Amirante Islands, Andaman Islands, Australia, Bahrain, Bangladesh, Cargados Carajos, Chagos Archipelago, Cosmoledo Atoll, Diego Garcia Atoll, India, Indonesia, Kenya, Kuwait, Laccadives, Malaysia, Maldives, Mauritius, Mozambique, Nicobar Islands, Qatar, Reunion, Rodrigues, Saudi Arabia, Saya de Malha Bank, Seychelles, Singapore, Somalia, South Africa, Sri Lanka, Tanzania and Thailand (WoRMS and Algaebase 2016).

DISCUSSION

Marine organisms are a unique source of chemical compounds like cosmetics, nutritional supplements, molecular probes, fine chemicals and agrochemicals other than those used for the production of pharmaceuticals (Rocha 2016). The genus *Palythoa* contains one of the deadliest toxins ever discovered, Palytoxin (PLTX) (LD_{50} in mice 300 ng/kg), but it is generally believed that highly toxic species are not sold in home aquarium trades (Deeds et al. 2011). Palytoxin is considered the causative agent of several cases of human seafood poisoning resulting in systemic symptoms (Rocha 2016). This very potent marine toxin was also isolated from *Palythoa tuberculosa* and studied to determine the effect of isolated smooth muscles (Ito et al. 1976). According to Ramos and Vasconcelos (2010), this toxin may be present in the marine food web ecosystem structure and function, and suggested the need to evaluate the ecological impact of the distribution of PTX and its analogs, as well as the impact of the toxins along horizontal and vertical levels of the food chain in different ecosystems.

From the taxonomic and biodiversity point of view, Zoanthids and many other taxa from the phylum Cnidaria, do not leave skeletal remains (unlike Scleractinia) when they die. Therefore, it is essential to have a database on this fauna for comparison and monitoring (Ono et al. 2008). The present study reveals that the following parameters have been delineated from the studied species.

Based on Reimer (2007), this species was described by Delage and Herouard (1901), Reimer et al. (2011) and Klunzinger (1877). Walsh and Bowers (1971) redescribed *Palythoa tuberculosa* (Esper 1791) during the study of Hawaiian zoanthids. The WoRMS (2016) database reported that Espar (1791) first described the species. Since

the oldest literature is Espar (1791), the identified species is reported here as *Palythoa tuberculosa* (Espar 1791). According to the present studied species, comparison of underwater measurement and measurement taken from photograph, suggested that the oral disk diameter is between 0. 8 to 1. 0 cm and the tentacle count is 29-33 in number.

First and foremost thing it was observed with floral species that the Order of these species was mentioned in the WoRMS (2016) is Siphonocladales however, in the Algaebase (2016) has been mentioned these species belong to the Order Cladophorales. Eventhough both the places were registered by the same author Guiry and Guiry (2016), the confusion has been raised for the classification of these two species among the scientific community. So, this should be clarified and confirmed with any one of the Orders.

The floral species identified in these locations exhibited many similarities, but most of the time, it led to confusion with their morphological characters. However, *D. versluysii* is smaller, completely solid and rounded in structure while *D. cavernosa* has hollow sacks, which are easily ruptured and convoluted.

The two algae species studied, *D. versluysii* and *D. cavernosa*, are considered as native algae of the Hawaii Island. The species D. *cavernosa* reportedly have invasive tendencies in reef communities (Botany 2001). This hollow structure trapped many organisms, mud and gases. The trapped mud particles enhanced the availability of nutrients in the surrounding water column (nutrient reservoir) by leaching. If this invasive species of *D. cavernosa* increases in the coral environment of Andaman and Nicobar Islands, it may destroy the coral reef as well as fishery resources because it will cover most of the crevasses available in between the corals and disturb animals, especially fishes. Till date, because of this particular species, there is no significant disaster identified from these islands. However, it can also be inferred that due to the coral bleaching that happened in the recent past (2010), the carbonate level in the water might have been enhanced and provide the opportunity for the species *D. cavernosa* to thrive in the environment. This has been proven by its distribution, i. e. the station Chidiyattapu recorded a severe coral bleaching during 2010, 2012 where the species *D. cavernosa* was identified. Furthermore, among the study sites, only Chidiyattapu exhibited the species *D. cavernosa*, this confirms the invasive theory. However, it is highly essential to avoid the destruction, thus the distribution of this species has to be monitored, to understand its impact on the coral reef environment.

Another interesting fact in this study is that wherever *D. cavernosa* was identified, the fauna *Palythoa tuberculosa* was absent. Therefore, it may be concluded that in the study area, the species *P. tuberculosa* cannot grow in the environment where *D. cavernosa* proliferates. However, when comparing all other reported distribution sites of these three species, as referred to in Table 2, it has been vice versa i. e., locations with *Palythoa tuberculosa* have been devoid of the alga *D. versluysii*. Since the reported sites do not exactly specify (few) the location (represented only by country's name), this concept has not been further processed, as it requires more work on these species.

Table 2. Detailed distributional list of *P. tuberculosa*, *D. verslyusii* and *D. cavernosa*

Distribution	***P. tuberculosa***	***D. verslyusii***	***D. cavernosa***
Africa	-	Kenya, Tanzania, East African Coast and Indian ocean (Coppejans et al., 1999); Weatern coast of Africa and Adjacent Island (John et al., 2004); Eritrea (Ateweberhan and Reine, 2005)	African Coast and Indian ocean (Coppejans et al., 1999); Dahlak Archipelago (Lipkin and Silva, 2002);Weatern coast of Africa and Adjacent Island (John et al., 2004); Eritrea(Ateweberhan and Reine, 2005)
Andaman Islands	-	-	Andamans (Silva et al., 1996); Chidyatapu, North Bay and Viper Island-Andaman Island (Palanisamy, 2012)
Australia	-	Dampier Archipelago (Huisman and Borowitzka, 2003); W. Australia (Huisman et al., 2009)	Dampier Archipelago (Huisman and Borowitzka, 2003); W. Australia (Huisman et al., 2009)
Caribbean Islands	-	Colombian Atlantic (Diaz-Pulido and Diaz-Ruiz, 2003); Republic of Trinidad and Tobago (Duncan and Lum, 2006)	Colombian Atlantic (Diaz-Pulido and Diaz-Ruiz, 2003)
Central America	-	Mexico (Pedroche et al., 2005)	Mexico (Pedroche et al., 2005)
Gulf of Mexico	-	-	(Algaebase Data, 2016)
India	Saurastra coast, Gujarat-major in Dwarka, Veraval and Sutrapada (Pandya and Mankodi, 2016)	-	India (Silva et al., 1996)
Indonesia	-	Papua New Guinea and Indonesia (Leliaert et al., 1998)	Papua New Guinea and Indonesia (Leliaert et al., 1998)

Japan	SouthernShikoko-Southern Pacific coast region and Bungo Strait (Reimer, 2007); Kagoshima (Ono etal., 2008); Okinawa (Reimer, 2010)	(Algaebase Data, 2016)	Honshu and Noto (Funahashi, 1973)
Kenya	-	Kenya (Bolton et al., 2007)	Kenya (Bolton et al., 2007)
Laccadives	-	-	Laccadives(Silva et al., 1996)
Maldives	Addu Atoll, NW tip of Gan Island (GBIF Data, 2016)	(Algaebase Data, 2016)	Kaafu (GBIF Data, 2016)
Mauritius	-	Mauritius (Coppejans et al., 2004)	Mauritius (Børgesen, 1940; Coppejans et al., 2004)
Mozambique	-	Mozambique(Silva et al., 1996)	Mozambique(Silva et al., 1996)
New Zealand	-	(Coppejans et al. 2004)	(Coppejans et al. 2004)
Nicobar Islands	-	-	Nicobar Islands (Silva et al., 1996)
North America	-	(Algaebase Data, 2016)	(Algaebase Data, 2016)
Pacific Islands	-	Solomon Islands (Womersley and Bailey, 1970)	Solomon Islands (Womersley and Bailey, 1970)
Pacific Ocean	-	Pacific Ocean (Skelton and South, 2000); Mariana Islands(Guam and CNMI) (Tusda, 2003);Chuuk, Pohnpei, Kosrae States, Federated states of Micronesia (Tsuda, 2006)	Mariana Islands(Guam and CNMI) (Tusda, 2003);Chuuk, Pohnpei, Kosrae States, Federated states of Micronesia (Tsuda, 2006)
Papua New Guinea	-	Papua New Guinea (Enomoto, 1990; Leliaert et al., 1998)	Papua New Guinea (Enomoto, 1990; Leliaert et al., 1998)
Red Sea	Gulf of Aqaba, Red Sea (Polak et al., 2011)	-	Hurghada, Red Sea and Egypt (Mohammed and Mohamed, 2005)

Rodrigues	-	Rodrigues (Coppejans et al., 2004)	Rodrigues (Coppejans et al., 2004)
Seychelles	-	Coetivy, Desroches, African Banks and providens, Farquhar, Aldabra, St. Joseph and D'Arros, Cosmoledo Astove, Mahe, Praslin, La Digue (Kalugina-Gutnik et al., 1992)	Coetivy, Desroches, African Banks and providens, Farquhar, Aldabra, St. Joseph and D'Arros, Cosmoledo Astove, Mahe, Praslin, La Digue (Kalugina-Gutnik et al., 1992)
Singapore	Palau Hantu, Palau Tekukor, Palau Tembakul (Ong et al., 2016)	-	Singapore (Pham et al., 2011)
South Africa	South Africa (GBIF Data, 2016)	SA-Kwazulu-Natal (Leliaert, 2004)	South Africa (Leliaert, 2004)
South America	-	Brazil (Oliveira and de., 1977; Almeida et al., 2012)	Brazil (Oliveira and de., 1977)
South-East Asia	-	Philippines (Silva etal., 1987)	Philippines (Silva etal., 1987)
Sri Lanka	-	Sri Lanka (Coppejans et al., 2009)	Sri Lanka (Coppejans et al., 2009)
Taiwan	Kenting (Coral reef, S. Taiwan), Lyudao (Coral reef, Island off E. Taiwan), keelung (Nonreefal N. Taiwan) (Reimer etal., 2011)	-	Taiwan (Lewis and Norris, 1987)
Thailand	-	Thailand (Prathep et al., 2011)	Thailand (Prathep et al., 2011)

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