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Monitoring and assessment of the emerging diseases in scleractinian corals of Andaman and Nicobar Islands

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During the survey 1386 colonies of hard corals, belonging to 27 genera were examined to identify the occurrence of different diseases and the disease prevalence data was collected for the entire study period. The percentage occurrence of the nine major diseases, which were prevalent among the corals in the islands, was as follows: White Pox disease (12.19), White Plague (11.04), White Band (12.77), White Syndrome (17.89), Pink Spot (1.01), Dark Spot (10.25), Pink Line Syndrome (15.30), Polychaete infestation (16.23) and Crown of thorn grazing (1.23). Area- wise analysis of the disease prevalence data showed that the highest number of incidences was at Marina park (21.3%), followed by North Bay (16.13 %), Car Nicobar (13.89 %), Radhanagar Beach (13.74%), Boat Island (12.44%), Tarmugli Island (9.85%), Silver sand beach (8.07 %) and Havelock Jetty (5.63 %). Among the coral species, *Acropora* spp. and *Porites* spp. were dominantly affected. The other affected species include *Platygyra* spp., *Gardineroseris* sp., *Goniastrea* spp., *Leptorea* spp., *Montipora* spp., *Favites* spp., *and Lobophyllia* spp.

[**Keywords:** Disease prevalence, Health status, Infection, Pollution, Reefs]

Introduction

The Andaman and Nicobar Islands consists of 572 islands, islets and rocky outcrops covering about 948.8 km^2 coral reefs and 762 km^2 mangrove areas. There are 106 protected areas in these Islands, 96 designated wildlife sanctuaries, 9 national parks and one biosphere reserve[1]. Though natural and anthropogenic impacts on coral reefs of these islands are increasing consistently, lack of scientific studies on their effects hinder the conservation plans. The tremendous increase in tourism pressure related activities coupled with the dumping of anthropogenic wastages upon reef areas are affecting the coral ecosystem.

Since the first report of coral disease[2], the rate of discovery of new diseases has increased dramatically[3]. Although coral disease is emerging as one of the major factor responsible for coral reef deterioration worldwide[4,5&6], the present status on ecology and pathology of coral diseases from Indo-Pacific reef is largely unknown. The corals of the world have been threatened by environmental changes, pollution and direct human interference[7]. Coral diseases generally occur in response to biotic stresses such as bacteria, fungi, virus and/or abiotic stresses such as increased sea surface temperature, UV radiation, sedimentation and anthropogenic pollutants[8,9]. Diseases can cause significant changes in coral reproduction rates, growth rates, community structure, species diversity, and abundance of reef associated organisms[10,11]. Diseases can be more detrimental to corals when compared with abovementioned ones. Outbreaks of white band disease during the 1970's and 1980's[12] devastated Scleractinian corals. This disease was responsible for the mortality of more than 90% of the Acroporid corals in the Caribbean wide[13]. Although over 40 different coral diseases and syndromes have been reported worldwide, only a few etiological agents have been confirmed. Most pathogens remain unknown and the dynamics of disease transmission, pathogenicity and mortality are poorly understood. Investigations aimed at identifying the factors responsible for such infections will help in the

management of the reef ecosystem[14]. Most of the studies in the Indo-Pacific were carried out in Great Barrier Reef. Other than black band disease, skeletal eroding band and white band disease[15], there are isolated reports of multiple incidences of diseases from the Caribbean and other coastal waters[16]. For example, yellow band disease affected ten species in the Arabian Gulf[17]; the encysting stage of a trematode has infected *Porites compressa* in Hawaii causing enlarged pink polyps[18]; fungal-algal associations have affected *Porites lobata* in French Polynesia[19] and cyanobacteria have affected *Porites lutea* in the Indian Ocean[20]. Fungal invasions on the hard corals of India have also been reported in Indian waters[21&22]. Pink line syndrome that affects massive corals, *Porites* is well documented for Indian reefs[20,23&24].

Studies on the health and disease of the coral reefs of Andaman and Nicobar Islands are scanty. Damage and death of corals in four out of five observed sites in Mahatma Gandhi Marine National Park (MGMNP), Wandoor has already been reported[25]. The infestations of 'crown of thorns' and the occurrence of live bait fishes in the marine national park area have also been observed[26].Major threats such as diseases, bleaching and the like were reported in 1999[27]. In 1991, Jeyabhaskaran et al[28] reported the association of fungi with massive corals of Mahatma Gandhi Marine National Park, Wandoor. All these studies were pointing out the vulnerability of reefs due to anthropogenic activities and bleaching. The coastal marine waters of Port Blair are reported to be contaminated with household wastes, solid wastes, drainages and garbage from hotels[29], which may account for the proliferation and colonization of disease causing microbes in coral reefs.

In this context, coral reefs in eight regions of this archipelago were monitored continuously for a year to assess the health of the scleractinian corals. This paper reports the major diseases affects the health of coral community in these Islands. Six diseases reported in this article have not been observed (at Andaman and Nicobar Islands) hitherto.

Materials and Methods

To determine the prevalence of coral diseases, eight sites in Andaman and Nicobar Islands were monitored during 2008-09. The survey areas were divided into three stations based on their geographic location. The stations were further divided into experimental sites and control sites. Experimental site were the ones, which had direct anthropogenic stress on the reef, whereas the control sites were devoid of direct anthropogenic interference. Water samples were collected and analyzed for hydrographical variables such as air temperature, sea surface temperature, dissolved oxygen, pH, salinity, CO_2 and transparency.

Station 1 is situated in the southern tip of the south Andaman Islands. Experimental sites were selected near Port Blair town area which has direct human impact. Aberdeen Bay and North Bay were selected from this area. Both reef communities are directly exposed to the local and tourism activities; the navigation channel nearby has an effect on the reef. The control sites were selected from Mahatma Gandhi Marine National Park (MGMNP), which has no public accessibility. The sites selected from MGMNP are Boat Island and Tarmugli Island.

Station 2 is situated in the Ritchie's Archipelago of the South Andaman Islands. Havelock Island, one of the largest and most populated Islands of this archipelago is selected for the study. Experimental site from this station is the reef adjacent to Jetty itself which is observed to have stress similar to that of the other experimental sites. The control sites in this station are reefs near Silver sand beach and Radhanagar beach. At present both the sites have less accessibility to public but the increasing tourism activity may have much more adverse effects.

Station 3 is situated in the Nicobar Islands. Only one site was selected in this station as the whole Island is considered to be less affected by human activities. Survey has been carried out in the western coast of this Island.

The preliminary studies at all the sites are conducted by snorkeling and skin diving and were confined to the reef flat area. This has limited the chances of recording the diseases beyond a depth of 10 m. Detailed surveys are carried out using both skin diving as well as Self Contained Underwater Breathing Apparatus (SCUBA). Qualitative as well as quantitative observations of the colonies are done following the Line Intercept Transect survey method[30]. Each transect is laid out perpendicular to the shore line, on the reef flat area to study the health condition of the reef. Triplicate transects are laid at each time for accuracy and average of these transects are taken for further calculations. Observations are taken for each colony to estimate the reef components in each transect (Table 1). Within each transect coral colonies were identified and examined for diseases. Further, calculations are also made based on this estimation to assess the health of the reef. All the sites were investigated during three predominant seasons in the year 2008–09.

Table 1: Benthic substrate composition in the study sites. (Others include clams, sea anemones, sponges etc.)

Site	Live Coral (%)	Dead coral (%)	Dead coral with algae (%)	Rock (%)	Sand (%)	Soft Coral (%)	Others (%)
Aberdeen Bay	44.0	29.4	23.3	0.0	3.1	0.0	0.2
North Bay	60.5	8.2	13.0	6.3	5.8	3.7	2.6
Boat Island	9.8	15.9	16.6	11.9	42.5	1.3	2.1
Tarmugli Island	28.5	21.0	33.5	0.0	15.6	1.3	0.2
Havelock Jetty	10.0	0.7	41.7	20.4	22.3	0.6	4.4
Havelock Silver sand	29.6	21.5	21.7	0.0	23.8	3.2	0.1
Havelock Radhanagar	17.5	34.0	12.9	25.1	7.6	1.6	1.5
Car Nicobar	44.3	7.2	0.0	32.1	12.7	3.6	0.1

Diseased corals were observed carefully underwater for morphological changes. Photographs were taken using Canon Powershot A80 and Canon Powershot A580 cameras with an underwater housing. The numbers of coral colonies examined were calculated genus-wise. Relative percentage of corals affected by diseases was expressed with respect to the number of particular genera affected with the disease, while absolute percentage affected was expressed against the total number of colonies examined.

Results

The hydrographical parameters such as air temperature, surface temperature, dissolved oxygen, pH, salinity and CO_2, and Transparency for the region were 3.4°C, 30.2°C, 5.1 ml/lit, 7.9, 33.8 ppt, 0.1 ml/lit and 9.5 m respectively.

Out of the areas, surveyed North Bay and Aberdeen Bay registered high live coral coverage (60.5 and 44% respectively) (Table 1). A total of 1386 hard coral colonies belonging to 27 genera were examined during the survey period (Table 2). *Acropora* spp., and *Porites* spp., the predominant species in the study sites, were the worst affected. From observation, nine diseases were identified. Disease prevalence data for the entire study period was collected. The identified diseases are summarized below:

White pox disease

The distinct white patches and the potential for tissue loss throughout the coral colony distinguish white pox disease from white band disease. White pox diseases occur with irregular white patches or blotches on the surface of the coral which has distinctive white margins that leads to tissue degradation. When the tissue dies, the affected colony changes to pure white color, which may later get covered with algae. The tissue degradation progress is high along a distinct line (Plate 1, A and B). White pox disease is caused by *Serratia marcescens*[31], a common Gram-negative bacterium classified as a coliform and a member of the *Enterobacteriaceae* family. *S. marcescens* is found in the intestines of humans, insects, and other animals, and in fresh water, soil, and plants[32]. In the present study it was observed that the White pox disease is common in both western and eastern side of these Islands (Table 3) but the maximum occurrence was seen in Tarmugli Island and Havelock Jetty (27.63% and 18.67%). The affected coral genera were *Acropora, Porites*, *Platygyra* and *Gardineroseris* (Table 4).

White plague

White plague is similar in appearance to White Band disease, but it affects different species. This is characterized by a sharp line between exposed coral skeleton that separates living tissue from algal-colonised skeleton and form narrow band of bleached tissue that may be found adjacent to exposed skeleton. The bleaching of tissue will begin from the base or side of the colony but it may differ in different types (Type I, Type II, and Type III). Thirty-two species were reported to be affected by this disease[33]. It is capable of destroying the coral community at a very rapid rate. In the present study this disease was observed (Plate 1, C) in four out of eight sites studied. The maximum occurrence was observed in Tarmugli Island, MGMNP and Silver sand beach (40 % & 33.33 %). The disease was also observed in Havelock Jetty (32%) and Marina Park (27.33%). The affected

coral genera include *Porites*, *Goniastrea*, *Leptorea* and *Montipora* (Table 4).

Table 2: Number of coral colonies examined and the genera identified *in situ*

Sl no	Genera	No of colonies
1	*Acropora*	441
2	*Austreopora*	12
3	*Diploastrea*	15
4	*Echinopora*	3
5	*Favia*	24
6	*Favites*	42
7	*Fungia*	18
8	*Galaxea*	15
9	*Gardinoseris*	36
10	*Goniastrea*	6
11	*Goniopora*	21
12	*Heleopora*	30
13	*Hydnophora*	6
14	*Leptoria*	30
15	*Lobophyllia*	9
16	*Millepora*	6
17	*Montipora*	36
18	*Pachyseris*	6
19	*Pavona*	15
20	*Physogyra*	3
21	*Platigyra*	45
22	*Pocillophora*	87
23	*Porites*	390
24	*Psammocora*	12
25	*Seriatophora*	18
26	*Stylophora*	27
27	*Symphyllia*	33
	Total	**1386**

White band

White Band Disease (WBD) have been observed commonly for many years but their etiologies remain vague[8]. Tissue peels off from colonies of Acroporid corals, leaving behind exposed white skeleton that get promptly colonized by filamentous algae. White band disease is characterized by complete coral tissue degradation of Acroporid corals (Plate 1, E). The disease exhibits a sharp demarcation between apparently healthy coral tissue and exposed coral skeleton. These signs are identical to plague, except that white band is Acroporid specific (and plague has not been found on Acroporids). Tissue loss usually proceeds from the base of the colony branch to the tip, although it can begin in the middle of a branch in some species. The major problem followed by pink line syndrome in North Bay is White Band disease as 20-60% of the examined Acroporid corals were observed to be affected by the same. Among eight sites this infection is observed in 4 sites *i.e.* Aberdeen Bay, North Bay, Boat Island and Car Nicobar. The disease prevalence was high in Car Nicobar with 90%. Mainly *Acropora* coral species were found to be adversely impacted (Table 3, Figure 1).

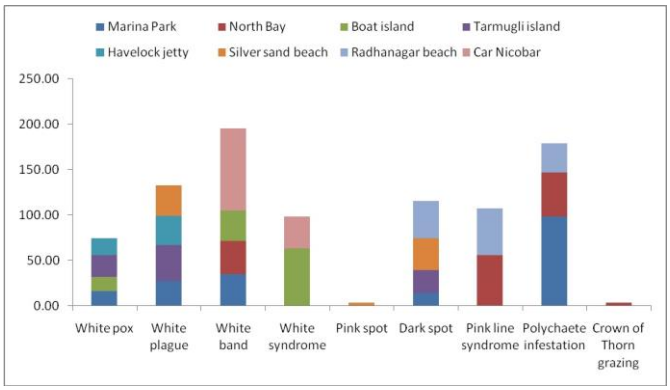

Fig.1 – Prevalence of coral disease in different site of Andaman & Nicobar Islands

White syndrome

"White" type diseases were first described in the Caribbean as far back as the late seventies with the initial discovery of White Plague Type I disease in 1977[34]. This was followed by many diseases such as Shut down reaction, White band, White plague, skeleton eroding band *etc*. The term white-syndrome was coined by the Australian Institute of Marine Science's Long Term Monitoring Project in recognition of the difficulty in diagnosing a disease(s) of unknown pathology based simply on visual field characters or signs. Typically white syndrome is expressed on a coral as a white band sharply cutting across live coral tissue with a clear area of necrosis where the dead white coral skeleton and the living coral colony meet (Plate 1, D). The drivers of white syndrome remain less known. Our study has assigned the nomenclature for the observed (across the study site), yet unidentified disease as white syndrome. This was commonly observed in the plate *Acropora* corals of Boat Island (MGMNP) and Car Nicobar (63.33% and 35 %) (Table 3).

Pink spot

It is difficult to tell if the pink colouration observed around dead and scarred tissue on *Porites* spp. hard coral colonies is the symptom of a disease (Plate 1, F) or simply a response of the coral to a variety of competitive, invasive or parasitic interactions. Appearance of swollen pink polyps indicates the occurrence of disease on coral. The syndrome was first described in the early 90's as pink

Table 3: Location specific occurrence of coral disease in the study sites. (ES: Experimental site, CS: Control site, MP: Marina Park, NB: North Bay, TI: Tarmugli Island, HJ: Havelock Jetty, SSB: Silver sand Beach, RNB: Radhanagar Beach, CN: Car Nicobar)

Sl No	Disease	Station 1				Station 2			Station 3
		ES		CS		ES	CS		CS
		MP	NB	BI	TI	HJ	SSB	RNB	CN
1	White pox	+ (16.67%)	-	+ (15.33%)	+ (23.67%)	+ (18.67%)	-	-	-
2	White plague	+ (27.33%)	-	-	+ (40%)	+ (32 %)	+ (33.33%)	-	-
3	White band	+ (35 %)	+ (37 %)	+ (33.33%)	-	-	-	-	+ (90%)
4	White syndrome	-	-	+ (63.33%)			-	-	+ (35%)
5	Pink spot	-	-	-	-	-	+ (3.67%)	-	-
6	Dark spot	+ (14.33%)	-	-	+ (25 %)	-	+ (35.67%)	+ (40.33%)	-
7	Pink line syndrome	-	+ (56 %)	-	-	-	-	+ (51.67%)	-
8	Polychaete infestation	+ (98.33%)	+ (49%)	-	-	-	-	+ (31.67%)	-
9	Crown of Thorn grazing	-	+ (3.20%)	-	-	-	-	-	-

or white scar tissue forming in response to cysts caused by metacercariae of the digenetic trematode *Podocotyloides stenometra.* The flatworm has three life stages; the first stage is parasitic in nature where the host is a mollusc, while the second affects tissues of the coral, causing polyps to appear swollen and pink. This makes the polyp more prone to predation by butterfly fish, the final host for the parasite. This disease was observed only from Silver sand Beach of Havelock Island (3.67%) on *Porites* spp. (Plate 2, A). This disease was commonly observed to be detrimental to the members of *Acroporids, Favites* and *Lobophyllia* genera in the present study.

Dark spot

The Dark Spot Disease (DSD) was first noticed in Colombian reefs during the early 1990s[35]. Dark spot disease is present as dark pigmented areas of tissue on scleractinian corals. On the surface of corals circular or irregular shapes of dark purple, gray or brown patches of discolored tissue appear. The discoloured tissue increases in size and spreads to other parts of the colony. The darkened polyps are smaller in size than healthy polyp. The coral tissue remains intact, although at times lesions and coral tissue death are observed in the centers of the spots. Dark spot disease characteristically affects branching as well as massive corals. During our study such incidences were reported from four out of eight sites but the intensity was much high in Radhanagar (40.33%) followed by Silver sand beach (35.67%), Tarmugli Island (25.0%) and Aberdeen Bay (14.33%)

Pink line syndrome

Pink line syndrome in *Porites* corals were reported for the first time from Lakshadweep group of Islands[20]. This disease causes partial mortality of the coral. The dead patches were colonized by cyanobacterium. Morphologically this disease looks like that of Black Band Disease, the pink coloured polyps forming a pink line, bordering the dead patches. The responsible cyanobacterium was reported to be *Phormidium valderianum*[23.] This disease is very prominent in the *Porites* corals of the North Bay, where 56 percentage (Table 3) of the examined colonies were seen affected during 2009 (Plate 2, B). The rate of infestation in the corals of Radhanagar was comparatively less (51.67%).

Table 4: Prevalence of coral diseases in the areas studied and the genera of corals affected. (Avg % - Average of the percentage data collected during every survey)

Disease	Affected coral Genera	Number of affected colonies (n)	Relative percentage affected (Avg %)	Absolute percentage affected (Avg %)
White pox	*Acropora, Porites, Platygyra, Gardineroseris*	169	18.53	12.19
White plague	*Porites, Goniastrea, Leptorea, Montipora*	153	33.12	11.04
White band	*Acropora*	177	40.14	12.77
White syndrome	*Acropora*	248	56.24	17.89
Pink spot	*Porites*	14	3.59	1.01
Dark spot	*Acropora, Favites, Lobophyllia*	142	28.86	10.25
Pink line syndrome	*Porites*	212	54.36	15.30
Polychaete infestation	*Porites*	225	57.69	16.23
Crown of Thorn grazing	*Acropora, Porites*	17	2.05	1.23

Polychaete infestation

Boring polychaetes are very common in the massive corals of Andaman and Nicobar Islands. Normally 1-2 animal per meter is seen from the reefs of South Andaman. The polychaetes observed on massive corals are *Spirobranchus gignateus, Spirobrancheus spinosus, Sabellastarte indica* and *Sabella* sp. (Plate 2, C and D). When the number of polychaetes increases, coral changes to a diseased state. In places of infection where the polychaete density reaches 50-120 per metre, the coral community gets subjected to stress. Ultimately the increased numbers of polychaetes leave the coral under stress leading to heavy mortality of polyps and partial bleaching. The polychaetes leave a bleached coral with a small hole which also affects the health of the corals.

These Islands are not much polluted except the Port Blair in South Andaman which is the capital town. Port Blair has an area of 17.74 km^2, with a population of 1,00,186 (as per 2001 census). The coastal marine waters of Port Blair and its vicinity were reported to be generally contaminated with organochlorine pesticides such as lindane and DDT[29]. Corroborating the findings of the present study, the polychaete infestation on *Porites* corals was reported from multiple sites situated in South Andaman[7]. In the present study it was very clear that boring polychaetes affecting the massive corals are increasing tremendously in places where anthropogenic nutrient enrichment is high. The reef near Radhanagar beach was found to be infested by polychaetes but the number remained less competitive in comparison with Aberdeen Bay (98.33%) where all the examined *Porites* corals were infested with boring polychaetes. Such infestation episodes were also observed at North Bay and Radhanagar beach (49% and 31.67%)

Crown of thorn grazing

Acanthaster planci is one of the most beautiful creatures seen in coral reef ecosystem. They have 16 to 18 arms and are covered all over with long, venomous spines. A hungry starfish climbs up on a coral and pulls its stomach out of its mouth with its tube feet. The starfish has thousands of these flexible tube feet, each ending with a little suction cup. The feet pass the stomach from one to the next until the big yellow stomach is spread out over the coral. The stomach sloshes the live coral with digestive juices. The cells of the stomach scoff up the bits of dissolving coral. When the starfish has cleaned the coral right back to the white calcium carbonate skeleton, it sucks in its stomach and walks off, using those tube feet (Plate 1, E and F).

In general, less Crown-of-thorn starfish are encountered on a coral reef. Ideally it should be one Crown-of-thorn starfish for every kilometer of reef or less. Many reefs are notable with their absence. Crown-of-thorn starfish is observed prominently from North Bay only on the genera of *Porites* and *Acropora*. During every visit we have encountered *A. planci* feeding on corals, but not in epidemic proportions.

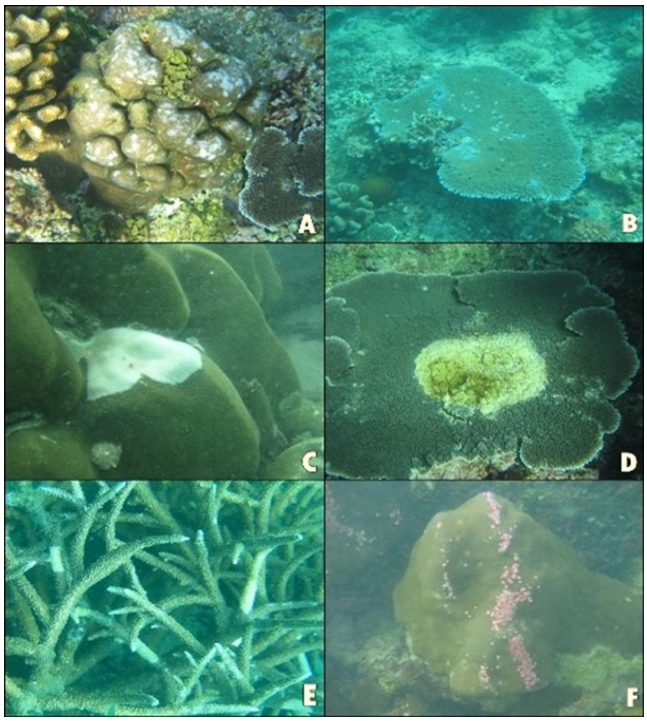

Plate 1: (A) *Goniastrea retiformes* affected with white pox. (B) *Acropora specifera* affected with white pox. (C) *Porites lutea* affected with white plague. (D) *Acropora hyacinthus* affected with white syndrome. (E) *Acropora formosa* affected with white band. (F) Pink spot disease on *Porites solida*.

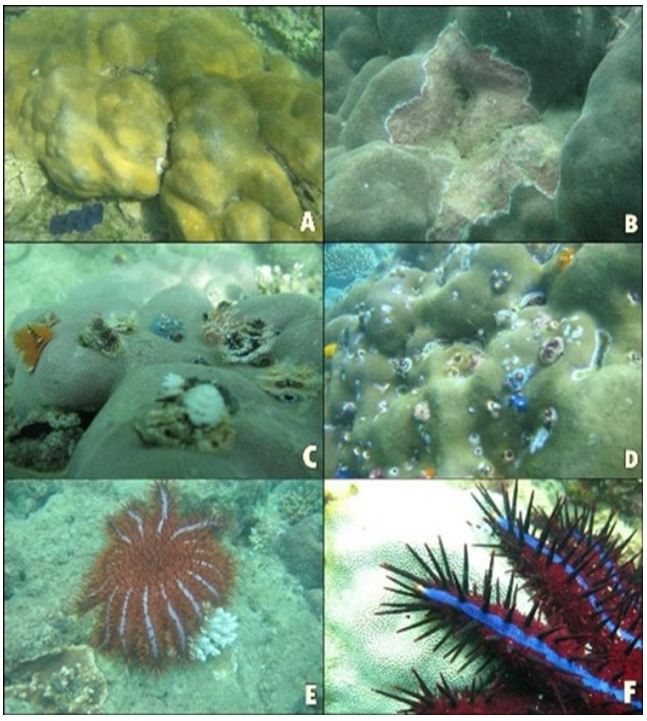

Plate 2: (A) Dark spot disease on *Porites solida*. (B) Pink line syndrome in *Porites solida*. (C) *Porites* colony with average polychaete infestation. (D) *Porites* colony highly infested with polychaete. (E) *Acanthaster planci* feeding on an *Acropora* colony. (F) *Acanthaster planci* feeding on *Porites solida.*

Discussion

The white pox, white band and black band diseases were reported from North Bay, Snake Island and New Wandoor reef corals during 2006[29]. Black band disease and mortality of massive corals due to sedimentation from MGMNP has also been documented[36]. Corals world-wide are vulnerable to various threats, both natural and anthropogenic. The present study corroborates these findings with the report of nine coral diseases in the Bay Islands. One or more diseases have been recorded from all the sites studied (Table 3). This shows the prevalence of diseases in hard corals of Andaman and Nicobar Islands. The control sites and experimental sites do not have any relevance in the disease prevalence as we have observed eight out of nine diseases from control sites (Table 3). The worst affected reef community was observed in Aberdeen Bay. The sewage channels are directly opens to the reef which makes the corals under stress. Most of the corals are partially dead or diseased. Sedimentation and smothering is also a major stress in this site.

Reports on coral disease from Indo-Pacific region are less compared to the other parts of the world.

The scarcity of literature pertaining to coral disease from Indo-Pacific reefs primarily due to lack of proper monitoring of the reefs, underestimates the disease distribution and abundance, despite the region encompassing more than 80% of worldwide reefs. Severe infestation of Caribbean reef region is posing a serious threat to the health of coral community. These investigations show the relevance of this study in Andaman Sea. It is imperative to monitor the reefs for the occurrence, abundance and distribution of coral diseases. Proper information about the occurrence and abundance of diseases can serve as the foundation of future progress related to reef-microbiology, biotechnology, bioactive component extraction, and management plan preparation and conservation strategies.

Among the identified diseases, it was observed that the White pox and White plague were prominent in four different coral genera, dark spot in three coral genera, Crown of Thorn grazing is observed on two different coral species, White band and White syndrome effect were observed in genera of *Acropora* and Pink spot along with Pink line syndrome and Polychaete infestation observed for *Porties* only. The genera *Porites* is affected by six different diseases, the

genera *Acropora* is affected by five different diseases and coral genera namely *Platygyra, Gardineroseris, Goniastrea, Leptorea, Montipora, Favites* and *Lobophyllia* were affected by single disease.

Conclusion

Coral diseases are common in all the reefs of the world due to postulated anthropogenic stresses including deforestation, tourism development, industry wastes and soil erosion[37]. Other natural causes are due to wind or ocean transport of dust, water current, tidal waves *etc*. Percentage prevalence of disease variations among the reefs makes it imperative to monitor all the reefs around the world. The present study also reveals the presence of many new diseases surfacing in the study area.

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