Coral disease prevalence in Mandapam group of islands, Gulf of Mannar, Southeastern India

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Assessment of coral disease prevalence was carried out in six islands in the northern region of the Gulf of Mannar during February 2007. Assessment was made in two sites in each island and three transects were laid in each site. white band, white plaque, white spot, pink spot, black spot, black band, yellow spot, yellow band and tumors were the observed common diseases in this regime. Overall coral disease prevalence was 8.9%. Prevalence was highest at Poomarichan Island (10.90%), followed by Manoli (9.38%), Pullivasal (9.28%), Hare (8.64%), Krusadai (8.27%) and Shingle (6.82%). Most common disease was pink spot in \textit{Porites} sp followed by black band in \textit{Porites} sp., \textit{Pocillopora} sp., \textit{Favia} sp., and \textit{Favites} sp. Tumors were also observed in low frequencies in \textit{Acropora cytherea}. Other affected species were \textit{Acropora cytherea}, \textit{Favia pallida} and \textit{Goniastrea} sp. Present study also consists the frequency of temperature anomalies, which can increase the susceptibility of corals to disease, leading to outbreaks where corals are abundant both in cover and diversity.

[Keywords: Corals, Disease, Temperature. Island]

Over the past few decades, coral reef communities around the world have been weakening due to a combination of natural and anthropogenic factors\textsuperscript{1}. These factors, acting alone or synergistically, have led to a reduction in coral cover\textsuperscript{2,3}. Infectious disease in coral, observed in the field as lesions or distinct bands of tissue loss, can be caused by bacteria, viruses, protozoa, or fungi. In addition to the loss of coral tissue, disease can cause significant changes in reproduction and growth rates, community structure, species diversity, and abundance of reef-associated organisms\textsuperscript{4}.

One of the central issues of coral reef conservation is to determine the major factors contributing to the decline of reefs. Among them, coral diseases have been largely neglected. Although the first coral diseases were described in the early 1970s\textsuperscript{5}, the first detailed quantitative studies of coral disease abundance and distribution were only conducted in the early 1990s on black band disease\textsuperscript{6,7}. Most of the research has been focused on other forms of disturbance, such as over-fishing and declining water quality, which have been considered more threatening to coral reef health\textsuperscript{8}. Over the last decade, reports of coral disease have increased considerably and more virulent diseases, new to science, have been described. The frequency of occurrence and the geographic and host species range of scleractinian coral diseases have increased in the past decade\textsuperscript{9,10,11,1}. There is an increasing concern over the ability of diseases to cause species shifts, restructure coral populations, and cause a decrease in coral species diversity\textsuperscript{12,13}.

To understand the role of coral diseases in effecting changes in community structure, it is necessary to quantify their temporal and spatial dynamics over multiple year time frames. Some postulated anthropogenic stresses linked to coral reef disease include deforestation and soil erosion. Wind or ocean transport of dust could potentially result in the introduction of terrestrial microbes into the marine environment\textsuperscript{14,15}. Disease can cause significant changes in coral reproduction rates, growth rates, community structure, species diversity, and abundance of reef-associated organisms\textsuperscript{4}. Disease related damage of coral reefs has been well documented in the Caribbean\textsuperscript{16}. There has been no basic information about the prevalence of the coral diseases in the Gulf of Mannar. The types and frequency of occurrence of coral diseases in the Mandapam coast of the Gulf of Mannar was studied in the present study.
Materials and method
Surveys were conducted during the month of February 2007. Six (Shingle, Krusadai, Pullivasal, Poomarichan, Manoli and Hare) out of seven islands were chosen in the Mandapam coast of the Gulf of Mannar for disease assessment. Sites were selected using manta tows to assess broad changes in benthic communities. Two sites were identified in each island with different depth (2m and 3.5m). Surveys were conducted using Line Intercept Transect (LIT) method to quantify coral disease prevalence. Each transect was covering an area measuring 20m x 4m (2m on each side of the transect line). At each site, three 20m transects were randomly placed parallel to the reef with a gap of 20m.
Diseased coral colony within each transect was recorded. After calculating the intercept (length) from the transition points recorded along the transect, the percent cover of disease affected life form categories was calculated by using the formula.

\[
\text{Percent disease cover} = \frac{\text{Total length of disease category}}{\text{Length of transect}} \times 100
\]

The analyses provided quantitative information on the community structure of the sample sites. All diseased colonies within the transect were noted and colonies per species were counted.

Two way statistical ANOVA has been performed to find out disease prevalence significance between two different depths.
Water samples were collected from all study sites. Physical and chemical parameters such as temperature, salinity, dissolved oxygen, and pH, and nutrient parameters such as calcium, magnesium, nitrate, nitrite, phosphate and silicate were analyzed using standard methods. Pour plate technique was used to estimate total bacterial count in marine water samples.

Results
The overall disease prevalence in the 6 islands (Fig. 1) was 8.9%. The corals in the Poomarichan Island were most affected with 10.9%, followed by Manoli (9.38%), Pullivasal (9.28%), Hare (8.64%), Krusadai (8.27%) and Shingle (6.82%). In Poomarichan Island, 8 types of diseases had been observed. Disease average differed in one type to another and is given in the Fig 2. Pink spot disease was the dominant form which had highest average with 3.63% followed by yellow band 1.48%, white spot 1.37% and lowest recorded disease was yellow spot (0.35%). In Manoli Island, pink spot disease was dominant with highest average percent (3.06), followed by white plague (1.45), yellow band (1.35) and the lowest recorded was white spot and yellow spot (0.35). In Pullivasal Island, pink spot disease was dominant with 2.89% followed by black band (1.44%), and lowest recorded was tumor (0.17%). In Krusadai Island, pink spot disease was the dominant with 2.86% followed by black band (1.41%), yellow band (1.35%) and the lowest recorded was black spot (0.1%). In Hare Island, pink spot disease was the dominant form with 2.71%, followed by black band (1.92%), and the lowest in the white plague (0.17%). In Shingle Island, black band disease was the dominant which had highest average percent of 2.19, followed by pink spot 1.92 and the lowest was white plague 0.21.
Disease prevalence was low in the second site (3.5m) of all the islands compared to the first site (2m) and the data are given in Fig 3. Two way ANOVA shows significance in disease prevalence between two different depths (Table 1). Temperature...
and microbial load were low in second site (3.5m) of all the islands compared to the first site (2m) and the data are given in the Tables 2 and 4 respectively. Nutrient level was not much varied between depths and sites and the data are provided in the Table 3.

Nine different disease states were documented from the seven major coral genera documented in the Mandapam coast. Distribution of different coral diseases varied widely. The coral genera *Porites* was highly affected (6.07%), followed by *Pocillopora* (1%), *Montipora* (0.99%), *Acropora* (0.36%), *Favities* (0.15%), *Goniosteria* and *Favia* (each 0.15%) (Fig. 4). The pink spot was widespread (occurring at all islands surveyed), while the others, such as *Pocillopora* black band disease and *Montipora* white band disease only occurred at particular site. Among the seven coral genera, overall disease prevalence differed among species to species. Among all genera, *Porites* has been affected with more diseases such as pink spot, white plague, white spot, black spot, yellow band, and black band. *Pocillopora* has been affected only with black band disease. Tumor was only found in *Acropora*. The underwater photographs of some of the coral disease types in Mandapam Group of Islands are provided in Photos 1 to 7 (Fig. 5).

**Discussion**

Over the last 20 years, coral reefs have been under increasing stress from natural and anthropogenic causes, including climate change, poor water quality and over fishing. Diseases have now also been added to the list of significant causes of reef degradation worldwide. After 20 years of research, the source or sudden emergence of the majority of disease in coral reefs is largely unexplainable. Global warming can be correlated with the recent disease increase because warm temperature anomalies may facilitate the emergence and spread of pathogens or spread of other stressful agents.

<p>| Table 1—Statistical result for diseases prevalence at two different depths |</p>
<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>% of total variation</th>
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<td>depth</td>
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<td>0.0024</td>
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<td>disease category</td>
<td>82.64</td>
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<td>** Yes</td>
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<tr>
<td>P value summary</td>
<td>** Yes</td>
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<td>Disease category</td>
<td>Df</td>
<td>Sum-of-squares</td>
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<td>depth</td>
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<tr>
<td>Residual</td>
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<p>| Table 2—Physico-chemical parameters of Mandapam group of islands |</p>
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<tr>
<th>Location</th>
<th>Temperature (°C)</th>
<th>Salinity%</th>
<th>pH</th>
<th>DO(mg/l)</th>
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</thead>
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<tr>
<td></td>
<td>2m 3.5m</td>
<td>2m 3.5m</td>
<td>2m 3.5m</td>
<td>2m 3.5m</td>
</tr>
<tr>
<td>Shingle</td>
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<td>35 35</td>
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<tr>
<td>Kruiseadai</td>
<td>30.1 29.6</td>
<td>35 35</td>
<td>7.9</td>
<td>7.9</td>
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<tr>
<td>Pullivasal</td>
<td>30.2 29.4</td>
<td>34 34</td>
<td>8</td>
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<tr>
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<td>30.1 29.6</td>
<td>34 33</td>
<td>8.1</td>
<td>8.1</td>
</tr>
<tr>
<td>Manoli</td>
<td>30.1 29.5</td>
<td>36 35</td>
<td>8.1</td>
<td>8</td>
</tr>
<tr>
<td>Hare</td>
<td>29.9 29.4</td>
<td>36 35</td>
<td>8.2</td>
<td>8</td>
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</tbody>
</table>

<p>| Table 3—Nutrient levels in Mandapam group of islands |</p>
<table>
<thead>
<tr>
<th>S.No</th>
<th>Location</th>
<th>Calcium (mg/l)</th>
<th>Magnesium (mg/l)</th>
<th>Phosphate (µg/l)</th>
<th>Silicate (µg/l)</th>
<th>Nitrate (µg/l)</th>
<th>Nitrite (µg/l)</th>
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<td>1</td>
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<td>400 440</td>
<td>1210 1232</td>
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<td>72.5 69.3</td>
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<td>4</td>
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<td>480 520</td>
<td>1389 1500</td>
<td>1.2 1.1</td>
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<td>0.04 0.01</td>
</tr>
<tr>
<td>5</td>
<td>Manoli</td>
<td>440 480</td>
<td>1389 1500</td>
<td>1.3 1.5</td>
<td>67.5 65.7</td>
<td>0.2 0.4</td>
<td>0.03</td>
</tr>
<tr>
<td>6</td>
<td>Hare</td>
<td>360 400</td>
<td>1232 1299</td>
<td>1.0 1.2</td>
<td>70.2 77.3</td>
<td>0.3 0.4</td>
<td>0.02</td>
</tr>
</tbody>
</table>
that could affect the natural resistance (i.e., the physiological equilibrium between coral hosts and their natural flora), or could stimulate other bacteria living in reef sediments into becoming virulent.

Disease levels found in the Mandapam group of islands in the Gulf of Mannar were much lower than what has been reported for other reef areas, both in the Indo-Pacific and the Caribbean. Surveyed eight sites along the Great Barrier Reef (GBR) revealed that the prevalence of disease in hard corals ranged from 7.2-10.7\% in the Indo-Pacific and the Caribbean. In the Philippines, an overall prevalence of disease of 14.2\% was reported from 8 sites\(^\text{21,22}\). Disease prevalence ranging from 1.0\% to 28.2\% was noticed during the assessment of coral disease at 32 stations along the Great Barrier Reef. It has been observed in the present study that the average percent of disease prevalence in the corals of Mandapam coast of the Gulf of Mannar is 8.9. Even though the percentage seems to be low, the scientists and conservation managers should be more cautious that it could cause a huge mortality if it spreads. The present observations become important as they can be compared with all the reefs which are living dangerously in the midst of all the anthropogenic and natural threats throughout the Gulf of Mannar in the future.

The occurrence of disease would depend on a number of factors, such as host density, host susceptibility, environmental conditions, or mode of transmission\(^\text{26}\). The average precent of disease prevalence in all the islands is almost same and there is not much deviation. This is because all the islands are having similar bottom topography, and physical parameters.

Disease type’s prevalence variation in islands depends on the distribution of coral species, because certain diseases are species specific. It was reported that abundance and diversity of Acropora was highest on the reefs at French Frigate Shoals\(^\text{27,28}\) and accordingly Acroporid diseases were also dominant. Likewise, Porites is one of the dominant genera in the Mandapam coast and consequently, pink spot disease on Porites was more prevalent than other diseases because this disease affects only Porites. Unlike pink spot disease, black band disease can affect several genera such as Porites, Pocillopora, Favites, and Favia. Among these four genera, Pocillopora has been mostly affected with this disease.

White pox disease is caused by a fecal enteric bacterium of possible human origin\(^\text{29}\) and human sewage markers are strong on coral surfaces in near shore waters of the Florida Keys National Marine Sanctuary\(^\text{30}\). Bacteria associated with human fecal contamination have been found within the microbial mat that causes black band disease of corals\(^\text{31}\). The present observation revealed that corals of all the examined islands have been affected by diseases, however the percentage was highest in Poomarichan Island which is very close to the Mandapam Mainland and has the possibility of receiving untreated sewage disposals. The results also indicate that water samples of Poomarichan Island had high microbial load compared to other islands. Disease prevalence was lowest in Shingle Island, which had lowest microbial load and minimal impact of contaminants from the mainland could be the reason.

Coral disease dynamics are likely to be affected by a variety of biotic and abiotic factors, the relative importance of which will vary among regions, scales, and species\(^\text{32}\). Among all the diseases observed, the percentage of pink spot disease was high in all the islands, followed by black band disease. Seven diseases were found to affect Porites, three were against Montipora, two were against Acropora, and one was against Pocillopora. Patterns in disease prevalence among the coral genera suggest that Porites is the most susceptible genus to diseases especially against pink spot disease and Favia is the most resistant.
Fig. 5—Underwater photographs of some of the coral disease types in Mandapam Group of Islands (Photos - 1 to 7)
No. 1—White band in Montipora digitata, No. 2—White plague in Porites spp, No. 3—Black band in Favites spp, No. 4—Tumor in Acropora cytherea, No. 5—White band in Acropora spp, No. 6—Pink spot in Porites spp, No. 7—Yellow spot in Porites spp.
Diseases are thought to be one of the primary causes of mass coral mortality. Increased temperatures could affect vital biological and physiological properties of corals particularly their ability to fight infection, thus influencing the balance between potential pathogen and host. In addition, the pathogens themselves could become more virulent at higher temperatures. With increased human populations, the scale of human impacts on reefs has grown exponentially. Compounding these anthropogenic stressors are the impacts of global climate change, predicted to result in more frequent bleaching episodes and higher levels of disease. High temperatures and coral disease outbreaks are supported by small scale field studies indicating that prevalence and the rate of spread of several coral diseases within colony are higher during summer.

Present study infers that the disease prevalence was high in 2m depth when compared to 3.5m depth. The results also indicate that water temperature and microbial load were higher at 2m depth. The physico-chemical parameters and nutrient level did not show much variation between sites. All nutrient parameters were well within limits. Prevalence of all coral diseases had been lower in the 3.5 meter depth and the study results strongly indicate that temperature and microbial increments play an important role in disease prevalence.

Prolonged higher temperature leads to mass coral mortality, changes in community structure, and the loss of reef habitat. Maintenance of the water quality around the reef area is vital to prevent the diseases, for that the sewage disposals, factory and household effluents should be treated properly before discharge to sea which is nearer to reef area. The percentage cover and diversity of corals around the Gulf of Mannar islands is increasing because of high coral recruits in the past two years and if the water is continually polluted and the diseases persist it could check the coral cover and diversity. Long term monitoring of diseases and the isolation of causative agents is essential to understand and conserve the reef area effectively to preserve the fragile resources.

During the assessment, it was also observed that diseased dead branching coral had been occupied by algae. Studies would be conducted to find out the relationship between the diseased dead coral and algae; season and disease prevalence; microbial community changes in the reef sites; and relationship between disease and microbial communities. Photo documentation of tissue mortality in disease affected coral colonies and disease spread ratio would also be done.

The Gulf of Mannar is having one of the best reef ecosystems of the Indian Ocean, and it is important to properly conserve and manage this ecosystem. Nowadays coral disease is one of the major threats to the coral ecosystem worldwide and hence the present study is a baseline information for further continuous research and monitoring on this line in the Gulf of Mannar for better coral health.

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