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A Letter Open Access

Mass Mortality of *Porites* Corals on Northern Persian Gulf Reefs due to Sediment-Microbial Interactions

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Abstract Little information is available on coral diseases in the Persian Gulf; however, in the recent years, reports of coral diseases increased in particular from Iranian side of the Persian Gulf. In this paper we report a White Mat Disease resulting in mass mortality of *Porites* colonies at Hormuz Island. This outbreak infected 96% of all *Porites* colonies and killed 58±30% (mean ± SD) of all *Porites* tissues.
Keywords *Porites* mortality; White mat disease; Hormuz Island; Iran

1 Introduction

Being among the most diverse ecosystems on the Earth, the world's coral reefs have been threatened by global and local stresses over the last few decades resulting in vast destruction (Burke et al., 2011; Fisher et al., 2011). Disease has been among the most important contributors to the global degradation of coral reefs (Goreau et al., 1998; Weil et al., 2006; Bruno et al., 2007; Rosenberg and Kushmaro, 2011). Little information on the prevalence or types of coral disease, however, exists for the Indian Ocean including the Persian Gulf (Riegl and Purkis, 2012).

The Persian Gulf is known as one of the most extreme environments for coral reefs with high temperature fluctuations from 12℃ in winter (Sheppard et al., 1992) to 38℃ in summer (Baker et al., 2004), high salinity (up to 39 psu), high sedimentation rate, low depth (35 m in average with majority of coral reefs in depth <10 m) and low water circulation especially in the southern part of the Gulf (see Riegl and Purkis, 2012). In spite of being among the most tolerant coral reefs to thermal stress (Burt et al., 2011), coral reefs of the Persian Gulf encounter massive coral bleaching events due to temperature anomalies (Coles and Riegl, 2012; Kavousi et al., unpublished data). Moreover, 85% of the coral reefs in the Persian Gulf are considered threatened by local stresses (Burke et al., 2011). Furthermore, coral diseases have been recently reported as another serious threat to the coral reefs of the Persian Gulf.

Although little systematic and quantitative studies have been done in the Persian Gulf (Riegl and Purkis, 2012), in recent years, reports of recognized and uncharacterized coral diseases have increased, especially from the northern Persian Gulf including Larak, Qeshm, and Hengam Islands (Samimi-Namin et al., 2010; Kavousi and Rezai, 2011). In this paper, we report a White Mat Disease resulting in mass *Porites* mortality from Hormuz Island of the Persian Gulf.

2 Material and Methods

During a field survey around some Iranian islands of the Persian Gulf in late August and early September 2012, following a mass coral bleaching, an outbreak of a disease was observed on the reef-building corals of the east of Hormuz Island (27°03′N, 56°30′E; Figure 1). To estimate the benthic cover of reefs, 10-meter Line Intercept transects were established (n=9) at a depth of <4 m where majority of the reefs exist. The number of infected coral colonies was obtained by counting 100 coral colonies randomly. Photoquadrat method (n=70) was used to calculate the coral tissue mortality due to the white mats. Sedimentation rate in the area was obtained by using

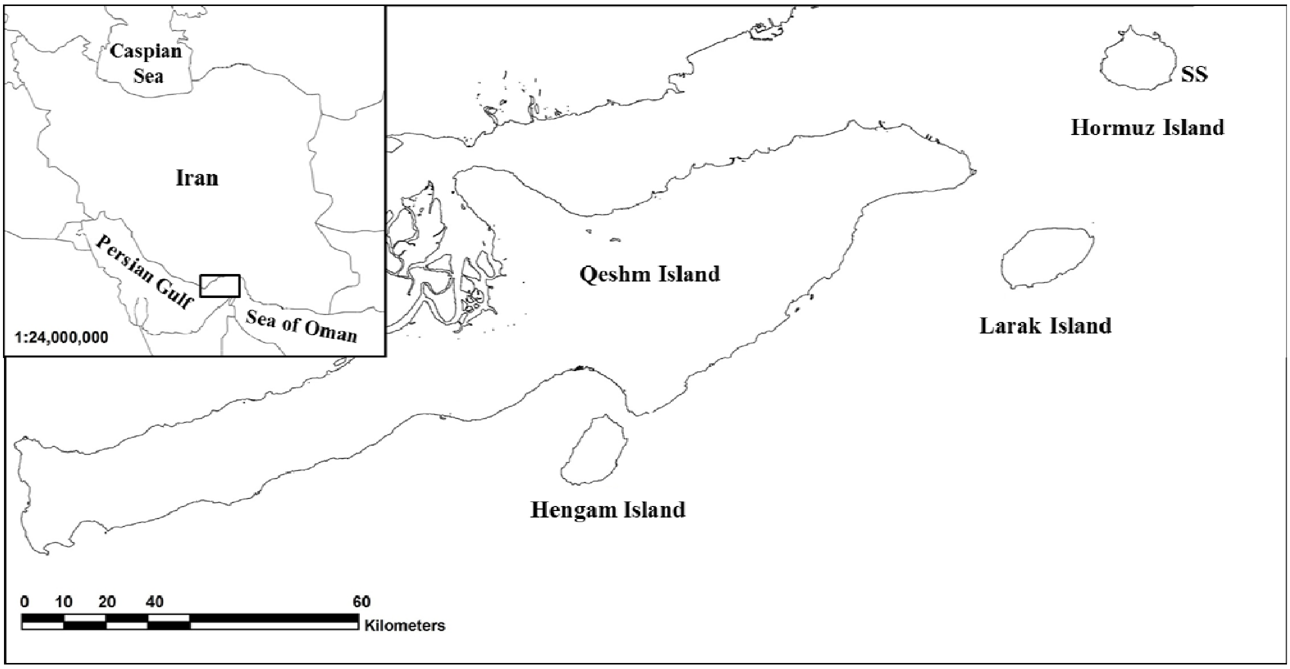

Figure 1 Map of the area including Hormuz Island where was examined in this study. SS= studied site in this study

the accumulated sediments collected with 10-day-sediment traps following the methodology mentioned in Hill and Wilkinson (2004). Three rods with 3 sedimentation traps attached to each rod (9 traps in total) were hammered to three sides of the reefs; however, the data presented here are from 6 traps because the other three traps were lost. Sedimentation rate is reported as gr/cm²/day.

3 Results and Discussion

The main reefs of Hormuz Island, located at the east and 2-4 m deep, include as main reef-builders zoanthids and scleractinian corals for 59.79±15.95% (mean±SD) and 8.68±7.01% (mean ±SD) of substratum, respectively. The predominant coral genus in the area is massive *Porites* (more than 85% of the reef-building corals). High sedimentation rate is a permanent characteristic of this site (Figure 2 A) and a rate of 0.052±0.014 gr/cm²/day was measured. In spite of this high sedimentation, corals and zoanthids have appeared healthy during the last three years (Figure 2B, personal observations); however, in summer 2012, the reef-building corals encountered coral bleaching (Kavousi et al., unpublished data) and outbreak of a disease that followed.

Overgrowth of invasive organisms such as algae (Goreau et al., 1998; Barott et al., 2012) and pathogenic bacteria (Kline and Vollmer, 2011) leading to coral mortality is prevalent worldwide but mass coral mortality from sulfate reducing bacteria is a rare phenomenon that was recorded on reef-building *Porites* corals of Hormuz Island of the Persian Gulf in Summer 2012.

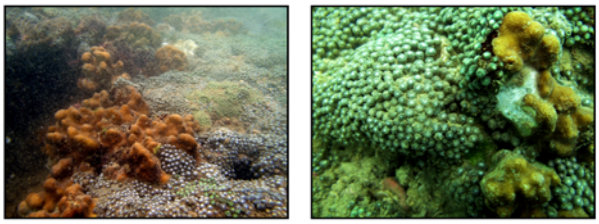

Figure 2 A: Turbid waters due to high sedimentation around coral reefs at eastern Hormuz Island B: Deposition of sediments on live organisms such as corals and zoanthids as a permanent characteristic of this site

Whereas all coral colonies were affected by thermal stress (from partially bleached to fully-bleached), the *Porites* corals were overgrown by a white mat of bacteria (Figure 3 A and B) that infected 96% of all *Porites* colonies and killed 58±30% (mean ± SD) of all *Porites* tissues. The same phenomenon was also observed on several coral genera on the south of Hormuz and Larak Islands.

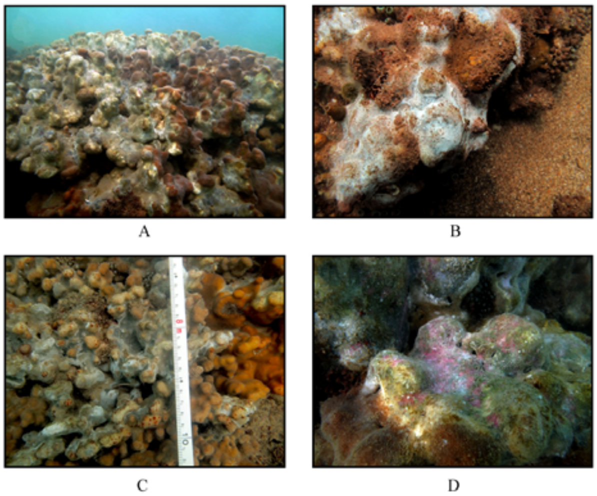

Figure 3 A: Mass mortality of *Porites* colonies at Hormuz Island due to bacterial mats B: White mat on a *Porites* colony C: White mats changed overlying black layers due to iron sulfide precipitation D: Photosynthetic sulfur and non-sulfur bacteria are probably responsible for pink and green colors

Reports on post-bleaching coral mortality due to diseases are increasing worldwide (Bruno et al., 2007; Miller et al., 2009; Riegl et al., 2011; Bastidas et al., 2012). Although, coral reefs facing mild and sometimes severe bleaching can recover quickly (e.g. Goreau et al., 2000; West and Salm, 2003; Riegl et al., 2011), diseases can reduce resilience, coral cover, and reef resistance drastically for several years (Goreau et al., 2000; Rosenberg and Loya, 2004; Sutherland et al., 2004).

Massive *Porites* corals are known as the most tolerant corals to thermal stress (Goreau et al., 2000; Loya et al., 2001); however, the results of this study indicate *Porites* corals are still susceptible to the secondary effects of bleaching events including coral diseases. Moreover, reefs affected by coral diseases have less resistance and resilience (Goreau et al., 2000; Rosenberg and Loya, 2004) resulting in more likelihood of being overgrown by invasive organisms and competitors such as macroalgae and other reef builders; however, even under no visible stress, zoanthids are able to overgrow reef-building corals (Figure 4A, B, C; J. Kavousi, personal observation). The reefs to the east of Hormuz Island are now dominated by zoanthids (59.79±15.95%). Whereas reef-building corals were highly affected by the recent bleaching event and its consequences, zoanthids showed no sign of bleaching or sickness. The shift

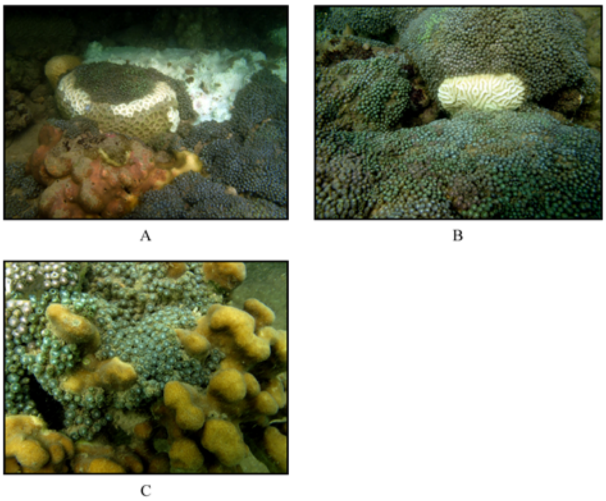

Figure 4 Overgrowth of zoanthids on coral colonies including A: *Favia* B: *Platygyra* C: *Porites* at the east of Hormuz Island

from coral dominated reefs to non-scleractinian coral-dominated reefs due to climate change and its consequences were reported (reviewed by Norström et al., 2009; Bell et al., 2013). This may lead to local extinction of reef-building corals of the east of Hormuz Island under ongoing climate change.

Sulfide oxidizing bacteria such as *Beggiatoa*, *Thiothrix* and *Thioploca*, etc. are suggested to be the dominant bacteria in the white mats (Jorgensen, 1977; Jorgensen and Postgate, 1982; Fenchel et al., 2012). A dark colored underlayer (Figure 3C) that appeared at the white surface of affected tissues less than 24 hours after the first observations is probably due to iron sulfide precipitation. The pink and green colored underlayers observed on the majority of infected coral colonies (Figure 3D) could be photosynthetic sulfur and non-sulfur bacteria; however, microbial examinations are needed.

Although sulfide oxidizing bacteria linked coral mortality was reported (Garrett and Ducklow, 1975; Mitchell and Chet, 1975), previous observations involved very localized coral mortality, often due to artificially induced stress in the laboratory or linked to sediment stress in the field (Weber et al., 2012).

Sulfide oxidizing bacteria are a visible epiphenomenon that is a result, not a cause, of mortality. Coral surface tissue smothered with fine-grained mud creates locally anoxic sites (Erftemeijer et al., 2012) that are colonized by anaerobic, heterotrophic sulfate-reducing bacteria. The Hydrogen Sulfide they produce then kills coral tissue (Weber et al., 2006; 2012). The sulfide-oxidizing bacteria live at the interface between the aerated water and the necrotic tissue, and oxidize Hydrogen Sulfide escaping from below with oxygen from above. They precipitate internal elemental sulfur granules (Jorgensen, 1977; Fenchel et al., 2012) that give them a distinctive white mat appearance (Richardson, 1998). The mat tends to trap and maintain anoxic condition (Jorgensen and Postgate, 1982) at the tissue surface (Miller and Richardson, 2012), hastening coral mortality. Thus the disease is a secondary microbial effect of sediment stress (Weber et al., 2012), not a primary pathogen that attacks coral tissue directly. The effects are worst where there is heavy sedimentation, especially coupled to organic loading (Weber et al., 2012), warm conditions, and weak water movement.

The increased number and outbreak of coral diseases reported from the Persian Gulf in the recent years may be evaluated as a sign of future frequent mass mortalities due to coral diseases which could result in reef degradation and coral extinctions. Therefore, it is necessary to monitor long-term effects of coral diseases along with doing histological and microbiological examinations in the Persian Gulf.

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