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9A Coral bleaching and climate change

# Status of coral reef health in the northern Red Sea, Egypt

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**Abstract.** This study aimed to provide baseline knowledge of coral diseases prevalence and coral health at nine reef sites in the northern Egyptian Red Sea: I (El-Ain Al-Sukhna), II (Ras Za'farana), III (Hurghada), IV (Ras Ghozlani), V (Old Quay), VI (Yolanda reef), VII (Ras Umm Sid, Sharm El-Sheikh), VIII (WoodHouse reef, Sharm El-Sheikh), and IX (canyon reef, Dahab). Sites IV, V and VI are located in Ras Mohamed, marine protected area. Field surveys of coral diseases and signs of compromised health in the studied reefs revealed a mean prevalence of 1.03%. Macroscopic observations were diagnosed as: black band disease (0.44%), white syndrome (0.13%), pink line syndrome (0.04%), ulcerative white spots (0.02%), skeletal eroding band (0.001%), coral bleaching (2.2%), *Drupella cornus* snail predation (0.1%), fish predation (0.2%), pigmentation response (0.13%), sediment damage (0.08%), algae overgrowth (0.06%) and sponge overgrowth (0.04%). Prevalence of coral diseases and bleaching were higher in non-MPA sites than in MPA sites. The highest prevalence of coral diseases was recorded on the coral *Favia stelligera*, followed by *Porites lutea*, and *Goniastrea edwardsi*. Enhanced local anthropogenic stresses and increasing sea surface temperature due to global warming are the suggested potential factors responsible for the initiation and the persistence of some coral diseases in the studied reefs.

**Key words:** coral health, coral disease, global warming, Red Sea, Egypt.

## Introduction

Coral reefs are among the most heavily degraded marine ecosystems. Over the last two decades, coral reef communities have experienced increasingly stressful conditions due to a combination of natural and anthropogenic factors (Wilkinson 2004). Coral disease potentially acts as a bioindicator of reef health (Green and Bruckner 2000) and recent increases in coral disease events have been linked to environmental stress and climate change (Lesser et al. 2007). Coral disease diagnosis is primarily macroscopic, taking into account characteristics such as the extent of tissue loss, tissue color and exposure of coral skeleton (Ainsworth et al. 2007).

Red Sea reefs are cited among the most diverse in the world in terms of overall species diversity (Loya 1972), yet the corals in this region are not well studied (Rinkevich 2005). In the Red Sea, coral reef degradation has increased dramatically during the last three decades, particularly along the Egyptian Red Sea coast due to enhanced anthropogenic disturbances and their interaction with natural stressors (Ali et al. 2011). These stressors are thought to cause coral diseases and bleaching leading to a loss of coral cover. Unfortunately, very little is currently known about the prevalence, distribution and pathology of coral disease in the Red Sea (Antonius and Riegl 1997; Al-Moghrabi 2001).

The aims of this study were to provide baseline knowledge of coral health and disease prevalence in the northern Egyptian Red Sea, and to identify coral species that were the most susceptible to each specific disease.

## Material and Methods

*Study area*

Data were collected from nine different reef sites along the northern Egyptian Red Sea coast (Fig.1). Sites were selected to represent reefs that were relatively undisturbed (Site IV, V, VI, and VIII) and reefs that have been impacted by human activities (Site I, II, III, VII, and IX). Sites IV, V and VI are located in Ras Mohammed Marine Park (Marine Protected Area).

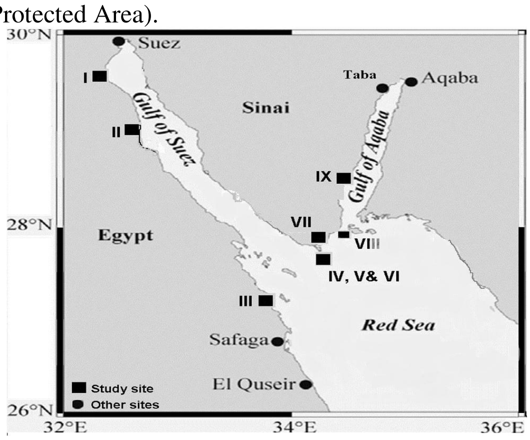

Figure 1: Map of nine coral disease prevalence survey sites in the northern Egyptian Red Sea. I El-Ain Al-Sukhna, II Ras Za'farana, III Hurghada, IV Ras Ghozlani, V Old Quay, VI Yolanda reef, VII Ras Umm Sid, VIII WoodHouse reef, and IX Canyon reef.

*Field survey*

Surveys were carried out during the summer months of 2009 and 2010 using SCUBA diving and snorkeling. At each site, three replicate 20m long and 2m wide belt transects (English et al. 1997) were surveyed at fixed intervals on the reef slope (at a uniform depth contour of 2-6m). All colonies within each transect were identified, counted, photographed, and checked for signs of disease, bleaching, predation and compromised health. Coral species and diseases were identified *in situ* and underwater photographs (SeaLife ECOShot/SL321) were used for further confirmation. Hard corals were identified to species level using the identification guides of Sheppard and Sheppard (1991), Wallace (1999), and Veron (2000). Coral disease, bleaching, predation and other signs of compromised health (pigmentation response, sediment damage, algae and sponge overgrowth) were identified by the characteristics of lesions using the guides of Beeden et al. (2008) and Raymundo et al. (2008).

*Data Analysis*

The prevalence of coral disease, bleaching, predation and other signs of compromised health was expressed as a percentage of the total number of coral colonies surveyed per transect. Mean prevalence and standard errors were calculated from all three replicate transects per site. Differences in the prevalence of disease and compromised health signs among affected hard coral species and sites were tested using separate one-way analyses of variance (ANOVA). Regression analysis was used to examine whether the prevalence of coral disease was related to live hard coral cover and species abundance. Cluster analysis (joining or tree clustering method) was carried out using STATISTICA software to examine the similarities among the studied sites in coral disease and compromised health occurrence.

**Results**

*Overall prevalence of coral diseases*

Field surveys in the northern Red Sea revealed an overall prevalence of 0.63% of coral diseases and 0.4% of signs of compromised health (Fig.2). The prevalence of each disease and compromised health state (Fig.3) was as follows; black band disease (BBD,0.44±0.02%), white syndrome (WS, 0.13±0.006%), pink line syndrome (PLS, 0.04±0.004%), ulcerative white spots (UWS, 0.02±0.001%), skeletal eroding band (SEB, 0.001±0.0001%), coral bleaching (0.07±0.01%), *Drupella cornus* snail predation (0.009±0.0004%), fish predation (0.005±0.0008%), pigmentation response (0.13±0.006%), sediment damage (0.08±0.007%), algae overgrowth (0.06±0.001%), and sponge overgrowth (0.04±0.003%).

*Variation of coral diseases among survey sites*

The prevalence of coral diseases and compromised health varied significantly among sites (ANOVA, F= 8.8, df=1, p≤0.05). Prevalence was higher in non-MPA sites than in MPA sites. The highest diseases prevalence (1.5±0.08%) was recorded at site III followed by site VII (1.4±0.1%) and site I (1.3±0.2%), while the lowest prevalence (0.07±0.02%) was recorded at site VIII (Fig.4). There was a weak positive relationship ($r^2$=0.02, p≤0.05) between the amount of hard coral cover and prevalence of coral disease and compromised health.

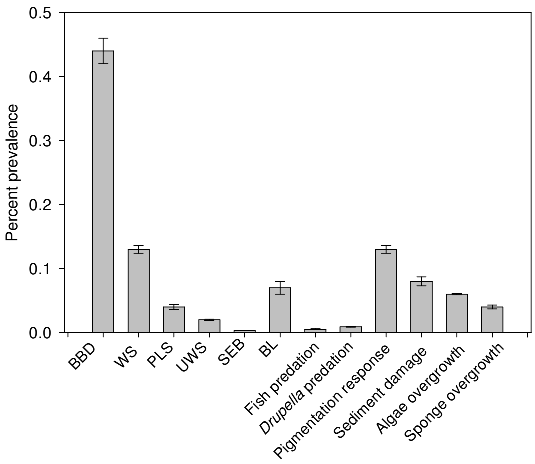


Figure 2: Mean prevalence of coral diseases and compromised health states across nine survey sites in the northern Egyptian Red Sea in 2009-2010. BBD, black band disease; WS, white syndrome; PLS, pink line syndrome; UWS, ulcerative white spots; SEB, skeletal eroding band; Bl, bleaching.

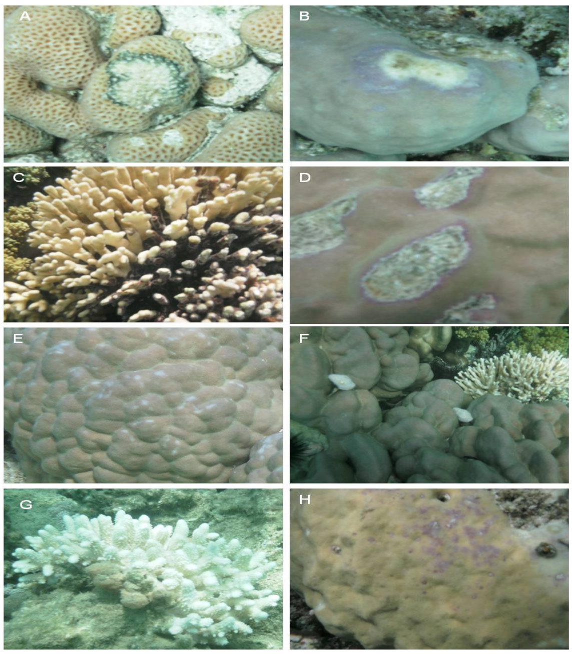

Figure 3: *In situ* photographs of diseases and compromised health signs affecting corals in the northern Egyptian Red Sea. A) BBD on *Goniastrea edwardsi*; B) WS on *Porites* and tissue bordering WS lesion is colored by pigmentation response C) SEB on *Stylophora pistillata*; D) PLS on *Porites lutea;* E) Fish predation on *Porites lutea*; F) *Drupella cornus* predation on *Porites lutea*; F) Pigmentation response on *Porites lutea*; G) Completely bleached *Acropora humilis* H) Pigmentation response on *Porites luea.* Full names of coral diseases as per Fig 2.

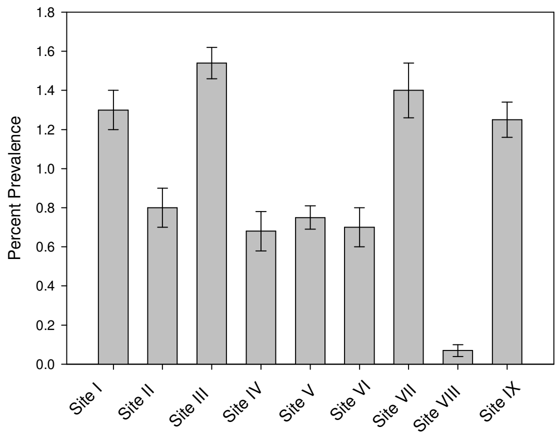


Figure 4: Mean prevalence of diseases and compromised health signs affecting corals in the surveyed sites in the northern Egyptian Red Sea (N = 9 sites; n = 3 transect per site; mean ± SE)

The studied sites were divided into two clusters based on the occurrence of particular diseases (Fig 5). The largest cluster includes reef sites located nearby the Gulf of Aqaba (sites VI, VIII, V, VII and IX), and site III. The second cluster includes sites in the Gulf of Suez (sites I and II).

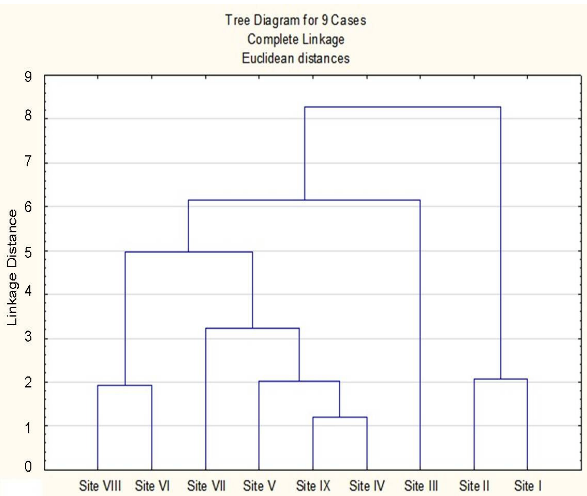


Figure 5: Cluster analysis dendrogram showing the similarities in the occurrence of particular coral diseases among sites in northern Egyptian Red Sea.

Distribution of the different coral diseases and compromised health varied among the studied sites. Bleaching was widespread (occurring at 8 out of 9 sites) along with other signs of compromised health (7 sites), BBD (6 sites), and WS (5 sites). Other diseases such as UWS, SEB, and *Drupella cornus* predation only occurred at a single site (Table 1).

| Disease/ syndrome | Sites |
|---|---|
| BBD | III, IV,V,VI,VII, and IX |
| WS | III, V, VI, VII, and IX |
| PLS | I and IX |
| SEB | II |
| UWS | VII |
| Bleaching | I, II, III, IV, V, VI, VII, and VIII |
| *Drupella* Predation | I |
| Fish predation | VI and VII |
| Other signs of Compromised health | I, II, IV, V, VI, VII, and IX |

Table 1: Distribution of diseases and compromised health signs affecting corals in the northern Egyptian Red Sea. Full names of coral diseases as per Fig 2.

*Variation in coral diseases among hard coral species*

There was a significant difference in disease prevalence among affected coral species (ANOVA, F=22.3, df=1, p≤0.05). The highest prevalence of coral disease was recorded in species *Favia stelligera* (6.1±0.3%), followed by *Porites lutea* (5.3±0.2%), and *Goniastrea edwardsi* (4.0±0.2%). The hard coral mostly affected by BBD and WS was *Favia stelligera* (5.0± 0.3% and 1.1±0.08%, respectively). Bleaching predominantly occurred on *Goniastrea pectinata* (0.7±0.03%) and UWS was reported mostly on *Goniastrea edwardsi* (0.5±0.02%). The hard coral most affected by PLS, fish predation and signs of compromised health was *Porites lutea* (0.6±0.03%, 0.2±0.01% and 2±0.1%, respectively) which was also the only species on which *Drupella cornus* predation was reported (0.1±0.07%). There was a positive relationship ($r^2$=0.57, p≤0.05) between disease prevalence and relative species abundance

**Discussion**

This study documents coral disease occurrence and prevalence along the northern Egyptian Red Sea and provides important baseline information in this region where limited quantitative coral disease data exists. The present results indicates a low coral disease prevalence of 0.63% on coral reefs in the area of study. This level of coral disease is much lower than those reported from other reefs both in the Indo-Pacific: 7.2%-10.7%, GBR of Australia (Willis et al 2004); 6.2%, the Solitary Islands in Australia (Dalton and Smith 2006); 8.9%, Southeastern India (Thinesh et al. 2009) and in the Caribbean: 11%, St. Lucia (Nugues 2002) and 5.28% (Weil 2004).

Distribution of coral diseases and compromised health states varied among the studied sites, which might be due to differences in species composition and the types of stressors affecting each site. The cluster analysis revealed similarities between sites located nearby the Gulf of Aqaba and Hurghada (Fig 5). These sites are heavily impacted by human touristic activities such as SCUBA diving and snorkeling. Additionally there was high similarity between sites I and II (non-MPA sites), which are impacted by oil pollution and massive construction activities.

Black band disease (BBD) was the most prevalent coral disease on the surveyed sites, accounted for 42% of the cases of coral diseases at the surveyed sites (Fig 2) with a lower prevalence (0.44%) than reported from the Great Barrier Reef (GBR, 2.8%; Dinsdale 2002) and the Florida Keys (0.72%; Kuta and Richardson 1996). BBD has also been recorded in other areas of the Red Sea (Antonius 1988 a, b; Green and Bruckner 2000; Al-Moghrabi 2001). The relatively high levels of BBD in the study were observed at sites nearby large cities including: Dahab, Sharm El-Sheikh, and Hurghada. This may be attributed to enhanced terrestrial sedimentation, nutrient enrichment and sewage discharge (Voss and Richardson 2006). These local stressors are largely associated with population growth in the coastal cities and towns, coastal development and expansion of tourism activities. It is important to note that the greatest numbers of BBD cases were recorded on faviid corals, where *Favia stelligera* was the most susceptible species to BBD. This is consistent with Indo-Pacific records of BBD for two massive faviid species, *Goniastrea pectinata* and *Platygyra Lamellina*, from the Philippines and a further seven massive faviids from the Red Sea (Willis et al 2004). Unlike in the Caribbean, where BBD primarily infects massive species (Kuta and Richardson 1996), branching pocilloporid and acroporid corals are important host species on the GBR. While BBD primarily affects faviids in the Red Sea and Caribbean, greater infection rates in pocilloporids and acroporids on the GBR might be attributed to differential species composition.

White syndrome (WS) is a common coral disease in the Indo-Pacific and is a collective term for conditions producing white symptoms on the GBR (Willis et al. 2004). In this study, WS had a prevalence of 0.13% in all studied reefs and accounted for 12.6% of the observed diseases. WS has been reported from other areas in the Red Sea (Antonius 1988a; Antonius and Riegl 1998), the Indo-Pacific (GBR, Willis et al. 2004; Philippines, Raymondo et al. 2005; Indonesia, Haapkyla et al. 2007) and the West Indian Ocean (Weil et al. 2006). The most susceptible coral species to WS in this study were *Favia stelligera* and the plate coral *Acropora hyacinthus*. Similarly, Beeden et al. (2008) reported that WS commonly affects plate species of genus *Acropora*.

Pink line syndrome (PLS) is an Indo-pacific coral disease and it was firstly described from Kavaratti Island, Indian Ocean in 2001. It is characterized by a band of pink-pigmented tissue separating dead skeleton from apparently healthy tissue. This band may begin as a small ring and progress outward horizontally across a coral colony (Sutherland et al. 2004). The results of this study showed that PLS had a low prevalence in all studied reefs, accounting for 3.8% of the diseases prevalence obtained. The coral *Porites lutea* was the most susceptible coral to PLS. These results are consistent with the findings of Ravindran and Raghukumar (2002) who reported that *Porites compressa* and *Porites lutea* were affected by PLS.

Skeletal eroding band (SEB) and ulcerative white spots (UWS) showed the lowest prevalence in the area of study (Fig. 2). *Stylophora pistilata* was the most susceptible coral to SEB which is consistent with results of Winkler et al. (2004) who reported that *Acropora* and *Stylophora* were the coral genera most heavily impacted by SEB in the Gulf of Aqaba.

Coral bleaching occurred more frequently among the investigated sites than any of the diseases or other signs of compromised health, but prevalence within sites was low. Elevated sea surface temperature associated with the global warming is a main cause of coral bleaching (Hoegh-Guldberg et al. 2007), and has previously affected Red Sea reefs in 1998 and 2002/2003 (Antonius 1988a, Loya 2004). The low level of bleaching in this study may have been caused by above average sea surface temperatures (SSTs) in the Red Sea at the time of our surveys. SST anomalies of 1°C (2009) and 1.5 °C (2010) above the maximum mean SST of 29°C (NOAA coral reef watch satellite) were recorded during the surveys.

Prevalence of *Drupella* predation and fish predation was very low (0.009% and 0.005%, respectively) compared to the prevalence of other compromised health states. *Porites lutea* was the only species subjected to both *Drupella* and fish predation. Other signs of compromised health were common in the study area, including: pigmentation response, sediment damage and competition (algae and sponge overgrowth). At some study sites, sedimentation from increased coastal construction activities constitutes one of the potential causes of coral tissue loss. *Porites* was the most affected coral by pigmentation response and it appears to respond to a variety of competitive and parasitic challenges by producing pink or purple pigmentation (Willis et al. 2004). In contrast to PLS, which has well defined pink lines bordering the dead patches in the affected colonies, reported pigmentation responses are in the form of spots or patches of brightly colored tissues.

This study has documented that Egyptian Red Sea reefs are currently impacted by a number of diseases and syndromes. These coral diseases affect both protected and non-protected reefs. Prevalence of coral diseases and bleaching were higher in non-MPA sites than in MPA sites. Enhanced local anthropogenic stressors and increased sea surface temperature associated with global warming are suggested potential factors responsible for the initiation and progression of coral diseases and bleaching in the studied reef sites. Under increasing exposure to anthropogenic stressors in non-MPA sites, natural resilience of coral reefs would be weakened, increasing the percentages of corals affected by diseases leading to the fragile health state of corals in the Egyptian Red Sea.

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