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Coral Health and Disease in the Spermonde Archipelago and Wakatobi, Sulawesi

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Abstrak

Survei pendahuluan terhadap penyakit karang dilakukan pada bulan Oktober 2011 sebagai bagian dari persiapan workshop penyakit karang di Indonesia. Penelitian sebelumnya telah dilakukan di TN Wakatobi Sulawesi Tenggara tahun 2005 dan 2007, dan kemudian survei secara kualitatif dilakukan pada bulan April 2011. Penelitian ini dimaksudkan untuk mengetahui penyakit karang di Sulawesi dan membandingkannya dengan hasil temuan di lokasi lain di dunia. Dari kedua lokasi yang disurvei, prevalensi penyakit karang relatif rendah dibandingkan kejadian di tempat lain di dunia. Penyakit sindrom yang banyak ditemukan di TN Wakatobi adalah white syndrome, black band disease, dan yellow tissue discoloration syndrome dimana secara makroskopik mirip dengan yellow band disease di Karibia. Di Kepulauan Spermonde, penyakit karang yang paling umum adalah white syndrome (WS) yang menyerang 13 genera karang. Meskipun prevalensi penyakit karang di P. Barranglompo dan Wakatobi relatif rendah, namun kedua lokasi berpotensi dampak lebih besar karena pengaruh peningkatan aktivitas manusia dan bila suhu perairan terus memanas. Penelitian ini menyediakan data dasar mengenai dampak penyakit karang terhadap terumbu karang di Sulawesi, Indonesia yang merupakan pusat keanekaragaman terumbu karang.

Kata Kunci: *penyakit karang, Pulau Baranglompo, Taman Nasional Wakatobi, Sulawesi*

Abstract

Preliminary surveys for coral disease were conducted in October 2011 as part of the first Indonesian coral health workshop in Barranglompo Island, part of the Spermonde Islands, South Sulawesi, Indonesia. Previous coral disease surveys conducted in Wakatobi National Park (WNP), South-East Sulawesi in 2005 and 2007, and qualitative surveys in April 2011, are included here to provide an overview of what is known about coral disease in Sulawesi and to compare results with reports from other regions of the world. On all reefs surveyed in these two locations, levels of coral disease were relatively low compared with global averages from other locations. In preliminary surveys of Spermonde reefs, the most significant syndrome detected was white syndromes, which affected 13 different coral genera. The most significant syndromes detected in WNP were white syndromes, black band disease, and a yellow tissue discoloration syndrome that was similar macroscopically to Caribbean yellow band disease. Although overall coral disease prevalence was low in Barranglompo and WNP, there is the potential for greater impacts of coral disease as anthropogenic influences increase and the oceans continue to warm. This study provides preliminary baseline data on the impact of coral disease within the reefs of Sulawesi, Indonesia, the center of coral reef biodiversity.

Keywords: coral disease, Barranglompo Island, Wakatobi National Park, Sulawesi

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INTRODUCTION

Outbreaks of coral diseases are a major contributor to coral mortality and reduced growth and recruitment (Harvell et al., 2002; Willis et al., 2004; Sutherland and Ritchie, 2004; Miller et al., 2006; Weil et al., 2006; Bruno and Selig, 2007; Harvell et al., 2007; Harvell et al., 2009; Weil et al., 2009). Global surveys between 2004 and 2009 showed high levels of coral disease at many sites, but particularly in the Caribbean (Ruiz-Moreno et al., in review). In that region, repeated outbreaks have contributed to widespread mortalities that have severely reduced populations of the once-dominant corals *Acropora palmata* and *A. cervicornis* (Hughes, 1994; Richardson, 1998; Aronson and Precht, 2001; Sutherland and Ritchie, 2004; Miller et al., 2006; Weil et al., 2006; Harvell et al., 2007; Rogers et al., 2009; Weil et al., 2009). In the Indo-Pacific, disease outbreaks in the Philippines (Raymundo et al., 2005), Guam (Myers and Raymundo, 2009), and the Great Barrier Reef (GBR) (Willis et al., 2004; Sato et al., 2009, Haapkylä et al. 2010) may be contributing to the increasing rates of decline in coral cover (Bruno and Selig, 2007). Coral diseases are also emerging in East Africa (McClanahan, 2004), Hawaii (Aeby and Santavy, 2006) and Japan (Weil et al., in press).

Factors facilitating outbreaks of coral diseases are still poorly known, although the influence of certain anthropogenic factors is becoming clearer. In the Philippines, prevalence of diseases was higher outside Marine Protected Areas (Raymundo et al., 2009) and on reefs closer to highly populated areas (Kaczmarsky, 2006) than on less impacted or protected reefs. Along the GBR, reefs which supported tourist diving pontoons had 15-fold higher coral disease prevalence than reefs without these influences (Lamb and Willis, 2011). Nutrient enrichment from sewage, effluents or fertilizer is also associated with increased coral disease prevalence, virulence and severity (Bruno et al., 2003; Kaczmarsky et al., 2005; Voss and Richardson, 2006; Sutherland et al., 2010, 2011). One possible mechanism for this was suggested in a study on the impacts from effluent created by fish farms in Bolinao, Philippines. Corals transplanted near fish farms showed altered bacterial communities which increased the abundance of known human and coral pathogens. This implicates fish farms as a possible source of coral disease pathogens (Garren et al., 2009).

Additionally, extremes in physical factors cause physiological stress and are likely associated with corals' susceptibility to diseases (Harvell et al., 2002; Muller et al., 2008). However, factors such as elevated temperature may also directly cause disease pathogens to proliferate (Toren et al., 1998), some coral diseases appear more prevalent during times of high water temperature (Patterson et al., 2002; Weil, 2004; Willis et al., 2004; Bruno et al., 2007) or low salinity (Haapkylä et al., 2011). Studies suggest that outbreaks may result when coral health is compromised, for example when environmental parameters, such as water temperature, exceed tolerance thresholds (Ritchie, 2006; Lesser et al., 2007; Muller et al., 2008). High coral disease prevalence has also been positively associated with high sunlight (Boyett et al., 2007; Sato et al., 2011), high coral cover (Bruno et al., 2007), and with certain species of fleshy macroalgae (Nugues et al., 2004). Such macroalgae may promote pathogen proliferation on their surface (Smith et al., 2006; Morrow et al., 2011) or act as disease vectors (Nugues et al., 2004).

To date, very little work has been done to investigate the health of Indonesian corals. Surveys within Wakatobi National Park (WNP) in South-East Sulawesi showed that prevalence of disease was low, with an average of 0.57% in 2005 (Haapkylä et al., 2007) and 0.33% in 2007 (Haapkylä et al., 2009; Fig. 1). Whether this trend is common throughout Indonesia or simply the result of resilience within a national park is unknown. Six described coral diseases were recorded during these surveys: white syndromes, growth anomalies, black band disease, brown band disease, *Porites* ulcerative white spot, and skeletal eroding

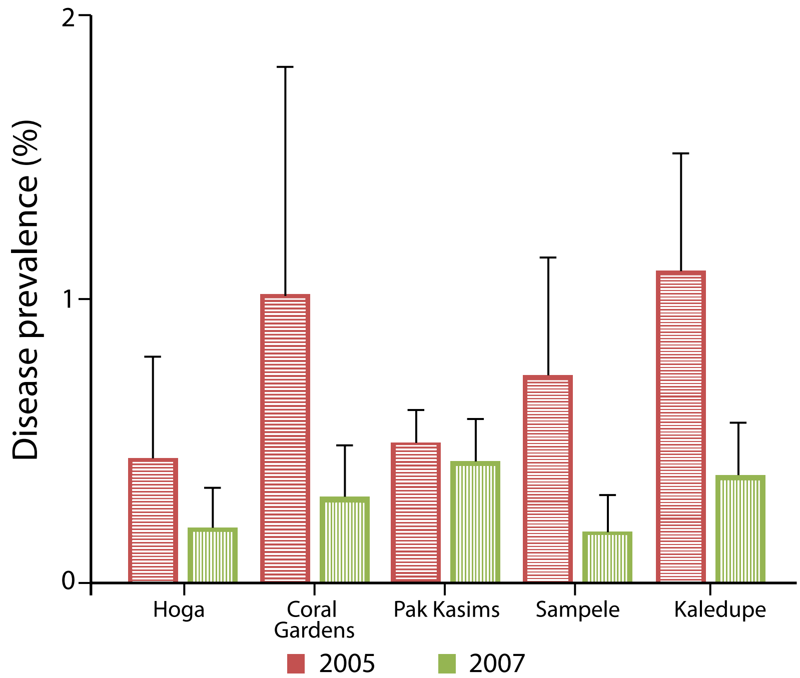

Fig 1. Results from the disease prevalence surveys conducted at five sites in the Wakatobi National Park in 2005 and 2007 (from Haapkylä et al., 2009).

band (Haapkylä et al., 2009), as well as other undescribed conditions (Haapkylä et al., 2007). Rates of disease progression, such as that from black band disease (Fig. 2), are comparable with those measured in other parts of the world, suggesting the potential for serious impacts from coral disease on the reefs of Indonesia (Haapkylä et al., 2009). In light of predicted climate change scenarios, it is likely that coral diseases will increase over time. These future scenarios identify an urgent need to improve our understanding of current coral disease dynamics in Indonesia.

The objective of this study was to obtain preliminary baseline data of coral

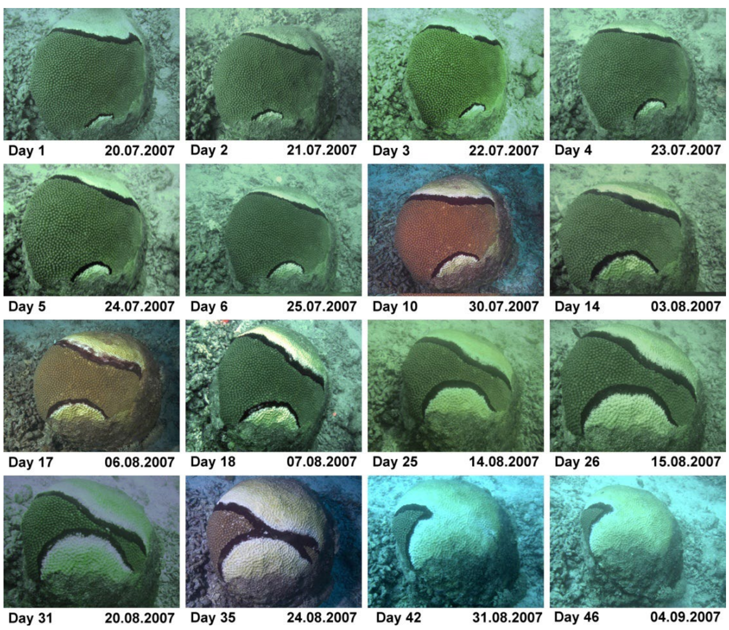

Fig 2. Progression of black band disease on a colony of the coral *Diploastrea heliopora* (diameter approximately 1 m) in Wakatobi National Park, showing more than 90% tissue loss over 46 days (Photos by J. Haapkylä).

disease prevalence and compromised health on reefs of Barranglompo Island in the Spermonde Archipelago in South Sulawesi in October 2011 and WNP in South-East Sulawesi in April 2011 (Figs. 3 and 4). Here we present the results of quantitative surveys conducted in the Spermonde Archipelago as part of the first Indonesia coral health workshop, and qualitative surveys in WNP. Photographs of coral diseases and compromised health categories observed are also presented.

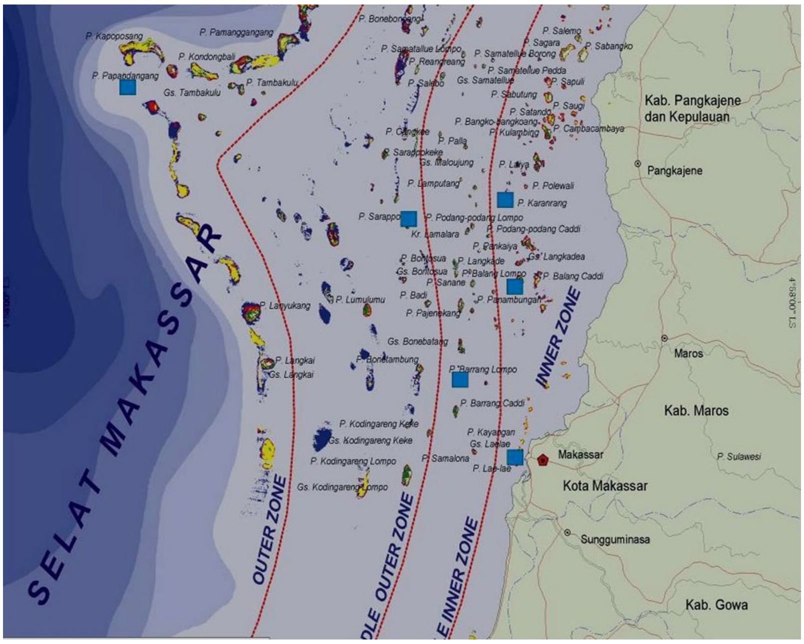

Fig 3. Map of the Spermonde Archipelago. Red lines indicate different human impact zones that are differentiated based on distance from the mainland of Sulawesi. The white dot indicates the location of the study site, Barranglompo Island.

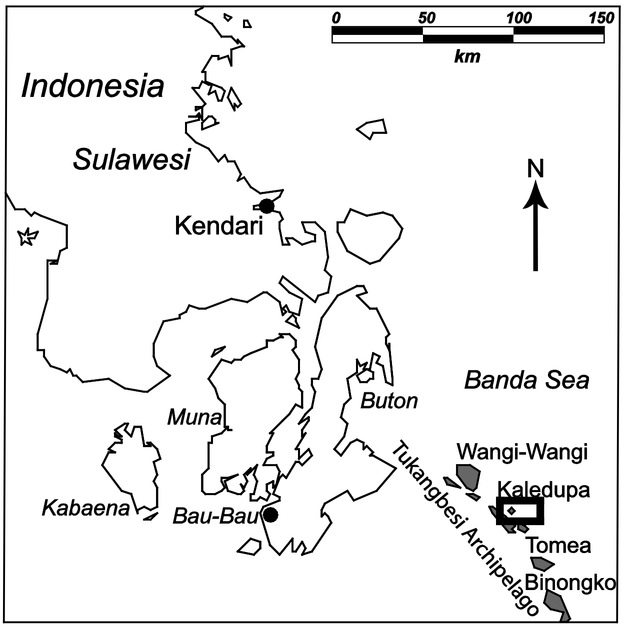

Fig 4. Map of South-East Sulawesi. The black box represents the location of Hoga Island, one of the study sites in Wakatobi National Park.

METHODS

The impact of coral disease was quantified on reefs adjacent to Barranglompo Island (119º19´48” E; 05º02´48” S) in the Spermonde Archipelago, South Sulawesi. The archipelago consists of more than 100 small islands, with Barranglompo located in the middle zone (Fig. 3), approximately 14.5 km from the mainland in the vicinity of Makassar, the capital city of South Sulawesi (population ~1.3 million). The island of Barranglompo supports a large human settlement (population ~3563) and reefs may be affected by both sewage effluent from the island and fluvial discharge from nearby mainland rivers during rainy seasons. In contrast, the second site was located on reefs surrounding Hoga Island, within Wakatobi National Park (Fig. 4). The island has very few (~150) permanent residents, but is a common tourist destination.

Disease prevalence on Barranglompo reefs was quantified in October 2011 by surveying transects in two depth categories: shallow (0–3 m) and deep (~10 m). Replicate, 15m-long transects were surveyed at each depth and the health status of each coral was documented by using 2-m belt transects (1 m on either side of the transect tape) totaling a 30 m^2 area per transect. Three transects were conducted on SCUBA within the deep reef area, whereas two transects were surveyed by snorkel within the shallow reef area. Along transects, each individual coral colony was identified to the lowest taxonomic unit possible by the surveyor and the health status of the coral was recorded. The coral health status was identified as (i) healthy, (ii) compromised, or (iii) diseased. A healthy colony did not show any signs of impairment. A compromised colony showed signs such as a pigmentation response, overgrowth by algae, or predation scars, but did not show signs of an infectious disease. A diseased colony was identified as a coral showing signs of a putatively infectious disease, such as black band, brown band, or white syndromes. For full methodological details on identifying coral disease and compromised coral health, see Raymundo et al. (2009). Values for the prevalence of coral disease and compromised health were calculated as the number of colonies with disease (or compromised health) divided by the total number of colonies recorded within the transect.

In addition to quantifying coral health, the total coral cover of each transect was estimated using the line-intercept method. Here, the distance that each substratum type (coral or non-coral) covered underneath the transect tape was recorded and used to determine the total percent coral cover within the transect. This metric provided another quantifiable measure, in addition to coral health status, by which to characterize the overall reef state.

The non-parametric Mann-Whitney U test was used to determine if there was a difference in disease prevalence and compromised health prevalence between shallow and deep reefs because variances were significantly different between the two depths. A Student’s t-test was used to test whether the prevalence of compromised coral health differed significantly from coral disease prevalence within Barranglompo after meeting all parametric assumptions.

In April 2011, qualitative surveys (n=4) were conducted within WNP. A team of 4 surveyors observed several reefs around Hoga Island, at depths ranging from 2 to 8 m while on SCUBA. Coral diseases and signs of compromised coral health were noted and photographs were taken. These informal surveys were conducted to determine if coral diseases present in 2011 differed from those recorded in previous surveys by Haapkylä et al. (2007, 2009) in 2005 and 2007.

RESULTS

Coral disease prevalence was generally low at the sites surveyed in Barranglompo (Fig. 5). Approximately 1.5% (± 1.0) of the surveyed coral colonies showed signs of disease at the deep site, whereas disease prevalence was, on average, 4.6% (± 6.0) at the shallow site. There were no statistical differences between the deep and shallow sites for any metric of coral health or reef state (coral cover, compromised health

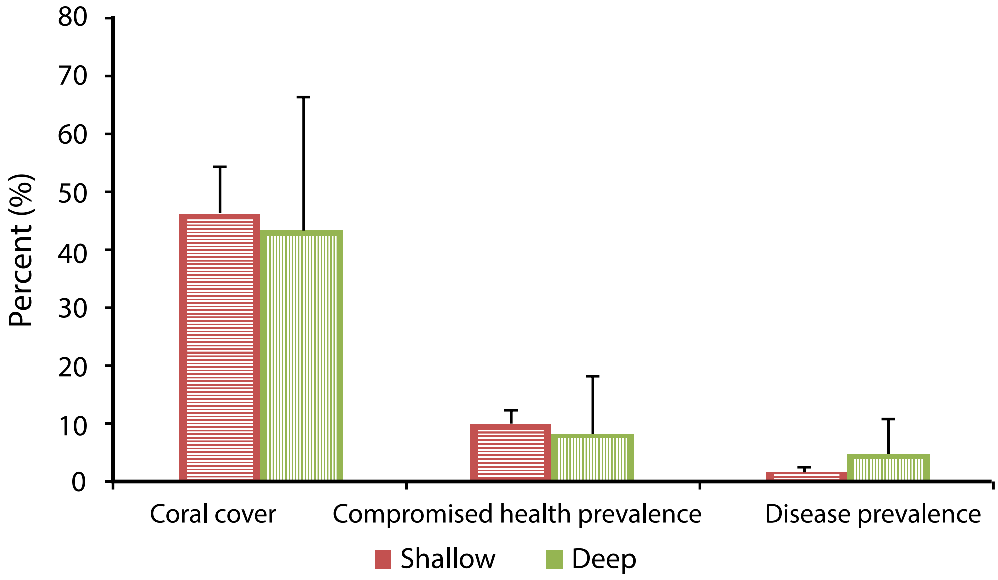

Fig 5. Comparison of coral cover (%), signs of compromised health (%), and disease prevalence (%) between a deep and shallow site at Barranglompo Island, Spermonde Archipelago, based on preliminary surveys of coral health conducted in October 2011 (n=3 transects at the deep site, n=2 transects at the shallow site). The error bars represent standard deviation.

prevalence, coral disease prevalence: Z=0, n_1=3, n_2=2, p=1.0; statistical results for each variable were the same). Since there were no significant differences between depths, the data were pooled for subsequent analyses. Overall, prevalence of compromised health signs was not significantly different than coral disease prevalence, although the average prevalence of compromised health from both depths was higher than coral disease prevalence (deep: 9.6% ± 2.7; shallow: 8.2% ± 9.9; t= -2.19, df=8, p=0.06; Fig. 5). Coral cover was relatively high at both depths, with the deep site having an average of 46.4 % (± 8.2) coral cover and the shallow site having an average of 43.6% (± 23.2) coral cover (Fig. 5).

A total of five coral diseases were observed during the surveys: skeletal eroding band (SEB), atramentous necrosis (AtN), white syndromes (WSs), brown band (BrB), and growth anomalies (GA) (see Fig. 6). The most common disease was WSs, observed on 42 coral colonies from 13 coral genera. Interestingly, 28 of these cases were found within a single transect, which is indicative of an infectious disease when susceptible host density is high. The other four diseases were much less common and observed on less than five individual coral colonies. Several different conditions that indicated compromised coral health were also observed. The most common conditions observed were algal overgrowth, patchy bleaching, cuts and scars, and pigmentation response (for examples see Fig. 6).

The informal surveys conducted in WNP showed high levels of a yellow tissue discoloration syndrome, similar in appearance to Caribbean yellow band disease, on *Diploastrea* (Fig. 7A). Although the syndrome was not reported in previous surveys, it had been observed in 2010 (J. Haapkylä, pers. observ). Other diseases observed around Hoga Island included black band disease, growth anomalies, skeletal eroding band, and white syndromes (for examples see Fig. 7). Patchy bleaching, a sign of compromised coral health, was also observed.

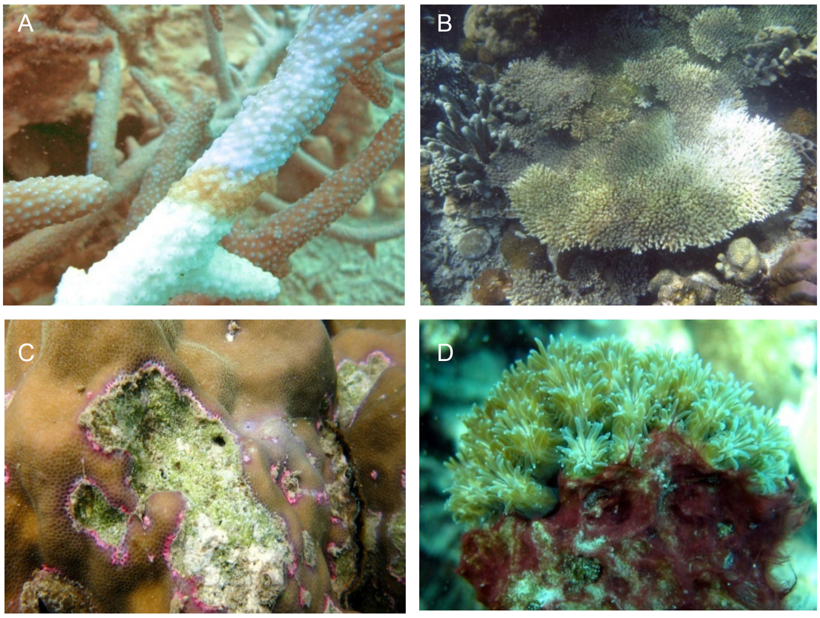

Fig 6. Images of coral diseases (A,B) and corals with compromised health (C,D) observed around Barranglompo reefs. A: brown band disease on branching *Acropora* sp. B: a white syndrome on *Acropora* sp. C: pigmentation response on *Porites* sp., and D: *Galaxea* sp. being overgrown by cyanobacteria. Photos by L. Raymundo (A,B), D. Harvell (C) and B. Willis (D).

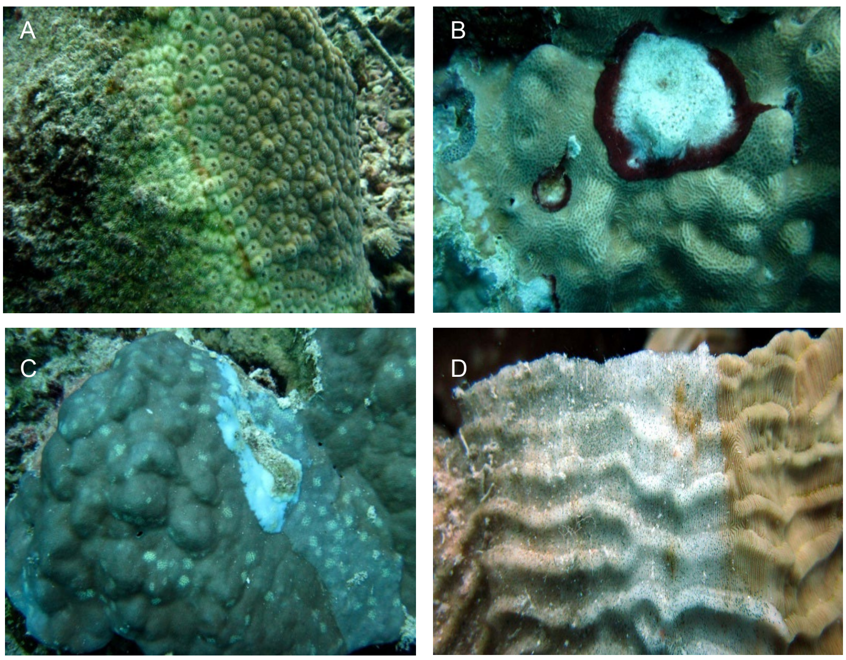

Fig 7. Images of coral diseases observed around Wakatobi National Park. A: yellow tissue discoloration on Diploastrea sp. B: black band disease on Pavona sp. C: growth anomaly on Porites sp., and D: skeletal eroding band on Pachyseris sp. Photos by D. Harvell.

DISCUSSION

Indonesian coral reefs lie within the Coral Triangle, the center of coral reef global biodiversity. Further, the Indonesian island system contains the second largest reefal surface area in the world (42,000 sq km; Bryant et al., 1998). As such, these reefs are of critical biological, cultural, and ecological importance. These very preliminary surveys of coral health indicate that even reefs in fairly impacted waters like Spermonde Archipelago have relatively low levels of coral disease. However, there are significant coral diseases present, all of which have been described from other reefs in the Indo-Pacific region, making this a critical time for completing baseline surveys.

Many of the local conditions that facilitate coral disease in other locations (for example, Philippines: Kaczmarsky et al., 2005; Garren et al., 2009; Great Barrier Reef, Australia: Lamb and Willis, 2011; Caribbean: Sutherland et al., 2010, 2011) are also impacting reefs within Indonesia, such as increasing tourism pressure, discharge of human sewage into coastal waters, aquaculture in near shore waters, eutrophication from land-based sources, and sedimentation from deforestation (Burke et al., 2011). In addition to these local factors, significant levels of bleaching occurred in 1998 and 2010. Warming events are predicted to increase some coral diseases (Bruno et al., 2007; Selig et al., 2006; Maynard et al., 2011). Fifteen years of monitoring data (1995-2010) on coral reef condition in the Spermonde Archipelago indicate that coral bleaching has only occurred in the last few years, and was especially significant in 2010 (Jompa and Yusuf, 2010). This monitoring program indicates that the average bleaching prevalence in the archipelago was around 15%, and bleaching typically spread from reef flats to slopes, with the most intense coral bleaching observed between 3–10 m depth. Seawater temperatures during the year of the bleaching event were around 2.37^{o}C warmer (during April-May 2010; Fig. 8) than average yearly seawater temperatures around the Spermonde Archipelago, 29.08^{o}C (Jompa and Yusuf, 2010). The higher prevalence of WSs than other diseases found in our 2011 Barranglompo surveys may partially reflect the impact of accumulated temperature stress on coral resistance to WSs (see Maynard et al., 2011). Furthermore, although coral disease prevalence was relatively low within the sites surveyed, atramentous necrosis and several cases of yellow tissue discolouration were observed in 2011 but not in the 2005 and 2007 surveys (Haapkylä et al., 2007, 2009). These results may be the first signs of an increasing impact of coral diseases in Indonesia.

Management of coral disease is in its early stages, though the urgency of the problem, in light of continuing coral loss, demands that strategies be developed (e.g. Beeden et al., 2012). Techniques to stop coral disease progression on infected colonies have been attempted on limited scales, including aspirating black band cyanobacterial mats from active lesions and then covering the lesion with epoxy (Raymundo et al., 2008) and phage therapy for known bacterial diseases (Efrony et al., 2007). Other possible methods to reduce the spread of coral disease among reefs may involve the quarantine of reefs where outbreaks are in progress and the potential removal of organisms acting as disease vectors when disease is highly prevalent (reviewed in Beeden et al., 2012). However, all of these approaches are labor- or resource-intensive and none have been attempted with any success on a large spatial scale. Given what we are learning about the role of water quality in coral health (Bruno et al., 2003; Kaczmarsky, 2006; Voss and Richardson, 2006; Garren et al., 2009), a logical first step is to improve water quality by reducing anthropogenic inputs into nearshore marine systems. This approach simply relies on the principle that corals growing in clean water will be under less stress than those growing in contaminated, high-nutrient, high-turbidity water. This will allow corals to develop and maintain strong defense and immune responses when they are exposed to pathogens. In addition,

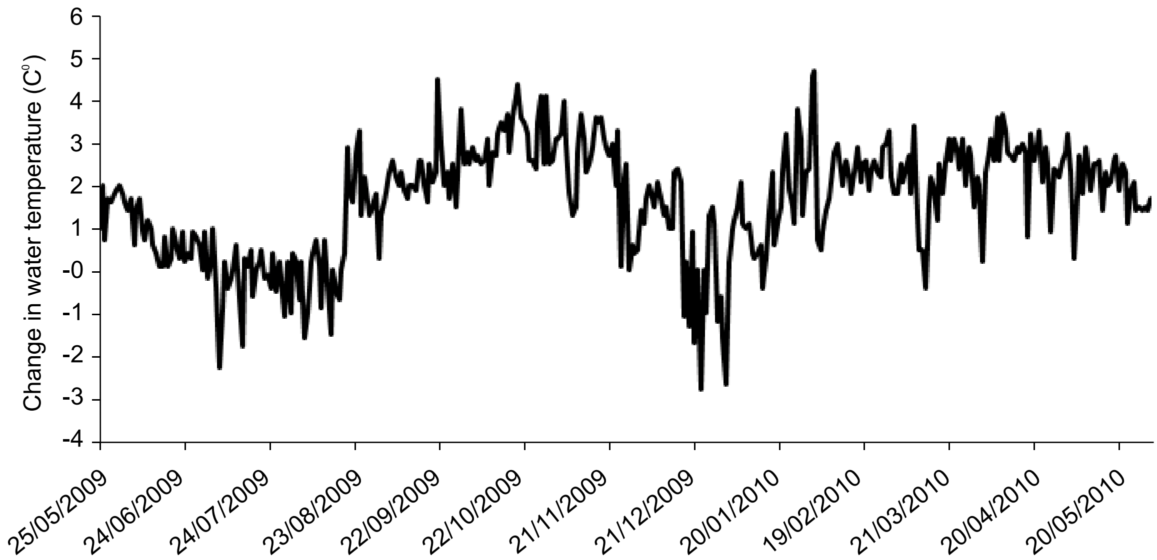

Fig 8. Annual pattern in the difference between daily seawater temperatures from 2009–2010 and average seawater temperatures taken over the past 15 years (1995–2010) in the Spermonde Archipelago (daily temperatures measured manually at Badi Island, Spermonde Archipelago; Yusuf et al., 2010).

increasing inputs of terrestrial bacteria, viruses and other potential pathogens (for example from aquaculture, Garren et al., 2009) may activate emerging diseases in organisms in the marine environment that were previously unexposed to these microorganisms (Mydlarz et al., 2006). In a clean, healthy environment, progression and severity of disease within host colonies, and transmissibility of disease to nearby susceptible hosts, is predicted to be lower than on reefs with similar coral communities where water quality is declining. By improving conditions at sites where coral cover has been greatly reduced by poor water quality, corals may show improved survival and recruitment. Well-constructed studies to test this hypothesis are needed to determine the efficacy of this approach as a management strategy for coral disease.

Another strategy which provides hope for managing coral diseases is the establishment of Marine Protected Areas. New studies suggest that functioning and enforced no-take MPAs, with an intact complement of fish, are associated with lower levels of coral disease (Raymundo et al., 2009; Page et al., 2009). In both the Philippines and Palau, low prevalence of coral disease was associated with high fish diversity (both functional and taxonomic diversity). In the Philippines, levels of coral diseases were lower in MPAs than their paired fished counterpart reefs. At each of these surveyed reefs, low abundance of corallivorous butterflyfishes was most strongly associated with both high fish diversity and low coral disease prevalence (Raymundo et al., 2009). The mechanisms by which this effect may operate are still under study, but likely involve both direct and indirect interactions between corals, potential vectors of disease, and microbes that cause disease. Reefs that are not harvested have intact communities with innate population-regulating mechanisms; on heavily fished reefs, some fish functional groups are completely eliminated, leaving certain community functions unfilled. Other organisms may undergo rapid increases, such as certain algal groups that are no longer kept in check via herbivory or smaller fish or invertebrates that are not controlled via predation. Sweatman (2008), for instance, found fewer outbreaks of the crown-of-thorns starfish (*Acanthaster planci*) within Australian MPAs. Again, the mechanism was not elucidated, but the author speculated that this effect of MPAs may be due to a cascade effect, which begins with protection of large predatory fish and results in increased predation on juvenile COTS by benthic invertebrates. It is likely that the overall effect of functionally complete marine communities on coral health will have multiple mechanisms, depending on the unique etiology of each disease. These mechanisms may involve a variety of organisms, including microbial communities (e.g. Dinsdale et al., 2008), which may interact with corals as pathogens, food sources or habitat, and the effects are likely to be indirect and complex. However, while elucidating these mechanisms is necessary for understanding and managing individual diseases, establishing and maintaining MPAs is a feasible management strategy for promoting overall coral health and limiting disease impacts. The newly established MPAs as part of the Coral Reef Rehabilitation and Management Program (COREMAP) may well increase coral health and resilience, as well as allowing fish populations to recover from over-fishing.

CONCLUSION

The preliminary data from this study show that levels of coral disease prevalence at the sites surveyed in Sulawesi were relatively low. However, surveys in WNP over several years indicate that the number of coral diseases may be increasing and that progression rates of diseases are comparable to rates found in the Caribbean and on the GBR. Furthermore, as the oceans continue to warm and pollution to the marine environment increases, coral diseases will likely become more prevalent. More comprehensive baseline surveys of coral health are needed to provide data on coral disease increases in cases of declining environmental quality, as well as coral disease decreases in response to improved management practices. Indonesia, with its extensive reefs of high biodiversity, coupled with high population densities and intensive harvesting of marine resources, should be a primary focus for disease research efforts in the future.

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