Status of coral diseases and compromised health syndromes on Pemuteran shallow reefs, North Bali island

W Karim
Department of Marine Science, Faculty of Marine and Fisheries, Udayana University Jl. Raya Kampus Unud, Kampus Bukit Jimbaran, Bali 80361, Indonesia

Corresponding author: widiastutikarim@unud.ac.id

Abstract. There are limited data of Indonesian coral diseases and compromised health syndromes. As the increased popularity of Pemuteran shallow reefs waters as one of tourist destination in the north Bali island, the coral health status is a particular interest in the term of ecology and socio-economy aspects. This research aimed to investigate the status of coral diseases and compromised health syndromes in Pemuteran shallow coral reefs. Research was conducted on March 2018 in Pemuteran waters, Buleleng regency, Bali island. Coral diseases and compromised health syndromes were measured within a modified 2 x 20 m belt transect with three replications in five sites. Result showed that the lowest percentage of live corals and the highest prevalence of coral diseases were at site 2 and 4 respectively. The identified coral diseases were Ulcerative white spots, White syndromes and Trematodiasis, while the algal aggressive overgrowth, predation of Drupella spp. and COT, sedimentation were found as some of the dominant agent of compromised health syndromes. The level of nitrate was extremely high at site 4 and site 5 that is snorkeling and diving spots. Furthermore, the concentration of organic matter was significantly high at all sites compare to other reported reefs area.

1. Introduction
Coral diseases have been reported as one of the main contribution in declining world coral reefs population [1] [2]. Caribbean reefs were the first areas that had affected by this pandemic that disrupted more than 95% of its coral reefs [3] [4]. However, this pandemic has rapidly infected other world reefs including Indo-Pacific reefs that lack of documentation [5] [6].

Inspite of the massive outbreak, the mechanism of disease infection remains unknown. Studies revealed that nutrient loading [7] [8] [9] and organic matter in the form of organic carbon [10] [11] [12] are assumed as the strongest drivers of coral disease. The excessive concentration of nutrient and organic matter are assumed to decrease the coral immune system due to acceleration growth rate of coral associated microorganism communities [9]. However, the potential role of each drivers has not widely examine as coral associated microorganism communities are diverse and host specific [13] [14] [15] [16].

This study provides basic data regarding the distribution, environmental stressors and prevalence of coral diseases and compromised health syndromes in Pemuteran shallow reefs, north Bali island. The beautiful landscapes and cultures bring about Bali island as one of the world tourist destination.
Nonetheless, it is currently threatening by rapid economy growth, overfishing and climate change [17]. Pemuteran waters in the north Bali is located in a small fishing village that recently gain popularity as tourist destination (Figure 1). Meanwhile, elevated human activities, overfishing and coastal development for tourist facilities are the main harmful factors for the marine life in this area. Thus this research aimed to investigate the coral diseases and compromised health syndromes in Pemuteran shallow coral reefs in order to provide a basic line information for the sustainability of coral reefs in this area.

2 Materials and Methods

2.1 Sampling sites and environmental parameters

Prior to investigation, reefs were selected based on its proximity to terrestrial runoff, river, human population and tourist facilities (hotels). The study sites were located in Selini beach, Pemuteran village, Gerogak district, Buleleng regency, north Bali island (Figure 1). The sampling sites have similar geomorphology and ecology with fringing reefs along the coastal line. Sampling was conducted using SCUBA in end of March 2018. Site 3 and 4 have populated area, in particular, site 3 has hotels and few anchored ships and site 4 have traditional shrimp ponds that channeling the outflow water to the surrounded coastal areas. In addition, there were three terrestrial runoff in site 4 which 2 of them were still actively flow into the sea all year. Site 1 and 2 had the lowest populated area and site 5 was the snorkeling and diving spot that located furthest from the coastal line. Each site was separated at 1 km away five in which coral diseases and compromised health syndromes were measured within 2 x 10 m belt transects placed randomly at 3-6 m depth. Diseased and compromised health syndromes were counted and noted following the description of Coral Disease Handbook [18] and Underwater Cards for Assessing Coral Health on Indo-Pacific Reefs [19]. Identification of corals were based on Veron [20] and Suharsono [21]. Disease and compromised health syndrome prevalences were calculated by:

\[
\frac{\text{Number of diseased colony per transect}}{\text{Total number of colonies per transect}} \times 100\% 
\]

![Figure 1. Map of study sites](image)

Each 1500 ml of water samples (two replicates) were collected at ±1 m above the coral colonies and out of the belt transects for nitrate and organic matter analyses. All samples were taken simultaneously with disease and compromised health syndrome observations. Nitrate was determined by the brucine method, while organic matter level was measured by titrimetric method [22].

2.2 Statistical analysis

Results from number of coral colonies, diseases and duplicate water samples were averaged. Simple linear regression analyses were used to detect relationships between disease prevalences and environmental variables. T tests were used to compare sites with high prevalence to sites with lower prevalence to show differences. Non-parametric Mann-Whitney Rank sum tests were performed when normality tests were failed.
3 Results and Discussion

3.1 Abundance and percentage of coral coverage

3.1.1 Percentage of coral coverage

The growth form of coral all over the sites was dominantly massive. The highest percentage of coral live was shown in site 1 that reached 100% whereas the lowest was at site 2 and 4 that lower than 30% (Figure 2). The percentage of live coral coverage at site 5 was relatively similar at site 3. It is assumed that the high percentage of live coral cover is related to the anthropogenic activities and land runoff in these sampling sites. The highest percentage of live coral at site 1 is likely due to low human activities in the coastal zone and there was no runoff that may affect the water quality. Similar assumption could be applied for site 4 where heavily human population and shrimps ponds inhabited the coastal zone. However, that assumption could not apply in site 2 that has low population and no river/runoff. According to the visual observation, the high number of dead coral at this site was resulted from fish bombing by traditional fisheries which was used to happen in this area long time ago.

Figure 2. Percentage of coral coverage at all sampling sites

3.2 Environmental parameters, number of coral colonies and prevalence of diseased colonies

The highest number of coral colonies was found at site 1, while the lowest number was found at site 2 and 4 (Table 1.). The highest prevalence of WS disease was shown at 4 and the lowest prevalence was found at site 5. This site had a WS prevalence of 7.96%, which was only significantly higher than site 5 ($P < 0.05$, t test). The highest prevalence of UWS disease was found at site 2 that had a prevalence of 13.43%, which was significantly higher than other sites ($P < 0.05$, t test). Water column nitrate in site 1, 2 and 3 were less than 0.16 μM whereas the highest level was detected at site 4 and it was significantly higher than in site 5 ($P < 0.05$, t test). In contrast to the level of nitrate, organic matter in all sites were detected higher than other reef areas, and there was no significant differences among sampling sites. Regression analysis revealed significant relationships between WS and UWS disease prevalence and water column Nitrate at site 4 and 5. Regression analyses also showed significant relationship between WS and UWS disease prevalence and water column organic matter.

Those concentration of water column nitrate were much higher than those in Kuta and Richardson [7] that measured in reefs in Florida Keys and Kline et al. [11]. Study of Voss and Richardson [9] indicated the rapidly increasing of tissue loss due to Black Band disease in Siderastrea siderea when treated with 3 μM nitrate. Whereas level of water column organic matter was extremely higher than those measured in several reefs polluted areas such as in Guam [23] and Guarajuba reef, Brazil [24]. The presence of organic matter in the form of dissolved organic carbon in the range of 5 – 25 mg l$^{-1}$ for 30 d resulted in coral mortality compared to the treatment of nutrients. It is suggested that the increased organic matter elevates the excessive number of microflora in the coral mucus, thus cause the imbalance between coral and its microflora communities. There was a tendency for WS disease prevalence to increase with the more dense human activities and land runoff. On the contrary, UWS disease prevalence demonstrated different patterns that is likely no related to the distance of human activities as the highest prevalence was in site 2. Despite the unknown driver of UWS virulence at site 2, it is assumed that the tidal current contributes to the virulence this disease. Moreover, this results suggest different agent and pattern may be contributed to the prevalence of this disease.
Table 1. Environmental parameters along the sampling sites that were used in correlation analyses

| Sites | Km a | % WS | % UWS | Nitrate (μM) | OM (mg l⁻¹) | Density colonies/m² | Colonies counted/site |
|-------|------|------|--------|-------------|-------------|---------------------|-----------------------|
| 1     | 3    | 3.12 | 1.52   | <0.16      | 54.56       | 2.3                 | 93                    |
| 2     | 2    | 4.38 | 13.43  | <0.16      | 49.72       | 1.2                 | 47                    |
| 3     | 1    | 4.59 | 1.38   | <0.16      | 60.04       | 1.7                 | 69                    |
| 4     | 0    | 7.96 | 4.05   | 8.23       | 52.03       | 1.2                 | 51                    |
| 5     | 2    | 2.55 | 3.86   | 2.42       | 50.98       | 2.2                 | 87                    |

*Km is distance from runoffs and rivers

WS White syndrome, UWS Ulcerative white spots disease, OM organic matter

3.3 Type and distribution of coral diseases
There were three diseases observed in this area, they were Ulcerative white spots (UWS), White syndrome (WS) and Trematodiasis. UWS only infected the massive Porites, while WS varied from massive Porites to Favites. Both WS and UWS were uniformly distribute in all sites with different prevalences (Table 2). Besides those two dominant diseases, Trematodiasis was detected on massive Porites only, however it was only observed in sub site 2 and 3 (Table 2.).

Table 2. Diseases affecting coral colonies at sampling sites in Pemuteran waters

| Site 1 | Site 2 | Site 3 | Site 4 | Site 5 |
|--------|--------|--------|--------|--------|
| *UWS   | Porites| Porites| Porites| Porites|
| **WS   | Porites| Favites| Porites| Porites|
| ***TR  | Porites| Porites| Porites| Porites|

3.4 Compromised health syndromes
Besides the diseased coral colonies, it is necessary to record the compromised health syndromes as well. Sedimentation was only found in site 1 at a few coral colonies. Besides overgrowth by sponge and soft coral that occasionally found, overgrowth algal were frequent syndromes which observed in all sites and all types of corals. Grazing activities by corallivorous gastropod Drupella spp. and sea star Acanthaster planci were found in limited numbers. Porites pink-line syndrome was another dominant syndrome observed that due to tube formers. This syndrome was only observed in massive Porites in all sites (Table 3.).

Table 3. Compromised health syndromes affecting coral colonies at sampling sites in Pemuteran waters

| Site 1 | Site 2 | Site 3 | Site 4 | Site 5 |
|--------|--------|--------|--------|--------|
| Porites| Porites| Porites| Porites| Porites|
4. Conclusion
This study provides the first status of types and distribution of coral diseases and compromised health syndromes in Pemuteran shallow reefs, north Bali island. Furthermore, these results revealed that organic matter might have more contribution to drive the prevalence of coral diseases rather than nitrate. However, it is needed more complete and accurate dataset of water quality in order to analyses the drivers of coral diseases.

5. References
[1] Rosenberg E, Kelloff C A, Rohwer F 2007 Oceanogr. 20 146–154
[2] Bourne D G, Garren M, Work T M, Rosenberg E, Smith G W, Harvell C D 2009 Trends Microbiol. 17 554–562
[3] Aronson R, Precht W 2001 Hydrobiol. 460 24–38
[4] Weil E, Smith G, Gómez-Agudelo D L 2006 Dis. Aquat. Organ. 69 1–7
[5] Raymundo L J, Reboton C T, Rosell K B, Kaczmarsky L 2005 Dis. Aqua. Organ. 64 181–191
[6] Haapkylä J, Seymour A S, Trebilco J, Smith D 2007 J. Mar. Biol. Assoc. U.K. 87 403-414
[7] Kuta K G, Richardson L L 2002 Coral Reefs 21 393–398
[8] Bruno J F, Petes L E, Harvell C D, Hettinger A 2003 Ecol. Letters. 6 1056–1061
[9] Voss J D, Richardson L L 2006 Dis. Aquat. Organ. 69 33–40
[10] Kuntz N M, Kline D I, Sandin S A, Rohwer F 2005 Mar. Ecol. Prog. Ser. 294 173–180
[11] Kline D I, Kuntz N M, Breitbart M, Knowlton N, Rohwer F 2006 Mar. Ecol. Prog. Ser. 314 119–125
[12] Baker D M, MacAvoy S E, Kim K 2007 Mar. Ecol. Prog. Ser. 343 123–130
[13] Rohwer F, Kelley S T 2004 Corals as microbial landscapes. In: Rosenberg E, Loya Y (eds) Coral
health and disease (Berlin: Springer) pp 265–277
[14] Rohwer F, Breitbart M, Jara J, Azam F, Knowlton N 2001 Coral Reefs 20 85–95
[15] Kellogg C 2004 Mar. Ecol. Prog. Ser. 273 81–88
[16] Wegley L, Yu Y, Breitbart M, Casas V, Kline D I, Rohwer F 2004 Mar. Ecol. Prog. Ser. 273 89–96
[17] Knight D, LeDrew E, Holden H 1997 Ocean. Coast. Manag. 34 153161-159170
[18] Raymundo L J, Couch C S, Bruckner A W, Harvell C D, Work T M, Weil E, Woodley C M, Jordan-Dahlgren E, Willis, B L, Sato Y, Aebly G S 2008 Coral Disease Handbook Guidelines for Assessment, Monitoring and Management (Melbourne: Currie Communications) p 94
[19] Beeden R, Willis B L, Raymundo L J, Page C A, Weil E 2008 Underwater Cards for Assessing Coral Health on Indo-Pacific Reefs (Melbourne: Currie Communications) p 22
[20] Veron J E N 2000 Corals of the World vol 1-3, ed M Stafford-Smith (Townsville: Australian Institute of Marine Science) 1382 p
[21] Suharsono 2008 Jenis-Jenis Karang di Indonesia (Jakarta: LIPI Press Jakarta) 344 p
[22] Strickland J D, Parsons T R 1972 A practical handbook of seawater analysis (2nd edn) (Ottawa: Fisheries Research Board of Canada) p 45-259
[23] Marsh J A Jr 1977 Terrestrial inputs of nitrogen and phosphorus on fringing reefs of Guam. Proc. 3rd Int. Coral Reef Symp. 2:331–336
[24] Costa O S Jr, Leão Z M A N, Nimmo M, Attril M J 2000 Hydrobiol 440 307–315

6. Acknowledgements
The author wish to thank: Ni Wayan Gita Kanela, Putu Hernanda Krishna Ariszandy and Nidzar Muhammad Rafly for sampling assistances. This study was funded by grants from Udayana University to W. K. and N. L. P. R. P.