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Coral Disease Prevalence in the Western Lombok Waters

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Abstract

Coral disease is one of the major threats to coral mortality, leading to severe degradation of coral reef ecosystems. Several studies on coral disease have been conducted in Indonesia; however, coral disease prevalence in Lombok waters remains unknown. This study aims to identify coral diseases, quantify their prevalence, and examine their relationships with coral reef covers. Two data collection methods used were the belt transect method for coral disease observation and underwater photo transect for benthic substrate cover assessment. Four types of coral diseases were identified: ulcerative white spots (UWS), pigmentation response (PR), white syndrome (WS), and white pox (WP). Additionally, two types of coral health disorder caused by other organisms were found, namely coralliophila and tube formers. The overall coral disease prevalence was 10.2±0.18% (± SE), while coral health disorder prevalence reached 6.0±0.62%. Coral diseases were only found in the massive corals: *Astreopora, Cyphastrea, Favia, Goniastrea*, and *Porites*. The condition of coral reefs was classified as moderate (fair), and coral diseases were distributed homogenously among sites. There were neither significant correlation between coral reef covers and coral disease prevalence, nor between coral reef covers and coral health disorder prevalence. Coral disease prevalence was more related to sponges and soft corals covers, while coral health disorder prevalence was more closely related to hard corals and rubble covers. The results suggest that coral disease is concerning in Lombok waters, and regular long-term monitoring coral diseases is required to achieve the sustainable development goal life below water.

Keywords: coral bleaching, coral reefs, disease prevalence, life below water, ulcerative white spots.

1. Introduction

Coral diseases are major threats that cause damage to coral reef ecosystems (Harvell et al., 2007; Riegl et al., 2009). Outbreaks of coral diseases have become major drivers contributing to the decline in coral cover across the Indo-Pacific region (Raymundo et al., 2005; Muller et al., 2012). The increasing frequency and distribution of coral diseases have led to increased coral mortality, thereby accelerating the decline of coral cover in the waters of the Great Barrier Reef (GBR) (Haapkylä et al., 2010), Guam (Myers and Raymundo, 2009), and Philippines (Raymundo et al., 2005). The same effect of coral diseases may also happen in the Indonesian archipelago, where coral communities are also coping with increasing anthropogenic threats.

Coral reefs of Lombok Island, within the Coral Triangle Area, is known for its exceptionally high marine biodiversity, but also face intense anthropogenic stress. As happened globally, coral reefs are experiencing degradation in Lombok waters (Bachtiar, 2004; Bachtiar and Hadi, 2019). A review on coral reef of Lombok showed that three major causes of coral reef degradation were blast fishing (46%), coral bleaching (18%), and boat anchoring (18%) in the period of 1996-2003 (Bachtiar, 2004). These causes have changed a lot in the last decade. Since 2000, more marine protected areas are established in Lombok waters that some management actions already implemented (Bachtiar and Hotmariyah, 2017). Predicted increasing seawater temperature in present and the next decades may increase coral disease prevalence worldwide. The occurrence of coral bleaching events in Lombok's waters in 1983, 1998, 2010, 2016, and 2020 (Bachtiar, 2002; Bachtiar and Hadi, 2019; Ghafari, 2025) indicated that seawater temperature rapidly increases. Three majors coral bleaching (1983, 1998, 2016) caused mass coral mortality and declining coral covers. Increasing temperature and sublethal bleaching may also increase coral susceptibility to diseases (Harvell et al., 2007). Coral diseases have the potential to alter reef community structure and cause coral mortality (Pollock et al., 2011).

The present study aims to identify the types of coral diseases infecting corals, quantify their prevalence, and examine the relationship between coral cover and disease prevalence. Studying coral diseases are important to provide early warning system on ecosystem functioning and baseline data for future coral reef monitoring. There are several studies on coral disease prevalence in Indonesia, but few have been carried out in the waters around Lombok. Previous studies include in the Wakatobi National Park by Haapkylä et al. (2007, 2009), where during the period of 2005-2007, which reported disease prevalence 0.57% in 2005 and 0.37% in 2007. Further monitoring by Muller et al. (2012) reported an increase in coral disease prevalence to 1.5%. Huda et al. (2018) examined the histological characteristics of two coral diseases on acroporiid corals in Labak Island of Madura. To date, only one study has reported coral diseases in the waters surrounding Lombok Island. Johan et al. (2017) reported for the first time the occurrence of white syndrome and pigmentation response (yellow syndrome) in coral colonies of Krakas Reefs, of northern Lombok. The study did not provide quantitative prevalence data for the reported coral diseases. This study addresses the existing information gap on coral diseases in Lombok waters.

2. Materials and Methods

This study was conducted from July to August 2025 in the waters of Teluk Nare (Nare Bay). It is located at northwest of Lombok Island (**Figure 1**). Nare Bay serves as a harbour basin for tourism boats traveling between Lombok to the Marine Protected Area of Gili Matra (MPA-GM). The MPA GM is the most visited islands in Indonesia, and highest number of diving and snorkelling tourism operators. There are more than 50 dive operators in the three islands.

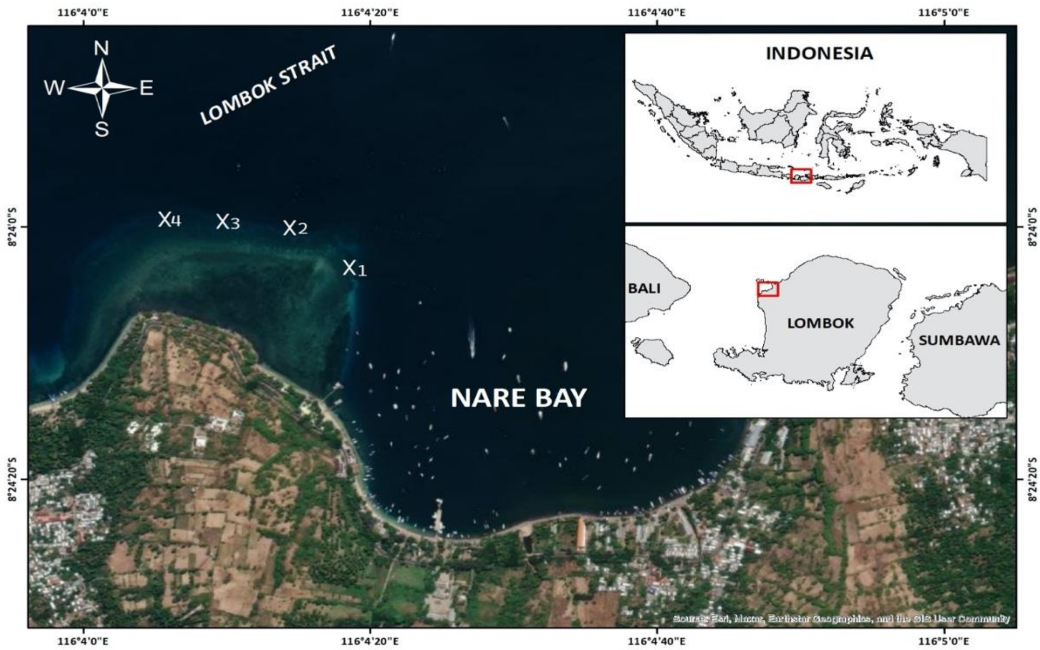

Figure 1. The research location map. Note X is location of coral disease studied.

Nare Bay may serve as the control site for coral reef comparison with MPA-GM, since it is only 17 km apart from the MPA-GM. Coral reefs can be found at both the northern and southern ends of the bay. The research was carried out at the southern end of the bay, as the northern area is heavily used for transportation routes. Nearby the southern coral reefs, there is a pearl oyster culture rafts at deeper water, that any intensive fishing activities will be sent out. Therefore, coral reefs of Nare Bay and MPA-GM are both somewhat protected from fishing pressure. In contrast, coral reefs of Nare Bay have no tourism activities, while MPA-GM reefs have high pressure from tourism activities.

Prevalence of coral disease may be in part related to coral reef status. Data on coral diseases and coral reef conditions was both collected at coral reefs of southern bay (Mentigi Cape). Four sites were haphazardly selected, which were considered representative of the coral reef conditions in the area (**Table 1**). Two data collection methods were applied; the belt transect method for coral disease observation (20 x 2 m^2) and underwater photo transect for benthic substrate cover assessment (50 frames in 50 m transect length). Both methods using the same transect line.

Table 1. Coordinate points the study sites.

Research Location	**Latitude (S)**	**Longitude (E)**	Habitat Characteristics
Site 1	8°24'04.9"	116°04'18.8"	Moderate coral reef condition, moderate fleshy seaweed cover.
Site 2	8°24'01.2"	116°04'15.4"	Moderate coral reef condition, high rubble cover.
Site 3	8°23'59.9"	116°04'09.1"	Poor coral reef condition, high fleshy seaweed cover.
Site 4	8°23'59.7"	116°04'05.1"	Moderate coral reef condition, high fleshy seaweed cover.

Coral disease data collection used the belt transect method at 7-8 m depth. A 20-meter transect served as a reference, then virtual lines were drawn parallel to the 1-meter transects on the right and left of the transect to form a rectangular area of 2 x 20 m^2 (Raymundo et al., 2008). The transects for coral disease data collection were along the same line as the coral reef cover data collection (50 m length). Coral disease data collection was carried out from 10th to 30th meters of the transect.

Coral reef data collection used the UPT (underwater photo transect) method on a 50 m long transect line. The UPT methods used were the same as described in Bachtiar and Hadi (2019). The resulting photos were then processed using CPCe 4.1 (Coral Point Count with Excel extensions) software (Kohler and Gill, 2006). Coral reef covers were identified at 30 random points within the photo frames using categories. Click or tap here to enter text. This CPCe software produced nine variables of coral reef covers, for example hard coral cover, soft coral cover, fleshy seaweed cover, etc. Prevalence was calculated by counting the number of coral colonies infected with disease based on the coral disease identification guide by Raymundo et al. (2008) found along a 20-meter belt transect. Disease prevalence was calculated using the following formula:

$$\text{Prevalence (P)} = \frac{\text{Number of infected colonies}}{\text{Total number of colonies}} \text{ x } 100\% \quad (1)$$

All data analysis was carried out using a software JMP Pro 13.0.0. Data of coral disease and health disorder are both normally distributed (Saphiro-Wilk test, W=0.921, W=0.945 respectively). Comparison of coral health (coral disease and coral health disorder) among sites used a one-way Anova. Data of coral reef covers on hard-coral (HC), dead coral algae (DCA), sponges (SP), fleshy algae (FS), and sand (S) were normally distributed. Their W values were 0.954, 0.872, 0.898, 0.963, 0.981, 0.888. and 0.927 respectively. Data on soft coral (SC) and rubble (R) covers, however, did not conform to normal distribution (W=0.701, W=0.660 respectively). Principal component analysis (PCA) was applied to see relationships between two variables of coral health and 8 variable of coral reef covers. PCA does not require normal data distribution.

3. Results and Discussion

3.1. Results

Four types of coral diseases were found, namely ulcerative white spots (UWS), pigmentation response (PR), white pox (WP), and white syndrome (WS) (**Figure 2**). In addition, two other types of health disorders were also found, namely coralliophila (CP) and tube formers (TF). Among the four coral diseases UWS was the most common, affecting 102 colonies from a total of 122 coral infected colonies. Besides, 72 colonies showed health disorder symptoms. All coral colonies suffering from coral diseases and health disorder were all massive growth form corals.

The overall prevalence of coral diseases in the waters of Nare Bay was 10.2±0.18% (mean ± SE, n = 8). Based on disease type, the prevalence was dominated by UWS, with an overall prevalence of 8.5±0.37% (**Figure 3A**). Other diseases recorded including PR, WS, and WP had low prevalence (<2,0%). Meanwhile, the overall prevalence of other health disorder was 6.0±0.62%, consisted of CP and TF with prevalence of 2.2±0.16% and TF 3.8±0.54% respectively.

Among the nine coral growth forms found in Nare Bay, only massive corals were observed to be affected by diseases (**Figure 3B**). A total of 122 infected colonies were recorded in massive corals. Within the massive coral group, overall prevalence was 13.6%, dominated by UWS (11.4%), PR (1.4%), WS (0.3%), and WP (0.4%). In addition, all health impairments were also found in massive corals, 72 massive coral colonies, with a prevalence of 8.0%.

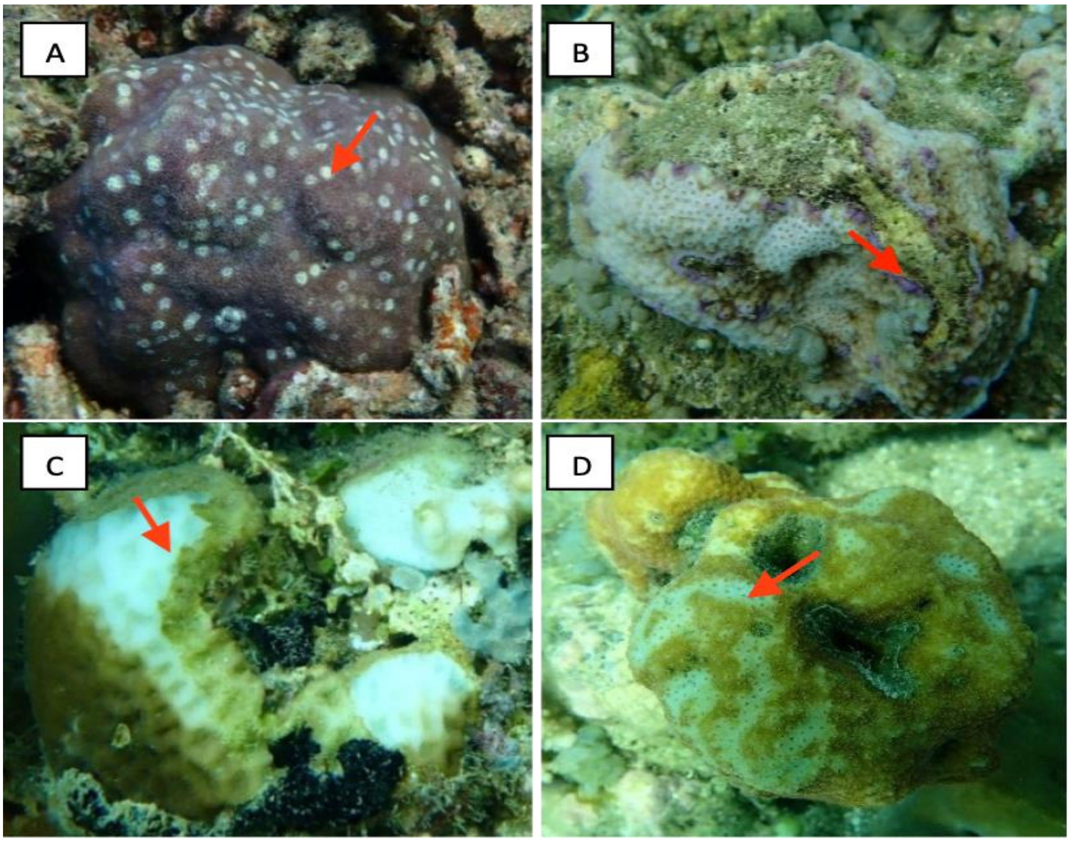

Figure 2. Four coral diseases found in Nare Bay waters were: A. Ulcerative White Spots (UWS), B. Pigmentation Response (PR), C. White Syndrome (WS), D. White Pox (WP). UWS was the most predominant disease. All infected coral colonies were massive corals.

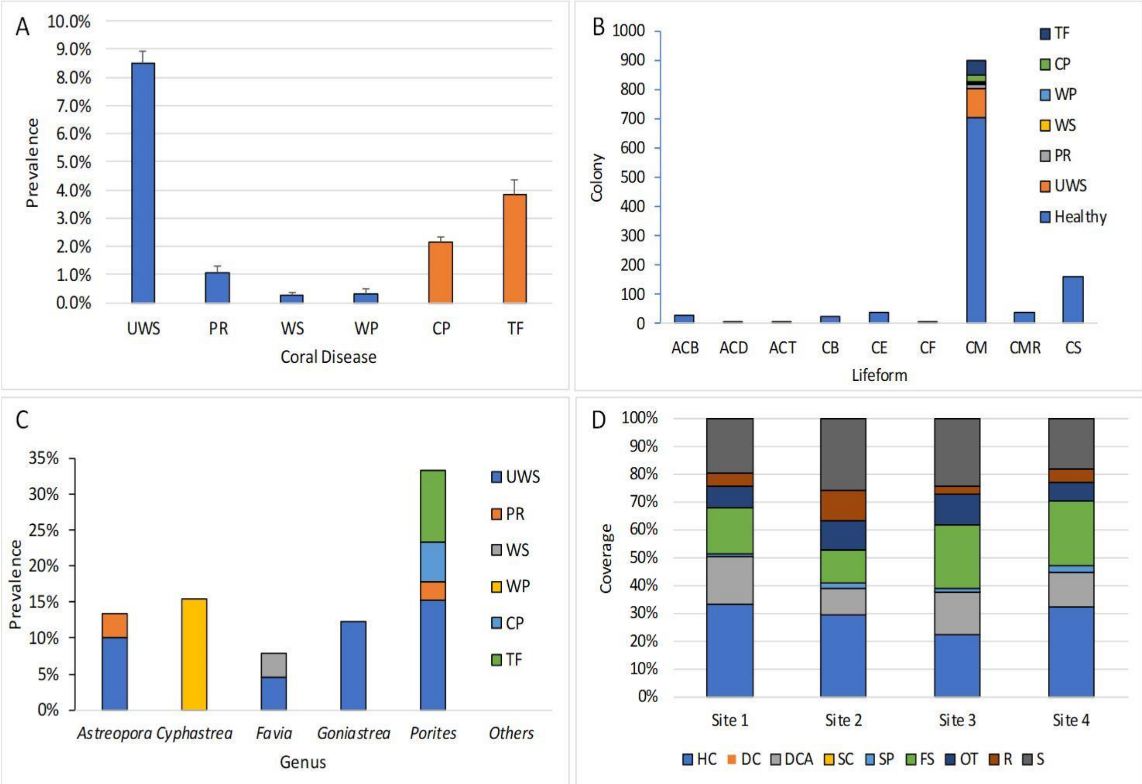

Figure 3. Coral diseases prevalence (A): UWS=Ulcerative White Spots, PR=Pigmentation Response, WS=White Syndrome, WP=White Pox, CP=Coralliophila, TF=tube formers; Coral Disease Distribution among Life-forms (B): ACB=Acropora Branching, ACD=Acropora Digitate, ACT=Acropora Tabulate, CB=Coral Branching, CE=Coral Encrusting, CF=Coral Foliose, CM=Coral Massive, CMR=Coral Mushroom, CS=Coral Submassive; Coral Diseases Prevalence at Genera Level (C), and Coral Reef Covers (D), HC= Hard Coral, DCA= Dead Coral with Algae, SP=Sponge, FS=Fleshy Seaweed, OT=Other Biota, R=Rubble, S=Sand. All coral diseases and health disorders affected massive corals. *Porites* is the most predominant genus and also the most infected by coral diseases and health disorders.

At the generic level, coral diseases were spread over five genera, namely *Astreopora, Cyphastrea, Favia, Goniastrea*, and *Porites* (**Figure 3C**). The highest disease prevalence was recorded in *Porites* (17.8%). Three coral genera were with two types of diseases, *Astreopora, Favia,* and *Porites*. The other two genera have only one type of disease. Additionally, coral health disorder was observed only in *Porites*, with a prevalence of 15.6%. In Nare Bay, there were 29 coral genera, and most of them (24 genera) were not infected by any coral diseases. These uninfected colonies included 50 *Acropora*, 88 *Pocillopora*, and 47 *Fungia* colonies, but none of them showed disease or growth impairment symptoms. All the five genera infected coral diseases were massive corals.

Massive coral was the most predominant coral life form, or coral functional group. Total colonies surveyed in belt transects was 1392 coral colonies. Massive corals had 74.9% composition, and the most predominant genus was *Porites* (44.3%). There were 29 coral genera representing 9 (nine) functional groups. Among the functional groups, massive corals were the most diverse group with 19 coral genera. Coral reefs status of Nare Bay was fair but show good diversity. Coral cover (HC) average was 29.3±2.19% (**Figure 3D**). A more detail comparison among sites shows that Site 3 falls into the *poor* category (HC<25%), while the other three sites are classified as *fair* (HC 25–49.9%). Furthermore, sand (S) coverage is prominent with >20% in three sites, but the Site 4. The macroalgae (FS) cover of 18.66±2.32% suggests a dominance of macroalgae, which may inhibit the growth of new corals through space competition. Average of dead coral with algae (DCA) cover was 13.52±1.46%, indicating a high proportion of dead corals overgrown by algae.

Among the four sites, coral disease prevalence was not different. Neither did, coral health disorder. Comparison of coral disease and health compromise prevalence showed there is no effect of site on their prevalence. Both variables did not significantly different among four sites (**Table 2**). Despite its low statistical power, these results showed that coral disease and coral health disorder were distributed about homogenously in the Nare Bay.

Table 2. Results of one-way Anova tests. There were neither effect of site on coral disease prevalence nor on health disorder prevalence.

Dependent variable	Independent variables (df)	F	P	Power
Coral diseases prevalence	Site (3, 4)	0.3494	>0.05	0.299
Health disorder prevalence	Site (3, 4)	1.0903	>0.05	0.299

Principal component analysis (PCA) showed that coral disease and coral health disorder variables are both on the same group (right side) (**Figure 4**). Both variables are not closely related as they were separated >90 degrees. The PCA also revealed relationships between coral disease and coral health disorder prevalence with coral reef covers. The PCA indicated that coral disease prevalence was more related to sponges and soft corals covers. On the other hand, coral health disorder prevalence was more closely related to hard corals and rubble covers. The correlation matrix of the PCA (**Table 3**) showed that all correlation coefficients between coral health and coral reef covers were insignificant. It should be noted, however, that a correlation coefficient was considerably high between soft coral cover and coral health disorder prevalence.

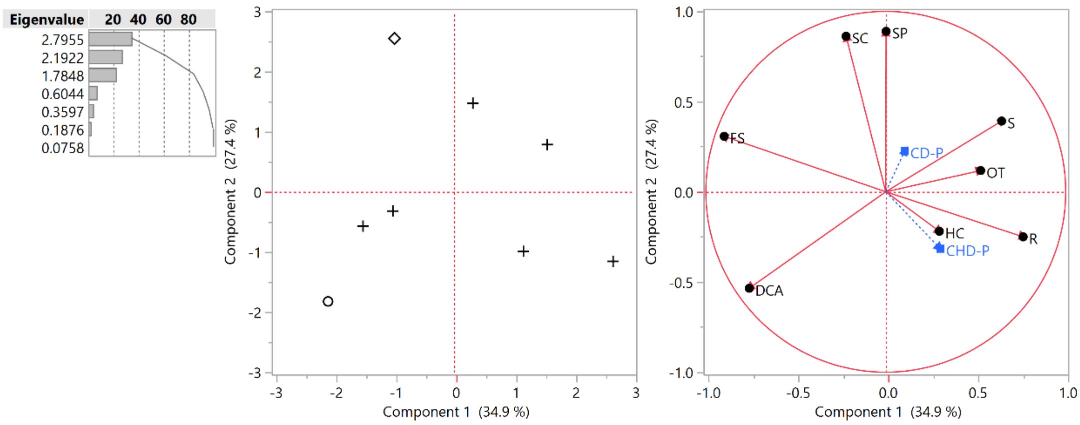

Figure 4. PCA on coral disease prevalence (CD-P) and coral health disorder prevalence (CHD-P) to coral reef covers. CD-P and CHD-P both had differential relationships with coral reef covers. CD-P was more related to SC and SP, while CHD-P was more related to HC and R.

Table 3. Correlation matrix from PCA. Critical value of the correlation coefficient is 0.7067 (n=8, α=0.05). None of the correlation coefficients were significant.

Coral reef covers	Coral disease prevalence (CD-P)	Coral health disorder prevalence (CHD-P)
HC	0.470	0.176
DCA	-0.078	0.208
SC	0.247	-0.634
SP	0.334	-0.190
FS	-0.288	-0.273
OT	0.199	-0.179
R	-0.340	0.218
S	0.069	0.280

3.2. Discussion

The results of this study revealed four types of coral diseases in the Lombok waters: UWS, PR, WP, and WS. This finding added 2 (two) newfound coral diseases distribution in Lombok, i.e. WP and WS, that were absent in previous study. Johan et al. (2017) previously reported only two coral diseases in northern Lombok waters, UWS and PR (or yellow syndrome). In the adjacent island, northern Bali waters, Karim (2019) found only two types of coral diseases, UWS and WS. However, in the north-west of Bali waters, Widiastuti et al. (2025) did not find the two diseases, but reported a new one, SCTLD (Stony Coral Tissue Loss Disease). These results may indicate that local environment determine which coral disease is more favourable to outbreaks.

In other region of Indonesia, number of coral diseases were found higher than in Lombok and Bali Islands. Johan and Idris (2022) reported 8 (eight) coral diseases in Sawu Marine National Park, eastern Lesser Sunda Islands. Since they used different disease category, this study is not comparable with the present study. Zakaria et al. (2021) reported 9 (nine) coral diseases infected coral colonies at three sites of the Western Sumatra and found that PR and UWS were the most prevalent diseases. This higher number of coral diseases are due to wider coral reef area surveyed.

Although Black Band Disease (BBD) was reported widespread at 29 sites from Sumatra to Papua waters, including eastern Lesser Sunda Islands (Pribawastuti et al., 2024), the present study did not find BBD in Nare Bay, as neither reported in Bali waters. BBD is reported more prevalent infected branching corals of Acroporidae, i.e. *Acropora* (Page and Willis, 2006; Wijayanti et al., 2018) and *Montipora* (Sato et al., 2009). However, none of acroporiid corals were affected by BBD in Nare Bay, although its abundance has reasonable composition in the coral communities.

The present study showed that UWS was the most prevalent and followed by PR. UWS disease was found only in *Porites* colonies. UWS is characterized by the appearance of small white spots on coral tissue, which can develop into open lesions. Raymundo et al. (2003) noted that UWS in *Porites* can lead to gradual tissue necrosis within the affected colonies. The susceptibility of *Porites* to UWS has also been reported across various Indo-Pacific locations, where this genus often exhibits the highest disease prevalence compared to other coral genera (Raymundo et al., 2005).

Pigmentation Response disease found in *Astreopora* and *Porites* indicate a localized immune response of corals to infection or physical irritation. This response is manifested by abnormal coloration often pink or purple on coral tissue, resulting from increased pigment production as a protective reaction to external stressors such as algal competition (Smith et al., 2006; Barott et al., 2009), elevated sea temperatures, or physical injuries caused by other organisms (Palmer et al., 2011). The occurrence of PR is not necessarily owing to bleaching or other conditions but may also results from biotic interaction such as coral predation (Fitt, 2025).

In addition to diseases, the study also found coral health impairments such as coralliophila (tissue-feeding snails) and tube formers (tube-building organisms such as polychaetes). Renzi et al. (2022) reported 20 positive correlations between disease prevalence and corallivore snail abundances. The presence of tissue-feeding gastropods can increase coral stress levels and even facilitate disease transmission, as tissue damage provides entry points for pathogens (Rotjan and Lewis, 2008). High incidence of coralliophila is likely the result of high abundance of invertebrate corallivores, i.e. polychaete bristle worms and *Drupella* spp.. It has been suggested that high abundance of *Drupella* spp. is due to predator overfishing and nutrient enrichment (Zhang et al., 2023). Further study is required to determine population dynamics of invertebrate corallivore populations in Lombok waters.

The present study also found that the four types of coral diseases infected only five coral genera *Astreopora*, *Cyphastrea*, *Favia*, *Goniastrea*, and *Porites*. All of them were massive corals. Since there were 14 other massive coral genera uninfected by the diseases, this result did not show that massive corals are more susceptible to coral diseases than other coral functional groups or coral life forms. It is more likely that each coral genus shows different susceptibility to specific type of diseases. *Acropora* and *Montipora* have been associated with black band disease (BBD) in Indonesia (Pribawastuti et al., 2024). However, BBD was also reported infecting

Goniopora at GBR (Byrne et al., 2025), that local specific conditions also have contribution to coral susceptibility. Eaton et al. (2025) showed that genotype and symbiont composition affected coral susceptibility more than ocean acidification and warming. The presence of WP in *Cyphastrea* and WS in *Favia* suggests the existence of diverse pathogens and possible environmental stressors triggering disease outbreaks, similar to patterns reported in other Indo-Pacific reef systems (Sussman et al., 2008). Overall, the variation in disease types among coral genera in Nare Bay reflects differential susceptibility among coral genera that may due to their differential responses to environmental stress.

The high prevalence (10.2%) of coral diseases in Nare Bay indicates that the health of its coral reef ecosystem is in a concerning state. This prevalence is considerably higher than previous reports, i.e. 1.5% in Wakatobi (Muller et al., 2012), 8.3% in Philippines (Raymundo et al., 2005), 0.2-12.6% in Guam (Myers and Raymundo, 2009), and 4.2% in larger Caribbean (Weil and Cróquer, 2009). Comparing diseases prevalence in decades time lap, however, not an apple-to-apple comparison. There is a possibility that coral diseases prevalence increases worldwide because of increasing seawater temperature. This finding suggests the importance of coral diseases monitoring in Lombok waters, particularly in the MPA GM.

Infected colonies were found across five coral genera, with *Porites* showing the highest prevalence. The dominance of UWS aligns with findings from other Indo-Pacific regions, where this disease is frequently associated with environmental stressors such as elevated temperatures, sedimentation, and eutrophication (Haapkylä et al., 2009). The dominance of UWS may also be due to the abundant of massive corals populations, particularly *Porites* in the area (Myers and Raymundo, 2009). The susceptibility of *Porites* to disease may be due to its high host density, which increases infection probability and enhances disease virulence. (Raymundo et al., 2003; 2005). Increasing coral bleaching events leaves the resistant coral *Porites* becomes more prevalent as other coral genera decline.

The present study also revealed that all coral reef cover components had no significant correlation with coral disease prevalence, or coral health disorder. Soft coral cover, however, showed considerably strong correlation with coral health disorder prevalence. Previous study showed that coral disease is related to nutrient enrichment (Kaczmarsky et al., 2005), raising seawater temperature (Ruiz-Moreno et al., 2012; Burke et al., 2023), host abundance (Myers and Raymundo, 2009), corallivore abundance (Renzi et al., 2022). Aeby et al. (2011) studied model to explain three coral diseases from its environment (temperature, coral cover, coral density, macroalgae, local populations, and other variables). They found that the three coral disease types were associated with host abundance and thermal stress.

In the present study, PCA showed that coral disease prevalence is related to sponges and soft corals, while coral health disorder was related to hard corals and rubble covers. Their insignificant correlation coefficients may be due to statistical power or sample size. It is also possible that each type of coral diseases is associated with specific component of coral reef covers. Williams et al. (2010) and Aeby et al. (2011) showed that diseases often exhibit complex and distinct relationships with their environment due to differences in its modes of transmission between hosts and disease causes. Modelling total coral disease prevalence (combining several diseases into one proportion value) may have different results from modelling each disease separately. Therefore, this insignificant correlation may only occur in the waters of Nare Bay and should be viewed as a preliminary finding that requires verification through studies with larger sample sizes to confirm the consistency and ecological significance of the observed relationship.

The present study had limitations in low statistical power. Generalization of the findings in the study are therefore to be considered carefully. Despite the limitations, the present study provided importance information in supporting the sustainable development goal number 14, life below water. Prevalence data serve as an indicator of ecosystem health that can be used to identify the vulnerability level of a site, determine conservation priorities, and evaluate the effectiveness of MPA. This study increase urgency to look at coral diseases within the MPA-Gili Matra. In addition, this information plays a role in the early detection of environmental changes that may trigger physiological stress in corals. Further study is needed to monitoring coral disease dynamics over time. Identification of disease-causing agents through microbiological and molecular approaches, and analysis of the relationship between disease prevalence and environmental parameters will have significant contribution to the coral reef management.

4. Conclusions

The present study suggested that coral disease is concerning in Lombok waters. Four types of coral diseases were identified in coral colonies at Nare Bay, Lombok Island, namely ulcerative white spots (UWS), pigmentation response (PR), white syndrome (WS), and white pox (WP). In addition, two types of coral health disorder were recorded, namely coralliophila (CP) and tube formers (TF). The four coral diseases were observed only in five massive coral genera: *Astreopora, Cyphastrea, Favia, Goniastrea*, and *Porites*. The most frequently observed disease was UWS, particularly affecting the most predominant coral population *Porites*. Overall, the prevalence of coral diseases was 10.2±0.18% (±SE), while the prevalence of coral health disorder was 6.0±0.62%. Coral diseases and coral health disorder were distributed evenly among four study sites. Correlation between coral reef covers and coral disease prevalence was not significant. Neither insignificant correlation between coral reef covers and coral health disorder prevalence. PCA results showed that coral disease prevalence was more related to sponges and soft corals covers, while coral health disorder prevalence was more closely related to hard corals and rubble covers. To achieve the sustainable development goal number 14, life below water, regular long-term monitoring coral diseases is required, particularly in marine protected areas.

Conflicts of Interest

There are no conflicts to declare.

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AI Writing Statement

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) for language editing and stylistic improvement. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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