J. Mar. Biotechnol. Immunol
Vol. 3 No. 1 (2025)

ISSN 3026-1457 (Online)
ISSN 3026-5274 (Print)

Journal of Marine Biotechnology and Immunology

Journal homepage : https://ejournal.immunolmarbiotech.com

Prevalence and Environmental Factors Affecting the Emergence of *Black Band Disease* and *White Syndrome* on *Montipora* Corals in Pari Island Waters, Seribu Islands, Indonesia

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OPEN ACCESS

Article Info
Received: Desember 17, 2024
Accepted: January 15, 2025
Published: January 31, 2025
Available online: January 31, 2025

Keywords:
Black Band Disease
Coral Disease
Montipora
Pari Islands
White Syndrome

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Abstract

Coral reefs play an important role in maintaining the balance of marine ecosystems, yet diseases such as Black Band Disease (BBD) and White Syndrome (WS) contribute to a significant decline in coral cover. This research aims to analyse the prevalence of BBD and WS in the genus *Montipora* in Pari Islands waters, specifically in the *leeward* (Station 1) and *windward* (Station 2) areas. Data were collected at a depth of 3-6 m, including data on coral cover, coral disease and health problems, and water quality parameters. Coral cover was measured using the Underwater Photo Transect (UPT) method along 20 m with three replications, while disease data used a 1 m wide belt transect to the left and right of the meter stretch. Data were analysed descriptively and comparatively by describing observations at each research station and comparing them between stations. The results showed that live coral cover in Station 1 was in the damaged category (15.50%), while Station 2 was in the moderate category (37.69%). The prevalence of BBD on *Montipora* corals was 1.09% in Station 1 and 0.32% in Station 2. Meanwhile, the prevalence of WS was higher with 2.15% in Station 1 and 4.05% in Station 2. The prevalence of both diseases was influenced by variations in seasonal conditions, especially fluctuations in water temperature, as well as high sedimentation which played a significant role in increasing the prevalence of WS.

1. Introduction

Coral reefs are increasingly threatened by natural and anthropogenic pressures, leading to significant declines in coral cover globally. Between 1957 and 2007, coral cover declined by approximately 50% worldwide (Eddy *et al*., 2021). In Seribu Islands, a similar trend was also recorded, with live coral cover declining from 39.53% in 2011 to 32.23% in 2015, as reported by TERANGI in Noviana *et al*. (2018). One of the main factors contributing to this decline is coral disease, which is now considered one of the greatest threats to coral reef health globally (Rosenberg & Loya in Miller *et al*., 2009).

Coral disease is characterised by tissue loss and lesions caused by bacterial, viral, protozoan, or fungal infections (Raymundo *et al*., 2008). These infections are often exacerbated by declining water quality, which weakens coral resilience and increases disease risk (Harvell *et al*., 2007). The Pari Island Waters, in close proximity to Jakarta Bay, exerts significant environmental pressures, including pollution, high sedimentation, and intensive human activities (Wouthuyzen & Abrar, 2020). These pressures are thought to be the cause of coral disease in the region.

Frequent cases of coral disease found in this area are Black Band Disease (BBD) and White Syndrome (WS). As found by Johan *et al*. (2014) where the highest prevalence of BBD was 3.61% and WS was 3.32%, both of which only attacked corals of the genus *Montipora*. *Montipora* corals are known to be susceptible to coral diseases, so they are often the focus of monitoring and research. Both diseases are fuelled by increased water temperatures, strong currents that

aid the spread of disease, as well as high sedimentation, further exacerbating these conditions. Sedimentation, in particular, is a major pollutant detrimental to coral health as it can carry toxic substances, pathogens, and excess nutrients (Sheridan *et al*., 2014).

This study aimed to evaluate the current status of coral diseases, specifically Black Band Disease (BBD) and White Syndrome (WS), affecting *Montipora* in the Pari Islands waters. This study also considered the differences in environmental characteristics between the windward side, which is more exposed to the waves, and the leeward side, which is more protected from the waves in this area. Understanding these dynamics is critical, given the changing environmental conditions in the region that have the potential to affect coral reef ecosystems

2. Material and methods

2.1. Materials

Montipora corals, as objects of this study, were observed in Pari Islands waters, Seribu Islands, Indonesia. Water quality parameters were measured both directly on site and at laboratory. Temperature, current speed, brightness, salinity, pH, and dissolved oxygen were measured on site, meanwhile total suspended solid (TSS), nitrate, and phosphate were analyzed at laboratory. The materials used for nitrate analysis include distilled water, filter paper, KNO_3, $NaNO_2$, artificial seawater, Cd grain, HCl, $CuSO_4$ solution, Cd-Cu grain, dillute NH_4CL-EDTA solution, and dye solution. For phosphate analysis, the materials used include H_2SO_4 solution, potassium antimonyl tartar solution, ammonium molybdate solution, ascorbic acid solution, mixed solution, and anhydrous potassium dihydrogen phosphate. For TSS analysis used distilled water and filter paper.

2.2. Methods

2.2.1. Sampling site

The research was conducted in June 2024 in Pari Islands waters, Seribu Islands, Indonesia. The research was conducted using purposive sampling method and two research stations were selected on the fringing reef at 3-6 m depth (reef crest) (Haapkylä *et al*., 2007). Station 1 was located in the south or leeward area, at coordinates -05º52.3353‘ S and 106º36.4993’ E. Station 2 was located in the north or windward area, at coordinates -05º50.9312‘ S and 106º35.2432’ E. The research location is presented in Figure 1.

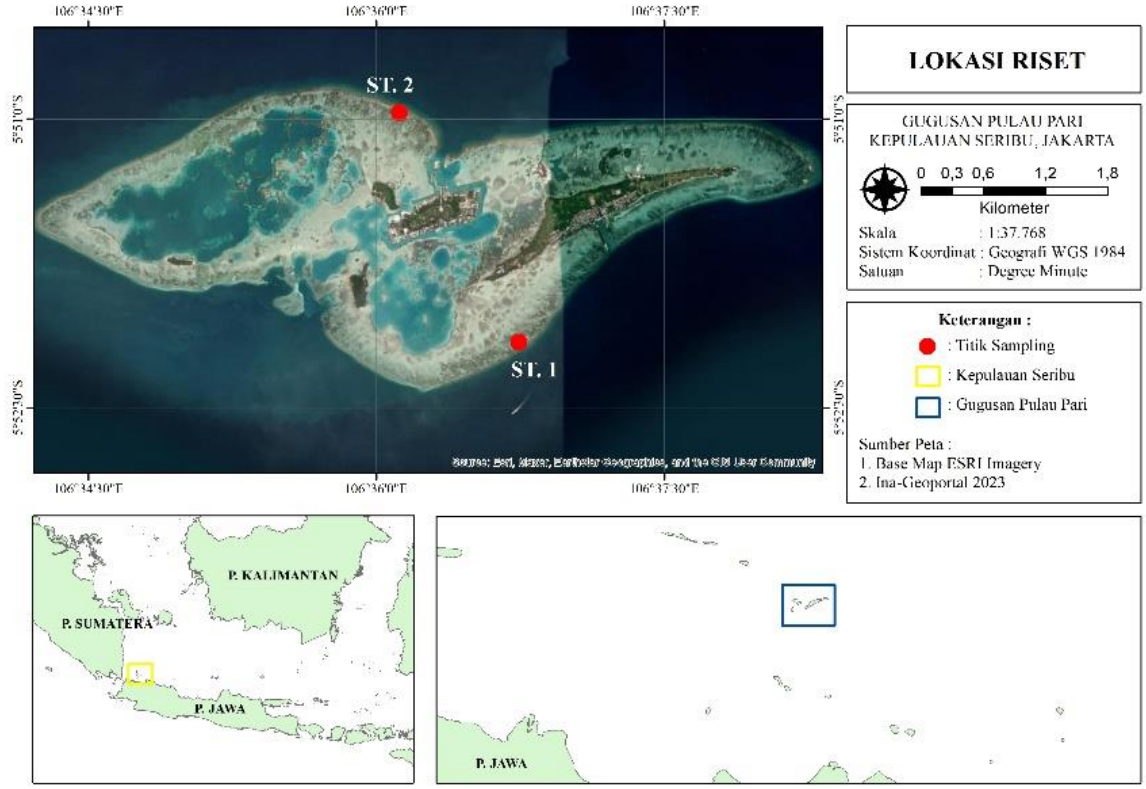


Figure 1. Research station in the Pari Islands Waters, Seribu Islands

2.2.2. Coral reef condition data

Coral reef condition was assessed based on coral reef cover. Data collection on coral reef cover was conducted using the Underwater Photo Transect (UPT) method. At each research station, data were taken twice, with three replicate transects of 20 m each and 5 m intervals (Figure 2). Photos were analyzed using Coral Point Count with Exccel (CPCe), selecting 30 random points per frame. Growth forms and substrate type were categorized into 29 groups based on English *et al*. (1997). Coral cover percentage were classifed into four categories according to Giyanto *et al*. (2017): damaged (0-25%), moderate (26-50%), good (51-75%), and excellent (76-100%).

2.2.3. Coral disease prevalence

Coral disease observations were conducted using the Belt Transect method based on Raymundo *et al*. (2008). At each station, data were taken twice, with three replicate transects. Each transect was 20 m long and 2 m wide (1 m on each side), with an interval between transects of 5 m, resulting in a total observed sample area of 240 m^2 (Figure 2). Observation focused on *Montipora* genus, recording health form and signs of disease such as Black Band Disease (BBD) and White Syndrome (WS), and others that endanger coral

health. Disease identification followed (Raymundo *et al*., 2008) guidelines. Infected corals were documented using underwater cameras, capturing both at the colony level and detailed images of affected areas. The prevalence of BBD and WS can be calculated using the following formula (Raymundo *et al*., 2008):

nitrate and phosphate. Water samples for TSS, nitrate, and phosphate tests were taken at a depth of 3 m around the coral reef area using a dark bottle containing 2 L of water which was then stored in a cool box before testing. Analysis of nitrate using the cadmium reduction method spectrophotometrically based on SNI 19-6964.7.2003 and

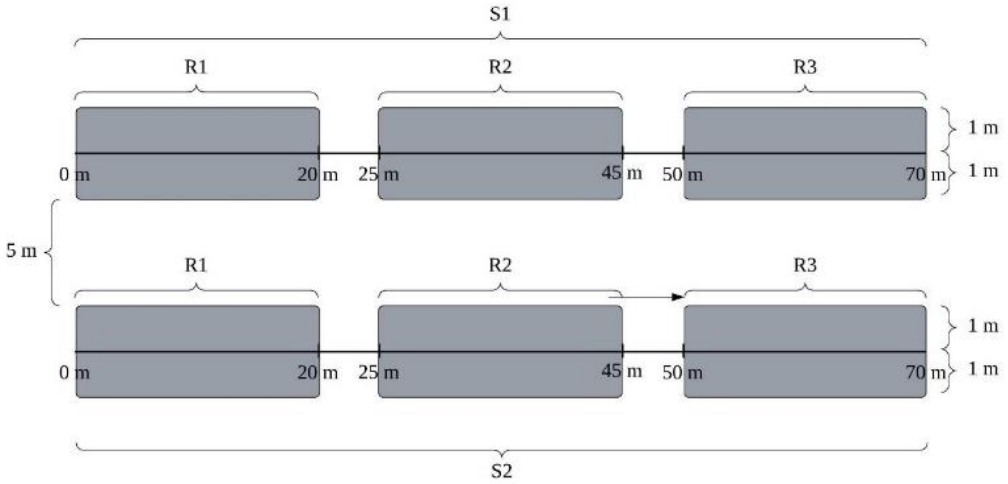
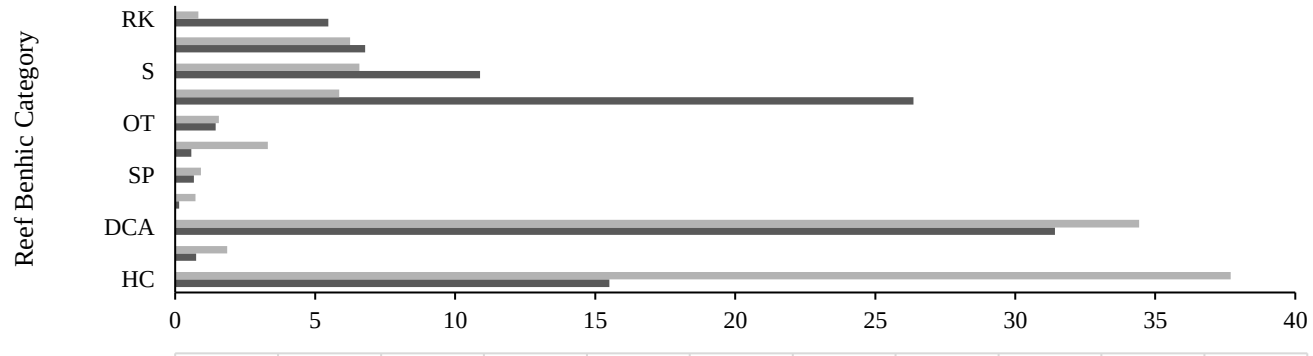


Figure 2. UPT method combined with belt transect method



	HC	DC	DCA	SC	SP	FS	OT	R	S	SI	RK
II (Windward)	37.69	1.86	34.42	0.72	0.92	3.31	1.56	5.86	6.58	6.25	0.83
I (Leeward)	15.5	0.75	31.42	0.14	0.67	0.58	1.44	26.36	10.89	6.78	5.47

Figure 3. Percentage cover of benthic reef categories in the Pari Islands Waters, Seribu Islands

$$Prevalence = \frac{Total\ of\ Monipora\ colonies\ infected}{Total\ Montipora\ colonies\ within\ the\ transect} \times 100$$

2.2.4. Water quality data

Data on water quality were collected at each research station. Water quality parameters measured in situ include temperature, current speed, brightness, salinity, pH, and dissolved oxygen. Meanwhile, parameters measured ex situ in the laboratory include Total Suspended Solid (TSS), phosphate levels using the ascorbic acid reduction method spectrophotometrically based on IK-MP.K-Ala01 was carried out at the BINALAB Laboratory, while TSS testing was carried out at the Laboratory of Marine Biogeochemistry, Faculty of Fisheries and Marine Science, Universitas Padjadjaran.

2.3. Data Analysis

Data on the percentage of coral cover as well as the prevalence of Black Band Disease (BBD) and White

Figure 4. Black band disease on *Montipora* at the research station

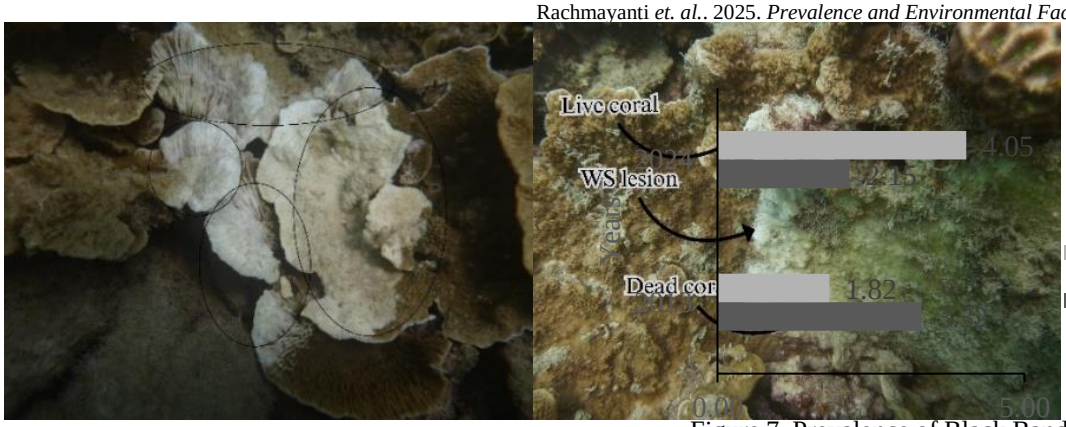


Figure 5. Black band disease on *Montipora* at the research station

Figure 7. Prevalence of Black Band Disease in Pari Islands Waters in 2013 (Johan *et al.* 2014) and 2024 (Research Results)

Figure 6. Prevalence of White Syndrome in Pari Islands Waters in 2013 (Johan *et al.* 2014) and 2024 (Research Results)

Syndrome (WS) were analysed descriptively comparative by explaining the results of observations at each research station and comparing them between stations. Meanwhile, water quality data were compared with the value of the Seawater Quality Standard for Marine Biota as stipulated in Government Regulation No. 22 of 2021 Appendix VIII on the Implementation of Environmental Protection and Management. This aims to assess the suitability of water quality in the Pari Island Waters with optimal conditions that support the survival of coral reefs.

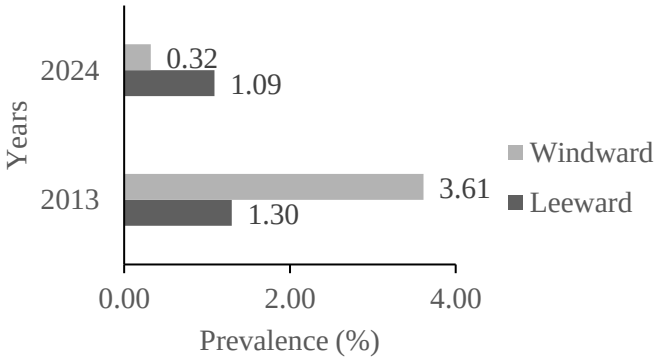
3. Results

Pari Island Waters has a distribution of coral reefs found starting from a depth of 1 m with a sandy substrate. The highest percentage of coral cover was found at station 2 (windward) which is included in the moderate cover condition, while station 1 is included in the damaged cover condition (Figure 3).

Total colonies of the genus *Montipora* counted at the two observation stations averaged 208 colonies with an area of 240 m^2. Among these colonies, signs of Black Band Disease (BBD) (Figure 4) and White Syndrome (WS) were found (Figure 5). The complete data are presented in Table 1.

Comparison of the prevalence of Black Band Disease and White Syndrome with the research of Johan *et al*. (2014) in Pari Island Waters shows changes, both decreases and increases, as shown in Figures 6 and 7.

The results of water quality measurements at both stations showed that the parameters of temperature, dissolved oxygen, current speed, and nitrate levels still met the quality standards that support the life of marine biota, especially coral reefs. However, several other parameters, namely salinity, brightness, pH, phosphate levels, and total suspended solid (TSS), were below or above the established quality standards,



thus less support coral reef life (Table 2).

Table 1. Coral disease prevalence at research stations

Station	Total of healthy colonies*	Total infected colonies*	Coral Disease		Coral disease prevalence (%)	Total (%)
			Type	Total of colonies*		
1	45,5±10,6	1,5±0,7	BBD WS	0,5±0,7 1±1,4	1,09 2,15	3,19
2	154±18,3	7±8,4	BBD WS	0,5±0,7 6,5±6,3	0,32 4,05	4,35

* Average of two belt transect points, BBD : Black Band Disease, WS : White Syndrome

Table 2. Results of water quality measurement at research stations

Parameters	Unit	Quality Standard*	Station	
			1 (*Leeward*)	2 (*Windward*)
Temperature	ºC	28-30	30,10	30,00
Current speed	m s^{-1}	-	0,50	0,10
Brightness	m	>5	3,93	4,57
Salinity	‰	33-34	29	28
pH	-	7-8,5	6,99	6,78
Dissolved Oxygen	mgL^{-1}	>5	7,27	7,70
Total Suspended Solid	mgL^{-1}	20	85,00	91,50
Nitrate (NO_3N)	mgL^{-1}	0,06	0,011	0,009
Phospate(PO_4)	mgL^{-1}	0,015	0,016	0,022

* Quality standards of Government Regulation of the Republic of Indonesia No. 22 of 2021, Appendix VIII (for marine biota)

4. Discussion

The percentage of coral cover at station 2 (windward) was in better condition than at station 1 (leeward). This is supported by more open water conditions that have cleaner and clearer water masses, thus allowing better coral growth (Wouthuyzen & Abrar, 2020). Meanwhile, at station 1 (leeward) there was a significant decrease in coral cover from year to year. In the leeward part, live coral cover was recorded at 40.50% ± 7.40 in 2013 (Johan *et al*., 2014), which then decreased to 32.81% in 2014 (Delpopi *et al*., 2015) and further to 15.50% in the research results. In line with the findings of Wouthuyzen & Abrar (2020), the rate of decline in live coral cover in the southern part of Pari Island Waters reached 2.6% per year. Furthermore, sewage runoff from 13 rivers that empty into Jakarta Bay has increased sediment and organic material levels in the waters around the Seribu Islands, including Pari Islands (Wouthuyzen & Abrar, 2020). This condition is exacerbated by the leeward position, which on average is more protected by waves, so that water circulation is reduced and sediments and waste accumulate more easily.

Coral colonies of the genus *Montipora* were also found more at station 2 than station 1. This is due to the dependence of the genus Montipora on the brightness of the waters, where the brightness at station 2 was 4.57 m better than station 1 3.93 m. Water clarity allows optimal light penetration, which is needed by Montipora to grow well, according to its characteristics which depend on clear water conditions and strong currents (Adelia *et al*., 2024). However, at station 2, it was found that many *Montipora* corals were covered by sediment, as many as 71 colonies were affected by sedimentation damage. This is thought to be caused by high land development into reclamation land and resorts located on Tengah Island, close to station 2 (Wouthuyzen & Abrar, 2020).

Black Band Disease (BBD) and White Syndrome (WS) were found to infect *Montipora* colonies at both station 1 and station 2. Black Band Disease is characterised by the presence of a black band across the colony surface, separating healthy tissue from dead tissue. This band consists of a consortium of bacteria, including *Cyanobacteria*, *Phormidium coralyticum*, *Desulfovibrio*, and *Beggiatoa* (Viehman *et al*. 2006). Meanwhile, WS is characterised by lesions in the form of thick white patches or lines that separate healthy and dead coral tissue. Ushijima *et al*. (2012) and Ushijima *et al*. (2014) in Rosyid & Luthfi (2019) identified *Vibrio coralliilyticus* and *Vibrio owensii* as infecting WS in Montipora corals.

White Syndrome was the most prevalent coral disease found with a prevalence of 2.15% on the leeward side and 4.05% on the windward side. There was a change in the prevalence value of WS found previously at the same location in Pari Islands waters found by Johan *et al*. (2014). In 2013, the prevalence of WS was higher in the leeward part at 3.32%, while the windward part was only about 1.82%. According to Johan *et al*. (2014), this is related to the causative factors of WS, which are influenced by temperature and sedimentation. Research conducted by Delpopi (2016), noted that TSS values in 2014 in Pari Islands waters were higher in the leeward than the windward area by 11 mgL-1. However, by 2024, this condition changes, with higher TSS values in the windward part at 91.50 mgL-1, which is one of the factors for the increased prevalence of WS in the area. High TSS can increase sedimentation, which brings organic matter to the coral surface, triggering toxic hydrogen sulfide accumulation and blocking light penetration for photosynthesis of symbiotic algae (zooxanthellae) (Weber, 2012). Limited photosynthesis can reduce the coral's primary energy availability, requiring the coral to use its energy to clear sediment through mucus production and tentacle movement, which can stress the coral and make it susceptible to disease infection.

The level of sensitivity of corals to sedimentation varies depending on the species. According to Palmer *et al*. (2010), *Montipora* spp. belongs to a genus that is more susceptible to sedimentation, which is related to sediment removal efficiency that varies by species and coral growth forms which are generally found in the form of foliose and encrusting forms, which causes sediment to easily accumulate on the surface of the coral.

At station 2, phosphate levels were also found to exceed the quality standard, amounting to 0.022 mgL^{-1}. High phosphate can interfere with the calcification process of corals, where corals start using phosphate ions to form skeletons when carbonate ions are reduced. The formed skeleton becomes lighter, porous, and susceptible to disease (Dunn *et al*., 2012). In addition, low values in pH and salinity can make corals stressed and susceptible to infection due to the disruption of calcium carbonate (CaCO3) formation.

Furthermore, data collection during the eastern (dry) season may result in a higher prevalence of WS compared to the western or transitional season. Based on research by Johan *et al*. (2015), the peak abundance of WS occurred in the dry season, with the highest abundance recorded during the dry season at 0.074 ± 0.11 col.m-2 (N=9), while the lowest abundance was recorded during the rainy season at 0.03 ± 0.02 col.m-2 (N=8). This condition was caused by the

temperature and light intensity that began to increase in the dry season, which caused stress on *Montipora* corals, making them more susceptible to infection.

On the other hand, the prevalence of Black Band Disease (BBD) was found to be low at both stations and lower than the prevalence of White Syndrome (WS), which was 1.09% at station 1 (leeward) and 0.32% at station 2 (windward). The decrease in prevalence found in this study may be related to the decrease in water temperature. In the study by Johan *et al*. (2014), which was conducted during the transition season between the dry season and the rainy season, found BBD prevalence of 1.30% in the leeward section and 3.61% in the windward section. Research by Delpopi *et al*. (2015) in Pari Island Waters also showed the highest prevalence in May (transitional season), which was 5.95% with an average of 4.07±1.51% and decreased in July (east season) with the lowest prevalence to 1.55% and an average of 3.47±1.78%. BBD is found to be present throughout the season with a peak during the transition period to the early rainy season (Johan *et al*., 2015).

In the transitional season, the water temperature in the Seribu Islands was recorded to be 0.35ºC higher than that in the wet and dry seasons (Johan *et al*., 2015). In addition, light intensity is also higher due to calmer waters and small wave fluctuations, which allow maximum absorption of sunlight to the bottom of the water (Delpopi *et al*., 2015). This increase in temperature is positively correlated with the prevalence of BBD, as the bacterial consortium that causes this disease requires that its activity be triggered by high temperatures and light intensity, ranging from 30-35 ºC (Harvell *et al*., 2007). Whereas in this study, based on satellite image data, data collection was carried out in the eastern season with an average water temperature that dropped to around 29.03-30.08ºC which previously ranged from 29.40-30.45ºC in the transitional season. When there is a decrease in temperature, it is likely that prevalence will decrease. This is because BBD infection does not always cause death to all colonies. Under certain conditions, BBD infections can stop and infected corals have a chance to recover (Delpopi *et al*., 2015). Infections can reoccur if the bacteria that cause BBD remain in the colony or come from the water column (Voss & Richardson 2006).

5. Conclusions

The condition of coral reefs in Pari Island waters shows the percentage of live coral cover of 15.50% at Station 1 (leeward) and 37.69% at Station 2 (windward), which falls into the category of damaged and moderate. Black Band Disease (BBD) and White Syndrome (WS) coral diseases were found to attack corals of the genus Montipora in all study sites. The highest prevalence of BBD was recorded at 1.09% at Station 1, while the highest prevalence of WS reached 4.05% at Station 2. The prevalence rates of both diseases are influenced by seasonal conditions, especially changes in water temperature, as well as high levels of sedimentation that contribute to the increased prevalence of White Syndrome.

Ethics approval

No permits were required.

Data availability statement

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Author contributions

FAR is doing research ideas, data curation, data collecting, data analysis, methodology, project administration, software, visualization, and writing the original draft. MUKA is doing methodology, supervision, validation, and writing review and editing. SA is doing methodology and supervision. SD is doing supervision and validation. OJ is doing methodology, supervision, and validation.

Funding

No funding available

Acknowledgments

The authors would like to thank Mr. Hasim and Chusnul Firaqie Ainni as the diving team who assisted in the data collection process.

Declaration of competing Interest

None

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