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Coral diseases and compromised health prevalence in Gili-Noko Waters, Bawean Island, Indonesia

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Abstract. *Asadi MA, Azhari AN, Fathah AL, Isdianto A, Setyanto A, Salim LH, Aprilianto RY, Munif MA, Faisal M. 2025. Coral diseases and compromised health prevalence in Gili-Noko Waters, Bawean Island, Indonesia. Biodiversitas 26: 1433-1442.* Coral reefs have important ecological and economic functions. Bawean Island, Indonesia known for its natural beauty and rich marine resources, has become an important tourism destination. This research aims to understand how environmental parameters and human activities influence the prevalence of coral diseases and their impact on coral reef diversity. The measurement of coral cover used a combination of Line Intercept Transect (LIT) and transect quadrants, while field data collection for coral disease assessment used a belt transect with a size of 20x2 m. The findings showed that coral cover in Gili-Noko Waters ranged from 65.90% to 74.86%, with various types of coral diseases identified. Identified diseases include Pigmentation Response (PR), Growth Anomaly (GA), White Band Disease (WBD), Yellow Band Disease (YBD), White Patch (WP), White Syndromes (WS), Unusual Bleaching Patterns (BL), Ulcerative White Spot (UWS), Sediment Damage (SD), and Fish Bites (FB). These diseases affect the coral genera. *Acropora* (437 colonies), *Isopora* (345 colonies), *Echinopora* (8 colonies), *Porites* (160 colonies), *Platygyra* (12 colonies), *Favia* (98 colonies), *Astreopora* (22 colonies), and *Lobophyllia* (3 colonies). *Stylophora* (2 colonies), *Millepora* (13 colonies), and *Fungia* (7 colonies). The correlation between environmental parameters and disease prevalence shows that dissolved oxygen levels have the most significant influence. Human activities have a significant impact on the health of coral reefs, highlighting the need for effective management and ongoing conservation efforts.

Keywords: *Acropora*, Bawean Island, compromised health, coral disease, fish bites

INTRODUCTION

Coral reefs serve multiple functions, both ecologically and economically. Coral reefs play a crucial role in safeguarding the shoreline from erosion resulting from currents, winds, and waves (Schoepf et al. 2023; Zhou et al. 2023). They accomplish this by forming reefs (calcium carbonate production and bioerosion), supporting food chains (primary and secondary production), and taking in and releasing nutrients (Brandl et al. 2019; Banister et al. 2024; Isdianto et al. 2024). Coral reef ecosystems offer both tangible and intangible economic benefits to human society, which remain undervalued and incompletely comprehended (Yasir and Fujii 2020). The community then uses coral reefs to provide ecosystem services for both tourism and recreation, generating large incomes for the local economy and increasing economic value over time (Bennett et al. 2015). When coral diseases and health issues reduce coral resilience, this dependency will shift (Moriarty et al. 2020). Biologic factors such as bacteria, viruses, fungi, and parasites, along with abiotic factors like climate change and anthropogenic activities, contribute to coral diseases (Thurber et al. 2020; Mujahidah et al. 2023). Diseased corals display color changes, damage to the coral biota's framework, loss of nets, and wounds or missing bands of coral tissue (Peixoto et al. 2017; Jogee et al. 2023). Similarly, local communities on Bawean Island, who rely on the sea for their livelihoods, experience comparable challenges.

Bawean Island in Indonesia with its abundant natural resources and natural beauty, exhibits enormous natural potential, making it an attractive destination for tourism and industrial development (Noor and Romadhon 2020; Sari et al. 2024). Located in the north of Java Island, Bawean Island occupies an area of approximately 199 km^2, and falls under the administrative jurisdiction of Gresik District, East Java Province (Noor and Romadhon 2020; Mujahidah et al. 2023). Bawean Island is a popular destination for snorkeling and diving activities because of its beautiful environment, beautiful natural panoramas and beaches, and attractive underwater natural views (Dewi et al. 2018). Good water conditions contribute to the abundance of marine resources (Altieri et al. 2017; Hamuna et al. 2018; Guntur et al. 2021), which local communities use for daily needs through fishing activities, marine ecotourism, and sea transportation (Dharmawan et al. 2020). Marine ecotourism on Bawean Island has developed rapidly, with various activities such as diving, snorkeling, and boat tours attracting many tourists every year (Nugraha et al. 2020). As a result, good management will support environmental sustainability and improve the local economy by generating income from the long-term tourism sector.

Based on the background explanation above, it is clear that environmental changes caused by human activities have a significant impact on the health of coral reefs in the region, which in turn affects local communities. Temperature, salinity, pH, and dissolved oxygen, as well as human activities, influence the prevalence of coral diseases and their impact on coral reef diversity (Moriarty et al. 2020; Oetama et al. 2024). Therefore, this research focuses on understanding how environmental parameters and human activities influence the prevalence of coral diseases and their impact on coral reef diversity. The aim is to develop effective conservation strategies to protect and restore coral reef ecosystems, which are a source of life for local communities.

MATERIALS AND METHODS

Study area

This research was carried out from July to August 2021 at four sites in the waters between Bawean Island and Gili-Noko Island, Indonesia, specifically in the waters east of Bawean Island and west of Gili-Noko Island (Figure 1, Table 1). In the eastern part of Bawean Island, Gili-Noko Island combines two islands: Gili Island, a large island, and Noko Island, a small island. Coral reefs thrive in the surrounding waters due to the clarity of the water (Arrasyid et al. 2023). However, this location is also full of tourist attractions such as snorkeling, diving, and beach tourism.

Table 1. The coordinate of research stations

Station	Latitude	Longitude	Description
1	-5.797933	112.764760	Northearn most station, reef flat with depth of 4 m and distance of 350 meter from the Gili-Noko Island
2	-5.800560	112.765555	Typically reef flat with depth 3.5 to 4 m and distance of 375 m from the Gili-Noko Island
3	-5.802580	112.765997	Reef slope with depth between 4 and 8 meter and distance 400 m from the Gili-Noko Island
4	-5.811339	112.763771	Southern most station, typically reef flat with depth 3 meter and distance of 900 meter from the Gili-Noko Island

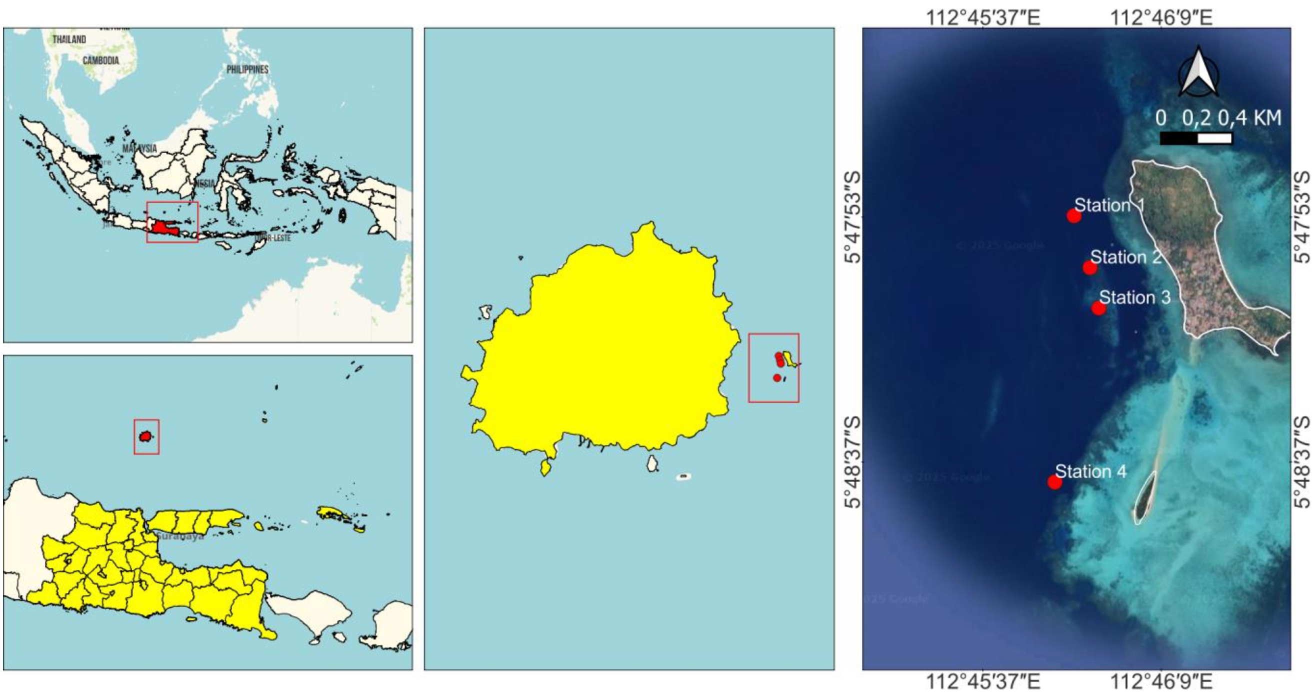

Figure 1. The research location in the waters of Gili-Noko Island, Bawean Island, East Java, Indonesia

This study was conducted between July and August 2021 across four locations in the waters situated between Bawean Island and Gili-Noko Island. The area is renowned for its rich biodiversity, particularly in reef-building corals and coral reef fish (Dewi et al. 2018). The transparency of the waters in Gili-Noko contributes significantly to the thriving coral reefs. This transparency indicates the degree to which light can penetrate the water. Clearer water has a lower concentration of suspended particles, allowing sunlight to penetrate to greater depths. This factor is essential for the coral reefs in Gili-Noko, as they depend on sunlight for photosynthesis and energy generation (Arrasyid et al. 2023). Consequently, this island serves as a primary destination for marine tourism activities such as snorkeling, diving, and beach tourism, and it holds significant potential for ecotourism development (Noor and Romadhon 2020). The map and the coordinate of research stations are presented in Figure 1 and Table 1.

Data collection

Coral reef cover data was collected using the Line Intercept Transect (LIT) method for 50 metres (Figure 1.A) (Urbina-Barreto et al. 2021; Asadi et al. 2024). An underwater camera assists the LIT method, which uses a 1x1 m transect quadrant for documentation. We calculated the coral data obtained using formula 1 to determine the coral cover. The coral reef health monitoring guidelines then classify the calculation results, classifying the condition of coral cover as 0-25% poor, 26-50% moderate, 51-75% good, and 76-100% very good (Giyanto et al. 2017). Meanwhile, Raymundo et al. (2008) used the Belt Transect method with a modified plot of 20x2 m (Figure 1.B) to collect data on coral disease prevalence. Underwater cameras play a crucial role in data collection, making it easier to detect diseases or health issues in coral. Diseases are visually identified through changes in coral color, such as white, yellow, pink, and black (Peixoto et al. 2017) The identification was subsequently compared using reference materials, including "Coral of the World" (Veron and Stafford-Smith 2000), "Underwater Cards for Assessing Coral Health on Indo-Pacific Reefs" (Beeden et al. 2008), the "Coral Disease Handbook" (Raymundo et al. 2008), and "Coral Finder 5.0" (Kelley 2022).

Understanding the prevalence of coral disease is essential, alongside the identification of diseases and health issues. Formula 2 is utilized to calculate prevalence, defined as the ratio of infected coral colonies to the total number of coral colonies present in the waters (Beeden et al. 2008) Additionally, it is vital to recognize all factors that may affect the incidence of diseases and health disorders, including their prevalence, particularly water parameters. The parameters assessed encompass dissolved oxygen content, temperature, depth, salinity, and pH levels. Subsequently, all collected data, which includes coral cover, disease and healthy coral abundance, disease prevalence, and water parameters, were compiled into Microsoft Excel for graphical and tabular representation.

$$Coral\ cover\ (\%) = \frac{\text{Total length of live coral}}{\text{Total transect length}} \times 100\%$$

$$P = \frac{Pi}{P0} \times 100\%$$

Where:
P : Prevalence Percentage
Pi : Number of coral colonies attacked by disease
P0 : Total colonies

Data analysis

The investigation into the correlation between environmental parameters and the occurrence of coral disease was conducted utilizing a Pearson correlation test, employing statistical software such as SPSS. The Pearson correlation method serves to quantify both the strength and direction of the linear relationship between two variables. This analysis assesses how each environmental parameter, namely temperature, brightness, salinity, pH, and Dissolved Oxygen (DO), correlates with the prevalence of coral disease. The results of the Pearson correlation yield correlation coefficient (r) values that range from -1 to +1, indicating the strength and direction of the relationship. Where, +1: perfect positive correlation; one variable increases, followed by an increase in other variables; r: -1: perfect negative correlation; one variable increase while the other decreases; 0: There is no linear correlation between two variables.

Subsequently, a statistical significance value (p-value) was calculated to ascertain whether the correlation findings were attributable to chance. A p-value of less than 0.05 is typically regarded as statistically significant, suggesting that the correlation results are unlikely to have arisen by chance, whereas a p-value greater than 0.05 indicates that the results lack statistical significance (Mondal and Mondal 2017; Schoepf et al. 2023).

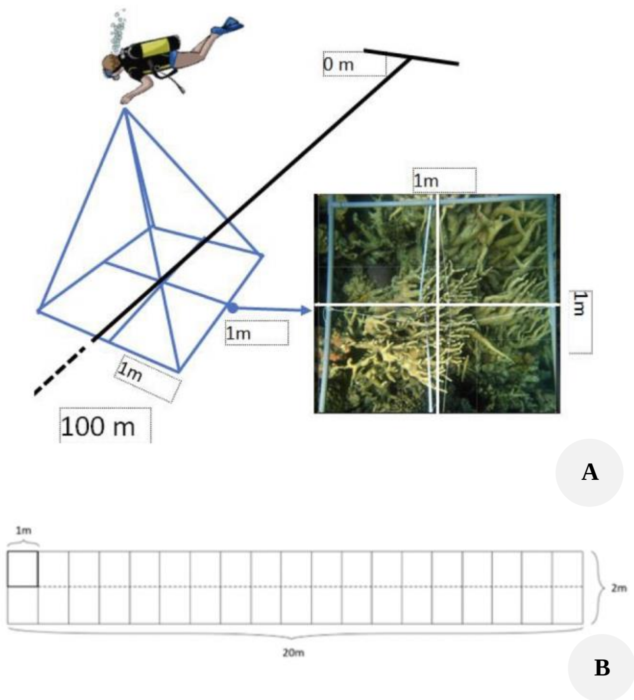

Figure 1. A. Illustration of LIT and quadrant transect placement; B. Illustration of belt transect

RESULTS AND DISCUSSION

Coral cover

The coral reef located in the Bawean Island continues to thrive, sustaining a wide variety of coral and reef fish species (Dewi et al. 2018; Asadi et al. 2024). In the waters surrounding Gili-Noko, Scleractinian coral coverage ranged from 65.9% to 74.86%, with an average of 70.4% (±4.3%). This level of coral coverage in Gili-Noko is notably higher than that observed in many other areas of Indonesia. For instance, the live coral coverage in the Panggang and Kelapa Islands of the Seribu Islands is recorded at only 26.8% and 45.2%, respectively (Fahlevy et al. 2019). Furthermore, in Petong Island, Batam, the coral cover is a mere 30.5% (Siregar et al. 2021). Similarly, in Menyawakan Island within the Karimunjawa Marine National Park, the coral coverage is also lower than that of Gili-Noko, standing at 46.1% (Wijayanto et al. 2021). Meanwhile, the average hard coral cover in the Philippines is only 22.8%, with a decline of about one-third over the past decade (Licuanan et al. 2019). Therefore, the coral reef in Gili-Noko boasts significantly higher coverage than many other regions in Indonesia and the Philippines, highlighting its exceptional health and resilience.

The coral coverage in the waters surrounding Gili-Noko displayed a rich variety of coral lifeforms. The *Acropora* Submassive (ACS) lifeform was identified as the most prevalent, representing approximately 25% of the total coral species observed in Gili-Noko Waters. The Coral Massive (CM) lifeform followed as the second most common, making up an average of 11.7%. Coral Foliase (CF), Coral Submassive (CS), and Coral Mushroom (CM) were documented only in station 4, demonstrating the highest diversity of lifeforms in the study area (Figure 3).

Coral genera and colonies

In the waters of Gili-Noko, a total of 11 genera of Scleractinian corals were identified. The genus *Acropora*, which includes the lifeforms ACB and ACT, exhibited the greatest abundance with 437 coral colonies, while the genus *Isopora*, represented by the lifeform ACS, followed closely with 345 colonies. In contrast, other genera displayed considerably lower colony counts; for instance, the genus *Fungia*, in the form of CMR, recorded only 7 colonies, and *Stylopora*, in the form of CB, had a mere 2 colonies (Figure 4). In the Indian and Pacific Oceans as well as the Caribbean Sea, the genus *Acropora* is a common type of coral that plays a significant role as one of the primary architects of reefs in warm water environments (Suwa et al. 2014; Banister et al. 2024; Furukawa et al. 2024). This prominence is due to its rapid growth rate, considerable reproductive capacity, and resilience to environmental changes (Thomas et al. 2024). Such traits allow *Acropora* to outcompete other coral species effectively. Meanwhile, *Fungia* is a monotypic genus that comprises only one species, *Fungia fungites*, which inhabits reefs in the Indo-Pacific region (Oku et al. 2020). The corals of *F. fungites* are predominantly solitary, with some individuals reaching a diameter of up to 12 inches (Grinblat et al. 2021). Juvenile forms initially attach to rocks, while larger specimens detach and adopt a free-living lifestyle (Oku et al. 2020). The investigation of juvenile corals in the Sempu Nature Reserve Strait, located in East Java, Indonesia, indicates that corals from the genera *Fungia*, *Astreopora*, *Lobophyllia*, and *Stylophora* are not present (Isdianto et al. 2024). This suggests that these genera are also scarce in other coral reef regions. This scarcity may be influenced by ecological factors such as limited suitable substrates for larval settlement (Wahab et al. 2023), competition with other coral species (Isdianto et al. 2024), or environmental conditions unfavorable for their growth (Conaco and Cabaitan 2020).

Furthermore, station 1 had the highest total colony density (around 10 colonies/m²), with approximately 8 healthy colonies/m² and 2 unhealthy colonies/m². Stations 3 and 4 have the lowest total densities (around 6 colonies/m²), with 5 healthy colonies/m² and less than 1 unhealthy colony/m² at each (Figure 5). In 2021, researchers looked at coral colony surveys all over the Hawaiian Islands. They found that the number of adult colonies (defined as colonies that are 5 cm or more) varied from 5 to 15 per square meter, depending on the site and the conditions of the habitat (Couch et al. 2021).

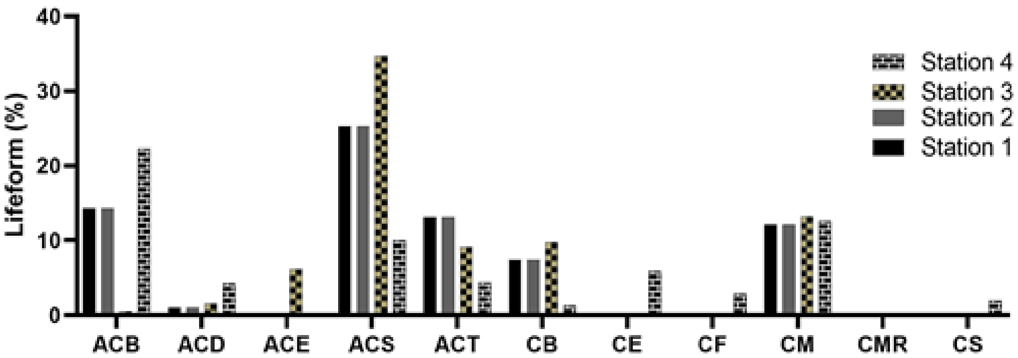

Figure 2. The coverage of coral lifeform in Gili-Noko Waters. Notes: *Acropora* Branching (ACB); *Acropora* Digitate (ACD); *Acropora* Encrusting (ACE); *Acropora* Submassive (ACS); *Acropora* Tabulate (ACT); Coral Branching (CB); Coral Encrusting (CE); Coral Foliose (CF); Coral Massive (CM); Coral Mushroom (CMR); and Coral Submassive (CS)

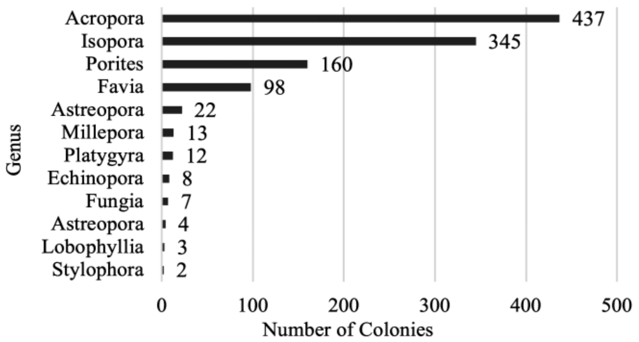

Figure 3. Number of coral colonies based on Genus in the whole research areas

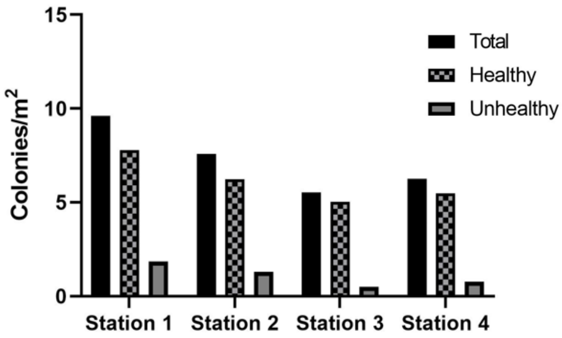

Figure 5. Coral colonies abundance in the research areas (colonies per m^2)

Coral colony density indicates how many colonies exist in a given area; a higher density is not always better, as it depends on the health and size of the colonies (Loke et al. 2024). Higher density may suggest favorable environmental conditions if the colonies are healthy and large, contributing to robust reef ecosystems (Shantz et al. 2011). However, if the colonies are small, high density might reflect fragmentation or stress, which could hinder reef recovery and growth (Pisapia et al. 2016). Conversely, lower density with larger colonies can indicate a stable and mature reef system, even if the total number of colonies is fewer (Dietzel et al. 2020).

Prevalence and types of coral diseases

Coral diseases and compromised health identification

Coral disease identification is critical to understanding the health of coral ecosystems. Several diseases affect coral reefs, including pigmentation response, growth anomalies, white band disease, yellow band disease, white patch disease, white syndrome, unusual bleaching patterns, ulcerative white spots, sediment damage, pufferfish bites, and damselfish bites. Symptoms of these diseases include changes in tissue color, skeletal deformities, growth problems, and tissue loss. They are usually only found in certain types of coral, such as *Porites*, *Acropora*, *Isopora*, *Platygyra*, and *Echinopora* (Aeby et al. 2020). Using the Coral Disease Handbook for field identification, the researchers identified various diseases affecting corals, as listed in Table 2.

Coral diseases and compromised health prevalence

Based on the data, station 1 exhibited the highest incidence of coral disease at 23.48%, whereas stations 3 and 4 recorded the lowest rates at 9.94% and 12.41%, respectively (Table 3). In stations 1, 2, and 4, UWS is identified as the primary coral disease, while station 3 is predominantly affected by BL. The presence of pufferfish and damselfish contributes to Fish Bites (FB) across all stations, resulting in a significant decline in overall health. Observations of diseases and health deterioration were noted, attributed to factors such as predation by natural coral predators like pufferfish and damselfish, the impacts of climate change, and excessive abrasion in the marine environment (**Error! Reference source not found.**).

Table 2. Coral diseases and compromised health

Disease/Compromised health	Main characteristics (Raymundo et al. 2008)
Pigmentation Response (PR)	Tissue color changes to white, purple, yellow, brown, or blue
Growth Anomalies (GA)	Skeletons appear larger or smaller than healthy adjacent tissues
White Band Disease (WBD)	Tissue loss is restricted by a band 2-10 cm wide, only on *Acropora*
Yellow Band Disease (YBD)	Tissue loss with a yellow boundary line next to healthy tissue
White Patch Disease (WP)	Tissue loss with diameters of 1-80 cm, corallite eroded
White Syndrome (WS)	Irregular tissue loss patterns different from white plague or WBD
Unusual Bleaching Patterns (BL)	Bleaching with discrete or halted boundaries, polyp color fades
Ulcerative White Spots (UWS)	Random white spots <1 cm in diameter, possibly merging with algae
Sediment Damage (SD)	Dispersed and uneven tissue degradation resulting from skeletons that are enveloped in sediment.
Fish Bites (FB)	Loss of tissue and skeleton damage due to predation by fish, including parrotfish, butterflyfish, pufferfish, triggerfish, and damselfish families, leads to significant health issues.

Table 3. Coral diseases and compromised health prevalence

Station	Prevalence (%)	Coral diseases and compromised health									
		Coral diseases (%)								Compromised health (%)	
		PR	GA	WBD	YBD	WP	WS	BL	UWS	SD	FB
1	23.84	0	0.32	1.29	0.32	0.32	2.25	1.29	10.61	1.29	5.79
2	17.11	0.99	0.66	0	0	2.63	0	0.99	3.95	1.64	6.25
3	9.94	0	0.90	0	0.45	0.45	0	3.17	2.71	0	2.26
4	12.42	0	0.81	0	0.42	1.60	0.21	2	3.22	1.23	3.21

Note: Pigmentation Response (PR); Growth Anomaly (GA); White Band Disease (WBD); Yellow Band Disease (YBD); White Patch (WP); White Syndromes (WS); Unusual Bleaching Patterns (BL); Ulcerative White Spot (UWS); Sediment Damage (SD); Fish Bites (FB)

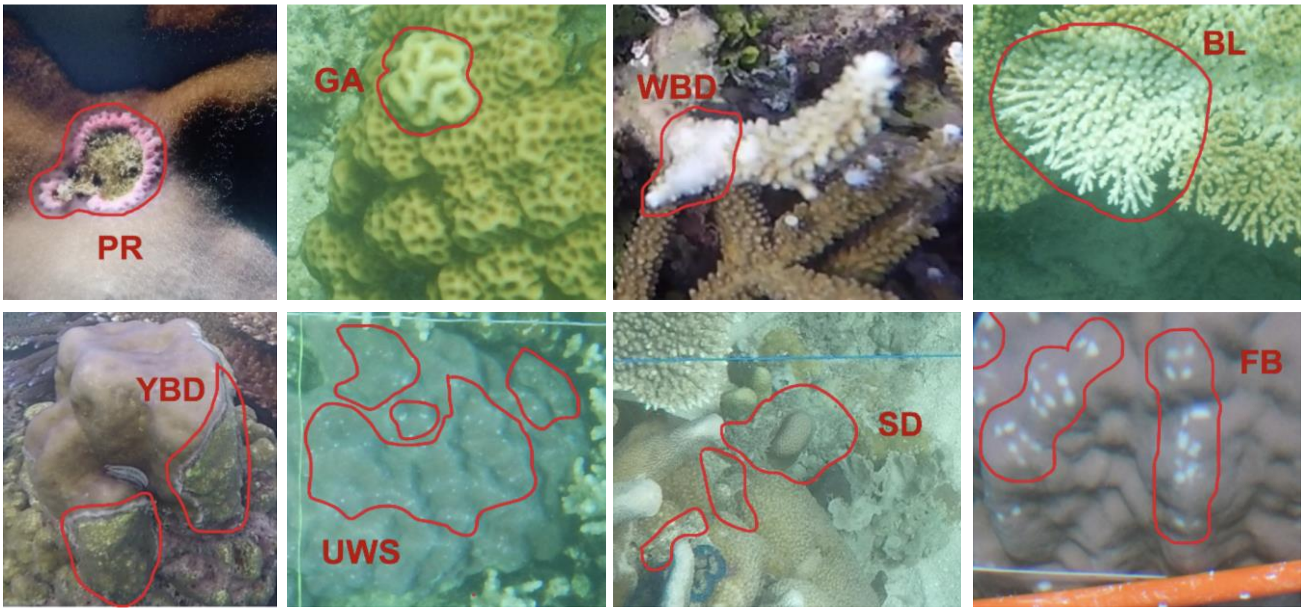

Figure 6. Types of diseases and compromised health. Note: Pigmentation Response (PR); Growth Anomaly (GA); White Band Disease (WBD); Yellow Band Disease (YBD); White Patch (WP); White Syndromes (WS); Unusual Bleaching Patterns (BL); Ulcerative White Spot (UWS); Sediment Damage (SD); and Fish Bites (FB)

Occurrence and prevalence of coral diseases in various genus

This section will examine the variety and frequency of different coral diseases and health issues impacting various genera. Table 4 provides a comprehensive overview of these diseases and health conditions, detailing the number of occurrences, the genera affected, and the total number of colonies impacted by each condition. The diseases listed include Pigmentation Response (PR), Growth Anomaly (GA), White Band Disease (WBD), Yellow Band Disease (YBD), White Patch (WP), White Syndromes (WS), and Ulcerative White Spot (UWS), alongside health conditions such as Sediment Damage (SD) and Fish Bites (FB). Coral diseases directly affect the tissues and overall health of corals, while non-classified health conditions also contribute to coral health challenges. Among the identified diseases, UWS is the most prevalent in *Porites*, impacting 57 colonies. UWS is prevalent in *Porites* corals primarily due to their susceptibility to infections by *Vibrio* species, which have been identified as causative agents of this disease (Arboleda and Reichardt 2010).

Furthermore, PR has been observed in three colonies of both *Acropora* and *Porites*. WP has affected a total of 16 colonies across the genera *Acropora*, *Isopora*, *Porites*, and *Platypyra*. YBD has been recorded in two colonies of *Porites*, as well as in other genera. Evidence of GA is present in seven colonies of *Acropora* and other genera. WBD also poses a threat to *Acropora* and additional genera. In terms of health conditions, FB is particularly widespread, affecting 49 colonies of *Isopora*, while SD has been noted in 10 colonies of *Porites* and *Favia*. This table illustrates the diversity and distribution of coral health issues among various genera, underscoring the susceptibility of coral ecosystems to a range of diseases and health conditions.

The Arabian Reef also yielded similar results, identifying 13 coral diseases. Aeby et al. (2020) found growth problems in *Porites*, *Platygyra*, and *Dipsastraea*, as well as black band disease in *Platygyra*, *Dipsastraea*, *Acropora*, *Echinopora*, and *Pavona*. They also found bleached patches in *Porites* and *Goniopora*, and yellow-banded tissue loss in *Porites* in this area. In a different study, four coral diseases were found near Rodrigues Island in the Republic of Mauritius. These were White Plague (WP), White Syndrome (WS), Black Band (BB), and Growth Anomalies (GA). Two compromised health conditions (CHCs) were also found. These were Pink Pigmentation Responses (PPR) in the form of Pink Patches (PP) and Pink Line Syndrome (PLS). The CHCs affect six tough coral genera, namely *Montipora*, *Porites*, *Goniastrea*, *Gardineroseris*, *Fungia*, and *Millepora* (Jogee et al. 2023).

Correlation between environmental parameters and disease prevalence

According to Indonesian Government Regulation Number 22/2021, which pertains to the Implementation of Environmental Protection and Management, the study areas exhibited optimal values for several parameters, such as brightness, pH, temperature, and Dissolved Oxygen (DO). However, non-optimal values, particularly salinity, were also noted. At the four monitoring stations, the salinity level recorded was 31 ppt, which is considered suboptimal for coral growth. In contrast, other studies suggest that a salinity range of 30-36‰ is ideal for coral development (Giyanto et al. 2017). Salinity is a crucial factor in determining the osmotic pressure of water; elevated salinity increases osmotic pressure, while lower salinity decreases it. As a result, salinity has an indirect effect on coral health due to its influence on osmotic pressure within living tissues, thereby presenting challenges to coral growth. Variations in salinity levels are influenced by factors such as evaporation, precipitation, river inflow, and the mixing of freshwater with seawater (Hamuna et al. 2018; Patty et al. 2020). Coral reefs, which are sensitive ecosystems, are significantly impacted by various environmental parameters, including temperature, salinity, Dissolved Oxygen (DO), pH, and water clarity (Table 5). These factors can greatly affect coral health and their susceptibility to diseases. Understanding the relationship between these environmental variables and disease prevalence is vital for developing effective conservation strategies (Table 6).

The results in Table 6 show the correlation values between X1 and X2. The minimal correlation observed between temperature and coral diseases, as well as the absence of correlation with salinity can be attributed to the limited range of data. This does not imply that there is no relationship between these factors and coral diseases. The connection between increasing sea temperatures and the prevalence of coral diseases is intricate and shaped by various influences. Although certain research indicates a link between elevated temperatures and a rise in disease occurrences, other studies suggest that this relationship is complex and may be influenced by other environmental and biological factors (Burke et al. 2023). Furthermore, variations in salinity affect osmotic pressure, but at this location, the salinity range does not differ much. Nonetheless, other studies, such as those by Aguilar et al. (2019) show that large variations in salinity can cause osmotic stress in corals, increasing their susceptibility to disease.

Table 4. Summary of coral diseases and compromised health issues

Disease/ Compromised health	Total occurrences	Genus (Lifeform)	Affected colonies
Coral disease			
PR	3	*Acropora* (ACB, ACT), *Porites* (CM)	*Acropora*: 2, *Porites*: 1
GA	7	*Acropora* (ACB, ACT), Other (Undisclosed Genus)	*Acropora*: 3, Others: 1
WBD	7	*Acropora* (ACB, ACT), Other (Undisclosed Genus)	*Acropora*: 6, Others: 4
YBD	2	*Porites* (CM), Other (Undisclosed Genus)	*Porites*: 1, Others: 1
WP	16	*Acropora* (ACB, ACT), *Isopora* (ACS), *Porites* (CM), *Platygyra* (CM)	*Acropora*: 6, *Isopora*: 3, *Porites*: 2, Platygyra: 4, Other: 1
WS	4	*Favia* (CM)	4
BL	20	*Acropora* (ACB, ACT),	*Acropora*: 14, Others: 6
UWS	57	*Porites* (CM)	*Porites*: 57
Compromised health			
SD	10	*Porites* (CM), *Favia* (CM)	*Porites*: 8, *Favia*: 2
FB	49	*Isopora* (ACS)	49

Table 5. Water quality in the western waters of Gili-Noko Island, Bawean, Indonesia

Parameters	Unit	Stations (ST)				Threshold	Category (Salsabila et al. 2024)
		1	2	3	4		
Water clarity	%	100	100	100	100	-	-
Depth	m	3-4	3-5	2-3	2-3	-	-
pH		8.4	8.4	8.4	8.4	7-8.5	Optimal
Salinity	ppt	31	31	31	31	33-34	Not optimal
Temperature	ºC	28.5	30	29	28.5	28-30	Optimal
Dissolved Oxygen (DO)	mg/L	8.6	8.6	8.6	8.6	>5	Optimal

Source: Peraturan Pemerintah Republik Indonesia Nomor 22 Tahun 2021

Table 6. Correlation of water quality parameters with coral disease prevalence

Parameters (X)	Correlation coefficient (r)	Significance (p-value)
Temperature (X1)	0.150	0.643
Salinity (X2)	0	1
pH (X3)	0.270	0.396
DO (X4)	0.535	0.073
Water clarity (X5)	-	-

The pH correlation coefficient is 0.270, and the significance value is 0.396 (>0.05), indicating a weak positive relationship that is not statistically significant. In this dataset, pH changes had little effect on disease prevalence. However, other studies, such as Prouty et al. (2017), show that ocean acidification (reducing pH) can increase coral disease prevalence by weakening coral skeletons.

The DO correlation coefficient is 0.535, and the significance value is 0.073 (>0.05), indicating that there is a moderately positive correlation that is approaching statistical significance. This suggests that dissolved oxygen levels have a greater influence on disease prevalence than other parameters. Research by Murphy and Richmond (2016) and Altieri et al. (2017) support these findings, showing that hypoxia (low oxygen levels) can increase coral susceptibility to disease. Meanwhile, the brightness correlation remains uncalculable due to its constant value for each repetition and point.

Pearson correlation analysis showed that in this study, Dissolved Oxygen (DO) levels had a more significant influence on the prevalence of coral disease than other environmental parameters such as temperature, salinity, and pH. However, it is important to carry out further analysis with larger and more diverse data to get a more comprehensive picture of the factors that influence coral reef health. Understanding the complex interactions between various environmental parameters and disease prevalence in corals requires further research.

Impact of human activities on coral health

Coral health is profoundly affected by various diseases, resulting in diminished resilience and heightened mortality rates (Hamuna et al. 2018; Noor and Romadhon 2020). The health of coral reefs in the waters surrounding Gili-Noko Island is notably influenced by human activities. Human activities like overfishing, coastal development, and pollution degrade coral reef quality by causing physical destruction, nutrient imbalances, and increased sedimentation (Asadi et al. 2019; Jogee et al. 2023; Banister et al. 2024). This region is a popular tourist destination renowned for snorkeling and diving, as well as fishing activities, and experiences considerable ship traffic from both commercial and tourist vessels. The coral reefs flourish in the island's shallow waters due to their clarity. It is crucial to preserve the cleanliness and transparency of these waters; if the coral reefs decline or fail to thrive, the volume of sediment fragments transported by currents will also diminish. Consequently, the sediment on Noko Island may erode, potentially leading to the island's subsidence over time (Arrasyid et al. 2023).

Local communities rely heavily on the sea for their livelihoods, engaging in both marine tourism and fishing. On this island, residents cultivate grouper fish using floating net cages, which has led to the establishment of a fishing village. Unsustainable fishing practices pose a threat to the health of coral reefs. Numerous coral reefs in the area have been adversely affected by destructive fishing methods, including the use of explosives and potassium cyanide (Arrasyid et al. 2023). Nevertheless, the local population recognizes the significance of coral reefs and has ceased the use of harmful explosives, poisons, and other damaging tools in their fishing practices (Dharmawan et al. 2020). Additionally, during tourism and economic shipping activities, individuals utilize smartphones to monitor safe passages to coral reefs and implement floating anchors to prevent damage to these ecosystems. However, the potential for coral damage remains, as boats and anchors can still cause harm at various locations. Furthermore, during the course of the research, it was noted that the waters surrounding Gili-Noko were largely unspoiled, exhibiting little sign of waste or litter. In contrast, a separate investigation conducted by Arrasyid et al. (2023) indicated that Gili-Noko Island faces challenges in waste management, resulting in a considerable accumulation of rubbish in the region. This waste is attributed not only to the island's own activities but also to external sources brought ashore by waves.

In conclusion, this study underscores the critical impact of environmental factors and human activities on coral reef health in Gili-Noko Waters, Bawean Island. The findings reveal that coral cover in the area is relatively high, yet various coral diseases, such as White Band Disease, Yellow Band Disease, and Ulcerative White Spot, are prevalent, impacting coral genera like *Acropora* and *Porites*. Among environmental factors, dissolved oxygen levels show the most notable correlation with disease prevalence, while human activities, including tourism and fishing, contribute to coral degradation. These studies emphasize the importance of sustainable management and conservation efforts to protect coral reefs, preserve marine biodiversity, and support the livelihoods of local communities that depend on these ecosystems.

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