Coral diseases and health issues: Case study in three islands from Makassar Strait

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Abstract. The Makassar Strait has a very diverse coral reef ecosystem spread from north to south, between the islands of Kalimantan and Sulawesi. Reef clusters are unique ecosystems and reports of coral disease in the Makassar Strait are limited. Coral disease is one of the main threats that has reduced coral cover levels. This study aims to analyze the percentage of coral cover, coral health problems and prevalence of coral disease on three different islands in the Makassar Strait (Barrang Caddi Island, Pannikiang, and Gusung Toraja). The percentage of coral cover was calculated using an underwater photo transect. The belt transect technique was used to record coral diseases and alterations. The findings demonstrated that coral health issues had a minimal impact on the research area's coral reefs, which were in moderate to poor condition. Six different coral diseases, with prevalence ranging from 0% to 1.68% were found in 12 coral reefs. The most prevalent diseases identified at the study site were white band disease and ulcerative white spot disease.

Key Words: coral reefs, Spermonde, ulcerative white spot, Wallacea, white band disease.

Introduction. Indonesia has the world's most diversified coral reefs (Mora et al 2003). Corals are calcium carbonate ($CaCO^3$)-based structures comprised of tens of thousands of tube polyps that cover the top surface (Cahyo 2017). Due to environmental change, coral reefs around the world are currently threatened (Praveena et al 2012; Rinkevich 2015). If habitat deterioration or health decline brought by biotic and abiotic factors occur, coral reefs may perish (Peter 1997; Yamashiro 2004). According to reports, these elements are what cause coral sickness (Green & Bruckner 2000; Weil 2004; Sutherland et al 2004; Raymundo et al 2005).

Coral disease is described as a breakdown of critical coral activities that can halt growth and reproduction (Johan 2010). Lesions or bands may appear on the diseased tissue of afflicted corals. These diseases are a consequence of fungi, viruses, bacteria, or protozoa (Kushmaro et al 2001). Disease-related coral tissue loss will result in reproductive problems, restricted development, and coral death (Kushmaro et al 2001).

Pathogen growth on corals is accelerated by a rise in seawater temperature (Sokolow 2009; Mydlarz et al 2010). High temperatures can make pathogens more deadly. The branching coral *Acropora palmata* from the Caribbean is known to have been attacked by and killed by the white pox coral disease, which nearly wiped out the species (Patterson et al 2002). At least 150 different coral species were affected by more than 30 documented coral diseases worldwide (Jones et al 2004).

There have been a number of studies on coral disease published in Indonesia (Yusri & Estradivari 2007; Muller et al 2012; Johan et al 2012; Sabdono et al 2015; Ponti et al 2016; Subhan et al 2021), but this knowledge is viewed as lacking due to the vast number of locations that have never been investigated. Sites that have never been investigated on this subject include Barrang Caddi Island, Pannikiang Island, and Gusung Toraja Island. Although there is no information on hard corals and their diseases, the diversity of soft corals has been investigated in these three islands (Putra et al 2022). This study aims to calculate the percentage of coral cover on the mentioned three islands in the Makassar Strait, identify types of coral health problems, and analyze the prevalence of coral disease, providing information on the status of coral disease in Indonesia, especially in the southern part of Sulawesi.

Material and Method

Description of the study sites. On three distinct islands in the Makassar Strait, including Barrang Caddi (BC), Pannikiang (PN), and Gusung Toraja Island (GT) were observed between August 2020 and February 2021 by boat (Figure 1). Each island consists of four stations. In total, there were twelve stations of observation: BC1, BC2, BC3, and BC4 in Barrang Caddi Island, PN1, PN2, PN3, and PN4 in Pannikiang Island, and GT1, GT2, GT3, and GT4 in Gusung Toraja Island (the numbers in the abbreviations refer to the cardinal direction, namely 1, 2, 3 and 4 are North, East, South, and West, respectively). The circumstances and features of various coral reef ecosystems could be described by the variations in the position and distance of each island from the mainland. Data analysis was conducted at the laboratory of Animal Biosystematics and Ecology, Department of Biology, University, Bogor, Indonesia.

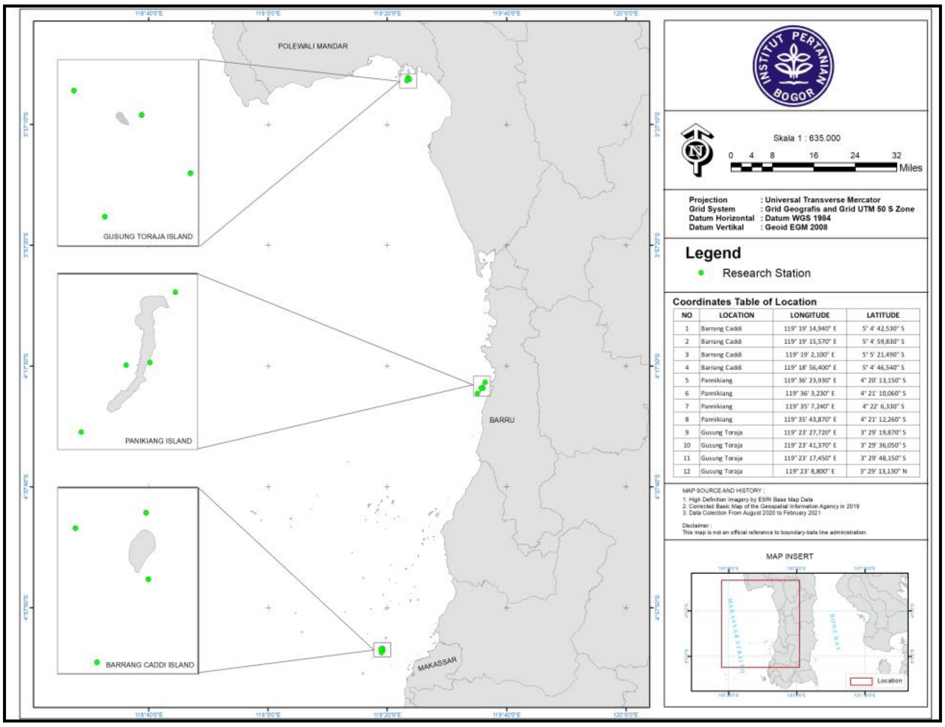


Figure 1. Coral sampling sites on the islands of Barrang Caddi, Pannikiang, and Gusung Toraja.

Sampling corals and water. Coral data collection variables in this study were the percentage of cover, health problems, distribution of disease, and the coral taxa affected by the disease. Data were collected by SCUBA diving at a depth of 5 m at each observation station. The method used was the underwater photo transect (Giyanto et al 2014). Data were analyzed using the Coral Point Count with Excel Extensions (CPCe) software. Data on the percentage of coral cover at each station was collected from a 58x44 cm quadratic transect placed on the right and left sides of the 60 m line transect at 1 m intervals alternately (Giyanto et al 2014). To determine the percentage of coral cover, 720 quadrants from 12 research stations were surveyed. According to the criteria for coral reef conditions based on live hard coral cover, the percentage of coral cover in each area was classified as: excellent (>75%), good (50–75%), moderate (25–50%), and low (<25%) (Hadi et al 2018).

Belt transects were used to calculate diseased coral species and families (Beeden et al 2008) with a modified plot of 2x60 m. 12 transects were used. Infected corals were recorded in the site. The category of coral health disorder refers to the Coral Diseases Handbook (Raymundo et al 2008). Using a Canon G16 underwater camera, photo documentation was also carried out. In addition, water quality data were determined to describe the condition of the waters at the time of data collection (Table 1). Water from each location was collected using platic containers. We used Divecom Scubapro, a saline hand refractometer ATC, and a pH meter to measure temperature, salinity and pH, respectively.

Table 1

Water quality variables from three islands in Makassar Strait

Variable	*Barrang Caddi*		*Gusung Toraja*		*Pannikiang*	
	Range	*Mean*	*Range*	*Mean*	*Range*	*Mean*
Temperature (°C)	29-30	29.75±0.25	29-30	29.5±0.29	30-31	30.25±0.25
Salinity (psu)	33-35	34.5±0.64	30-32	31±0.58	31-33	32.25±0.48
pH	6-8.3	7.37±0.54	7.4-8.6	8.33±0.30	8.2-8.5	8.32±0.06

Note: ranges represent the minimum and maximum values; values are presented as mean ±SE.

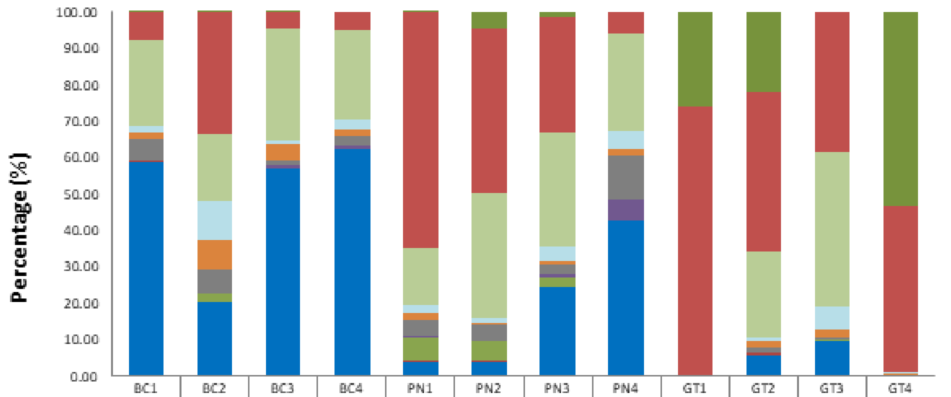
Statistical analysis. Using PAST (Paleontological Statistics) v4.04 software, data on the percentage of coral cover and coral disease were examined. Using non-metric multidimensional scaling (nMDS) and the Bray-Curtis coefficient, the percentage of coral cover at the 12 locations were compared for similarity (Clarke & Warwick 2001). One of the inequality indexes that is most frequently used in ecology is the Bray-Curtis index (de Voogd et al 2006). Based on Bray-Curtis similarity, the similarity of substrate composition in each group of stations at the three locations was compared using non-parametric one-way analysis of similarity (ANOSIM). Coral substrate categories consisted of coral (C), non-coral (NC), dead coral (DC), soft coral (SC), sponge (SP), other (OT), algae, rubble (R), rocks (RCK), sand (S), and silt (SI).

Results and Discussion

Percentage of coral cover. Twelve locations were inspected and examined for live coral cover. The BC location had 49.75% of the area in the medium category, while the PN and GT had 18.94% and 3.9% coral cover, respectively, being in the low category (Figure 2). Comparing BC to PN and GT, the location with the maximum coral cover was BC. One of the reasons for the lower percentage of live coral at this area was thought to be the high silt and sand substrate.

The percentage of live coral cover revealed that stations BC1, BC3, and BC4 were in the good category with percentages of 59%, 57.06%, and 62.67%, respectively. The proportion of live coral cover at PN4 falls into the medium category, with a percentage of 42.94%. Station BC2 had a damaged category of 20.28%, PN1 had 4.22%, PN2 had 4%, PN3 had 24.61%, GT2 had 5.78%, and GT3 had 9.83%. Living coral cover was absent from GT1 and GT4 stations, where high abiotic substrates predominated, with 74% sand cover at GT1 and 53.11% silt cover at GT4 (Figure 2).

The nMDS results revealed variations in the coral substrate between the GT and BC locations (Figure 3). The composition of the coral substrate when grouped by GT and BC location revealed a significant difference (p=0.029). However, there was no difference between PN and BC (p=0.318) or PN and GT (p=0.172).



	BC1	BC2	BC3	BC4	PN1	PN2	PN3	PN4	GT1	GT2	GT3	GT4
SI	0.11	0.22	0.11	0.00	0.06	4.50	1.44	0.00	25.72	22.06	0.00	53.11
S	7.28	33.39	4.33	4.78	64.56	45.22	31.56	5.78	74.00	43.83	38.44	45.83
RCK	23.94	18.00	30.67	24.56	15.83	34.39	31.50	26.67	0.00	23.50	42.56	0.00
R	0.17	0.00	0.06	0.11	0.00	0.06	0.00	0.06	0.00	0.11	0.00	0.00
Algae	1.44	10.72	1.22	2.83	2.28	1.33	3.94	4.94	0.00	0.94	6.28	0.11
OT	2.11	8.06	4.22	1.89	1.67	0.33	1.00	1.72	0.28	1.78	2.17	0.56
SP	5.56	7.11	1.61	2.50	4.67	4.56	2.61	12.39	0.00	1.00	0.33	0.39
SC	0.00	0.00	0.72	0.67	0.39	0.00	0.83	5.50	0.00	0.22	0.17	0.00
DC	0.00	1.94	0.00	0.00	6.22	5.00	2.50	0.00	0.00	0.00	0.22	0.00
NC	0.39	0.28	0.00	0.00	0.11	0.61	0.00	0.00	0.00	0.78	0.00	0.00
C	59.00	20.28	57.06	62.67	4.22	4.00	24.61	42.94	0.00	5.78	9.83	0.00
Average (%)	BC 49.75				PN 18.94				GT 3.9			

Figure 2. Percentage of coral cover on three islands; each island is divided into four stations: Barrang Caddi Island (BC1, BC2, BC3, and BC4), Pannikiang Island (PN1, PN2, PN3, and PN4), and Gusung Toraja Island (GT1, GT2, GT3, and GT4); coral substrate categories consist of coral (C), non-coral (NC), dead coral (DC), soft coral (SC), sponge (SP), other (OT), algae, rubble (R), rocks (RCK), sand (S), and silt (SI).

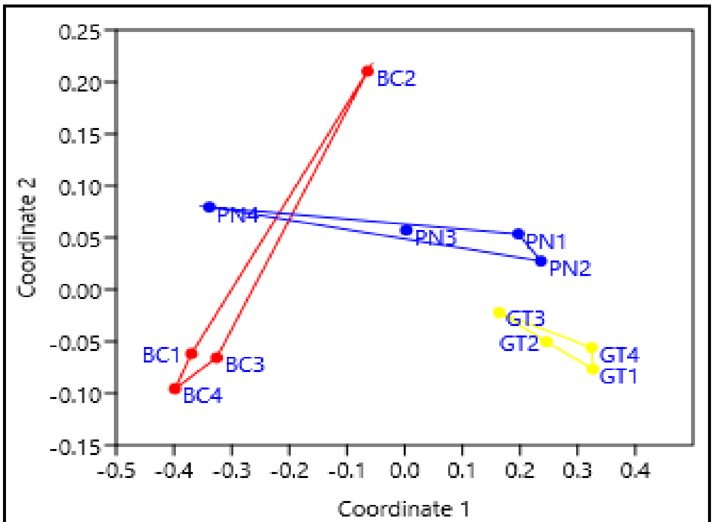


Figure 3. Non-metric multidimensional scaling (nMDS) differences in the composition of the coral substrate on the islands of Barrang Caddi (BC1, BC2, BC3, and BC4), Pannikiang (PN1, PN2, PN3, and PN4), and Gusung Toraja (GT1, GT2, GT3, and GT4); stress level = 0.01969.

Coral health disorder. The highest prevalence of coral health issues in BC was caused by predation, with 3.1% (±0.81), followed by pigmentation response with 2.6% (±0.68), and sediment damage with 0.04% (±0.04). The location of PN revealed the lowest prevalence value related to sediment damage at 0.21% (±0.21) and the greatest attributable to predation at 3.3% (±0.97). The lowest prevalence value was generated by growth anomalies with 0.75% (±0.44), while pigmentation response had the highest prevalence value in GT at 2.8% (±2.37) (Figure 4).

The aggressive competitive overgrowth by algae and sponge, which affected to the coral health problems was the highest in GT (1.38±0.38%) and in PN (1.2±0.38%), respectively (Figure 5a). Growth anomalies of corals caused by barnacles were frequently found at PN, 2.8±2.02% and by worms at GT, 0.75±0.44% (Figure 5c). The highest predation on corals was by *Drupella* occurred at a rate of 2.07±0.44% at BC sites, 2.64±0.96% at PN, and 0.75±0.44% at GT.

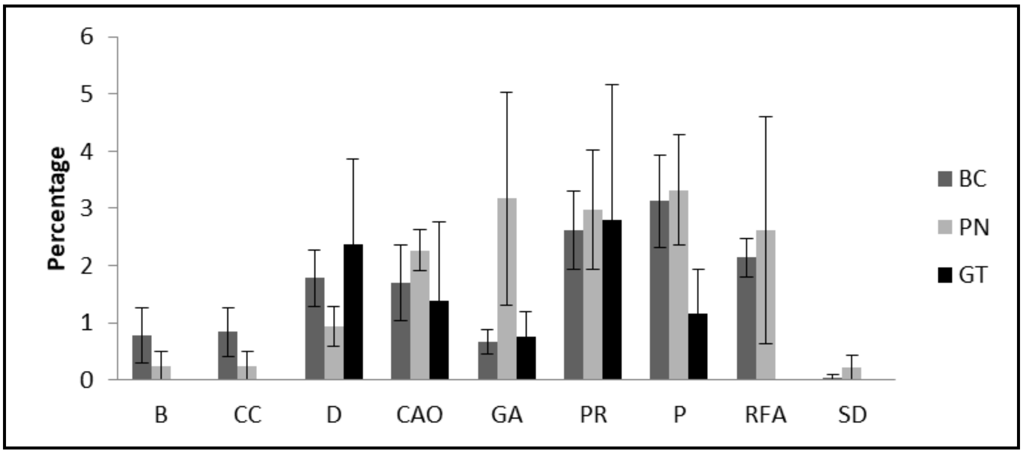


Figure 4. Prevalence of coral health disorders on Barrang Caddi, Pannikiang, and Gusung Toraja islands which are categorized into bleaching (B), competing corals (CC), diseases (D), competition aggressive overgrowth (CAO), growth anomalies (GA), pigmentation response (PR), predation (P), red filamentous algae (RFA), and sediment damage (SD).

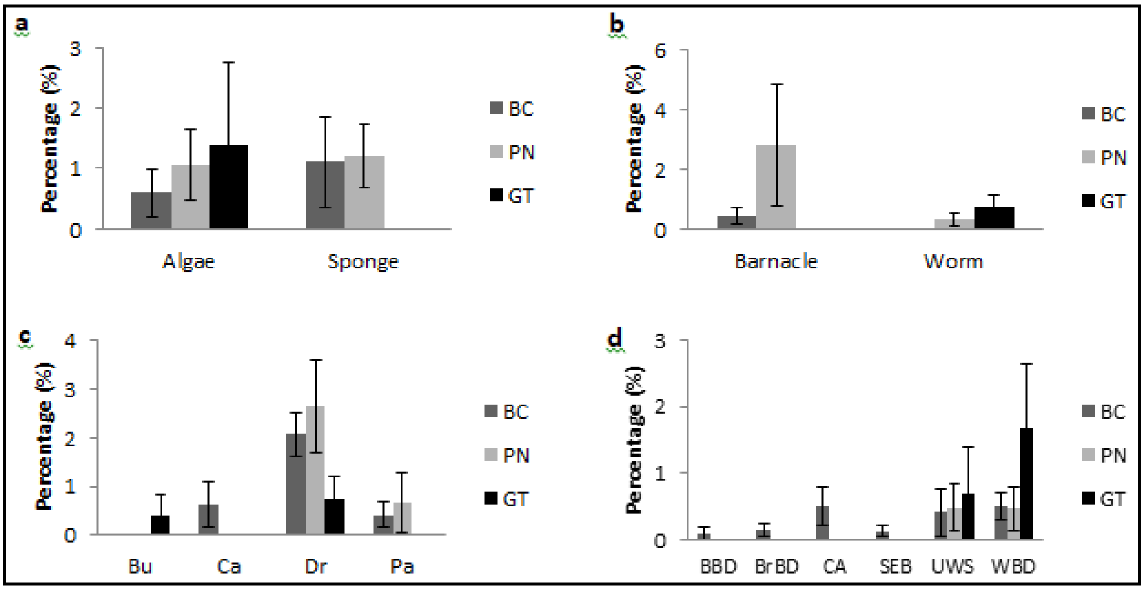


Figure 5. Prevalence of coral health problems in Barrang Caddi, Pannikiang, and Gusung Toraja locations by category: a - competition aggressive overgrowth caused by algae and sponges; b - growth anomalies caused by barnacles and worms; c - predation caused by butterflyfish (Bu), *Coralliophila* (Ca), *Drupella* (Dr), parrotfish (Pa); d - diseases caused by black band diseases (BBD), brown band diseases (BrBD), coralline algae (CA), skeletal eroding band (SEB), ulcerative white spots (UWS), and white band diseases (WBD).

This investigation identified six different coral diseases (Figures 5d, 6 and 7). Ulcerative white spot disease (UWS) and white band disease (WBD) were the most prevalent diseases, affecting 34 colonies of corals from 9 taxa. According to field observations, station BC4 had the most forms of coral disease, with six, followed by stations BC1, BC3, and PN4 with three. There are two distinct diseases at the GT3 station. Furthermore, there was only one kind of disease at stations BC2, PN2, and GT2. There was no coral disease at stations PN1, GT1, or GT4, in the interim.

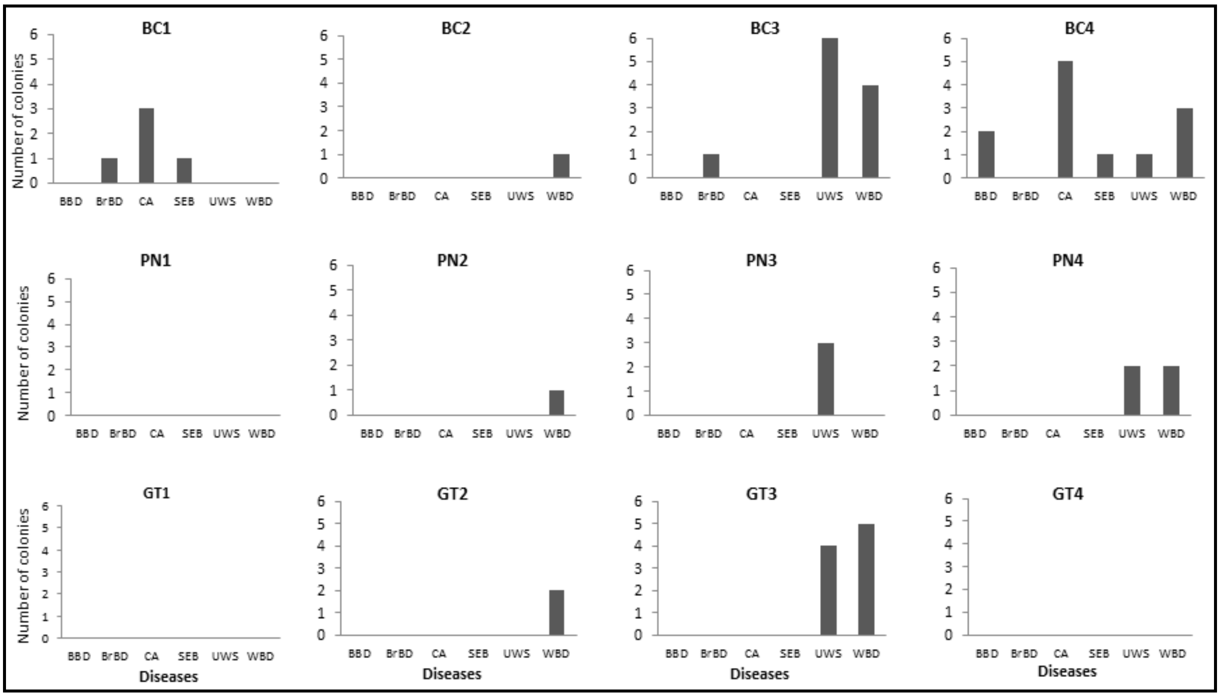


Figure 6. Distribution of disease distribution and number of coral colonies found in Barrang Caddi, Pannikiang, and Gusung Toraja sites. Disease caused by black band diseases (BBD), brown band diseases (BrBD), coralline algae (CA), skeletal eroding band (SEB), ulcerative white spots (UWS), and white band diseases (WBD).

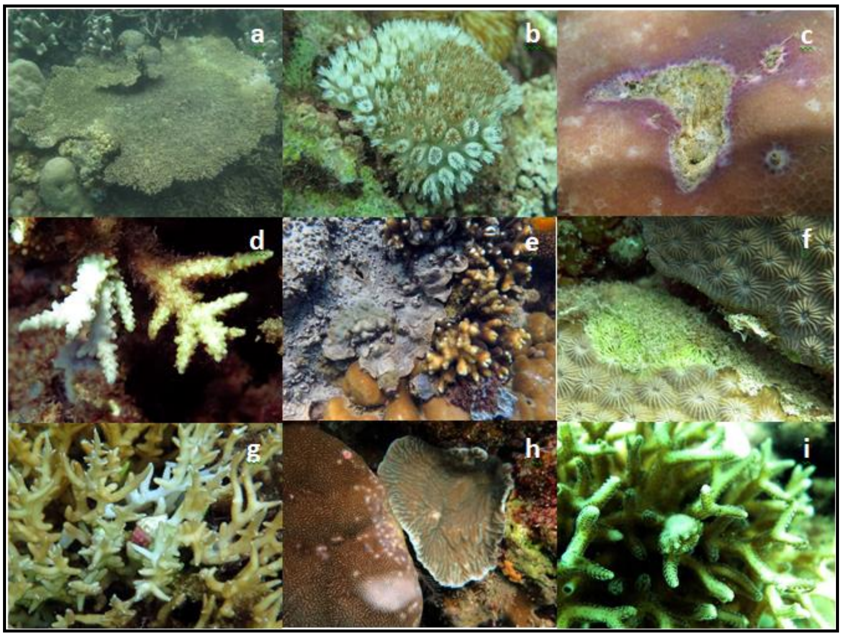


Figure 7. Coral health problems; (a) white band diseases on *Acropora* sp.; (b) bleaching on *Galaxea* sp.; (c) pigmentation response in *Porites* sp. Competitive aggressive overgrowth: (d) red filament algae on *Acropora* sp.; (e) sponges; (f) sediment damage to *Diploastrea* sp.; (g) predation by *Drupella* on *Seriatopora* sp.; (h) competing corals; (i) growth anomalies on *Seriatopora* sp.

This study documented the percentage of live coral, coral disease, and coral health problems in the Makassar Strait. The Makassar Strait is the separator between the islands of Kalimantan and Sulawesi, stretching from north to south with diverse coral reef ecosystems. The development of coral reefs in the Makassar Strait began 7000 years ago when there was a sea level rise (Imran et al 2013). Organisms that make up coral reefs in the Makassar Strait are more or less affected by inflows from the mainland of Sulawesi. These inflows come from rivers from the mainland, which carry suspended sediments through the water column. As a result, the sediment suspension is thought to affect the development of coral reefs in the Makassar Strait.

Results showed that each island's coral cover percentage varies. The least amount of coral cover was present where there was silt and sand in the stations near to the mainland (BC2, PN2, and GT1). High silt and sand substrate pressures on corals include shadowing, which reduces light intensity and photosynthesis, smothering, which results in the closure of polyps, killing the coral, abrasion, that weakens the calcium skeleton of the reef, and suppression of coral recruitment (Birkeland 1997). The stations with the highest percentage of coral cover are BC4, PN4, and GT3, which are the furthest from the mainland.

The study location's temperature ranged from 29 to 31°C. Temperatures between 18 and 31°C are ideal for coral growth (Veron 2000; Veron et al 2009). Corals may become stressed if seawater temperatures significantly fluctuate. Even under specific circumstances, zooxanthella can be released when the temperature rises by 1 to 2oC over normal limits. As a result, corals may begin to lose color (bleaching) (Ward et al 2000). The biological and physical processes of corals are impacted by temperature changes. In particular, corals' capacity to fight against sickness and infection is weakened, altering the relationship between potential pathogens and hosts (Rosenberg & Ben-Haim 2002). At higher temperatures, pathogens can become fatal (Rosenberg & Ben-Haim 2002).

The waters of the three islands (BC, PN, and GT) have a 30-35 psu salinity, which is consistent with the 30-35 psu salinity range of the waters overall (Edward & Tarigan 2003; Kuanui et al 2015; Ding et al 2022). At the research site, where the pH ranged from 6.8 to 8.6, there was no discernible variation in the degree of acidity. The pH range between 6 and 9 is ideal for coral reefs (Edward & Tarigan 2003). Coral reefs can thrive and expand in the research station because of these environmental factors.

Ocean currents affect the growth of coral reefs through controlling oxygen supply. Currents in the Makassar Strait flow to the south (Imran et al 2013) and the direction shifts east along the southwest coast of Sulawesi during the rainy season. Meanwhile, in the dry season, the current flows westward due to backflow from Sundaland (Imran et al 2013). Based on this, stations that are far from the mainland will receive the highest oxygen supply. Current velocity affects coral growth both directly and indirectly because the strength of the current is related to the distribution of oxygen and nutrients.

Nine different types of coral health issues were identified by this study (Figure 7), with pigmentation response (PR) having the greatest effect on coral health. It is thought that this disease results from the host's reaction to stressors, which compromises the health of the coral. The Porites genus typically exhibits coloration that is either purple or bright pink (Raymundo et al 2008).

The high competition between algae and sponges is also a factor causing the decline in coral cover (Sweet 2017). Coral reefs naturally have the ability to compete with macroalgae, but when the growth of macroalgae is faster than the growth of corals, it can affect their growth, and even cause death.

At the study site, the prevalence of coral disease was typically low, with a rate of 0-1.68% (Figure 5d). White band diseases (WBD) is more prevalent in BC and GT than ulcerative white spots (UWS) in PN. Compared to other areas, the coral reefs of GT Island had the most diseases. The location is under intense pressure from sediment intake in the form of silt and sand, according to quantitative data (Figure 2). Bacteria and nutrients delivered by sediments may have an impact on coral reefs (Weber et al 2006; Risk & Edinger 2011). The severity of coral disease will increase as a result of this process. Disease outbreaks also alter communities and species diversity.

Coral disease emerges as a result of intricate interactions among the host, the causal agent, and the environment (Work et al 2008). Events related to global warming are one of the elements that stress corals, affecting the vulnerability of the host to disease or pathogen virulence (Harvell et al 2002; Ward et al 2007; Bruno & Selig 2007; Maynard et al 2011; van Hooidonk et al 2016). Many coral diseases, such as black band disease in the Caribbean, Florida Keys, and Great Barrier Reef, exhibit a positive connection with temperature (Edmunds 1991; Boyett et al 2007). Additional factors that contribute to coral disease include human activities in coastal areas and sedimentation (Burke et al 2011; Mohammed et al 2022). The study site's coral conditions are most affected by UWS disease, according to field data.

Conclusions. This study showed that the percentage of coral cover in moderate conditions at the BC location was 49.75%, while at the PN and GT locations, with damaged conditions, the cover was 18.94% and 3.9%, respectively. The coral health disorders on three islands in the Makassar Strait consist of bleaching, competing corals, competing aggressive overgrowth, diseases, growth anomalies, pigmentation response, predation, red filamentous algae, and sediment damage. There were six coral diseases with disease prevalence from 0% to 1.68%.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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