

Distribution of Coral Diseases and Compromised Health Abundance in The Eastern Coastal Water of Kei Besar Island, Southeast Maluku

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Abstract. Coral diseases are caused by bacteria, fungi, or viruses due to stress or compromised health in the aquatic environment. This study identifies the abundance of coral diseases and compromised health in Kei Besar Island, Southeast Maluku. Data was collected using the Belt Transect method at six locations. 224 hard coral colonies were affected by eleven life forms and nine genera of coral disease, while 2172 hard coral colonies were affected by eleven life forms and 47 genera of compromised health. Coral Massive (CM) life form and *Porites* genus were the most affected. Six types of coral diseases and nine types of compromised health were identified. Kilwait and Ngefuit Bawah had the highest abundance of hard coral colonies affected by coral disease and compromised health, respectively.

1 Introduction

Coral reefs are a highly diverse and productive marine ecosystem. Nevertheless, coral reef coverage has declined rapidly in years [1]. Coral disease and compromised health are the primary agents that can accelerate the declining state of coral reefs by affecting their resistance to pathogenic microbial and viral infections [2; 3]. Coral disease involves the interaction between a host, the environment, and an agent (microbial and environmental agents) [4]. Coral disease is caused by microbial agents such as bacteria, fungi, virus, and protist which are usually preceded by a deteriorating condition due to stress or disturbance to the coral [5]. Meanwhile, compromised health is a decrease in conditions due to stress or disturbance from marine biota or environmental agents which may be considered abiotic diseases [4, 6].

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Diseases and compromised health in hard corals can occur naturally without human intervention, as well as in waters with good coral reef ecosystem management [7]. Several factors can influence the diseases and compromised health that infect hard corals naturally, including turbidity, light intensity, sedimentation, and water current speed [8]. Nevertheless, several cases have shown that anthropogenic activities can have a more profound effect on the spread of diseases and compromised health in coral reefs [2]. As evidenced by this study, anthropogenic activities such as runoff in the Ohoifau observation site may be the primary driver of sedimentation building near the coral reef ecosystem.

Changes in the community composition caused by coral disease and compromised health can lead to an increase in mortality and will impact the function of the coral reef ecosystem ecologically and economically. Monitoring the water quality, raising awareness among coastal communities about the importance of coral reef health, and enforcing regulations for managing and protecting waters at high risk for disease and health problems are all effective ways to mitigate these issues. There has been a paucity of data on the spreading of coral disease and compromised health due to a limited number of studies about coral diseases in Indonesia. The Kei Islands are located between three seas in Indonesia, namely the Halmahera, Banda, and Arafura Seas, all of which have substantial oceanic potential yet to be explored. This study provides the baseline data on coral disease and compromised health distribution on Kei Besar Island, Southeast Maluku.

2 Methods

The study was conducted from November 2nd to 18th 2018, which was located on six observation sites including Ohoifau, Hollat, Fako, Ngefuit Bawah, Weduar, and Kilwait in three sub districts of Kei Besar Island (Figure 1).

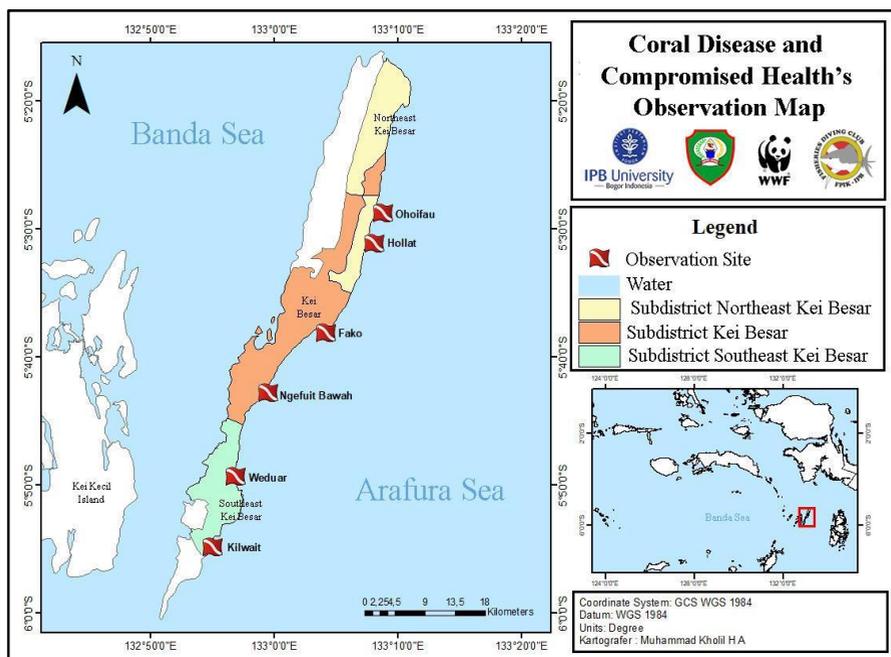


Fig. 1. Coral disease and compromised health's Observation Map in the eastern coastal water of Kei Besar Island in Southeast Maluku.

Most of the observation sites have a slope or flat contour and fringing reef type. Kei Besar Island has unique coastal tide occurrence called “Meti Kei”. Meti Kei is large tidal stretches which often occurs in September and October on Kei Islands [9]. Observations were carried out using the Belt Transect method, 6 replications (6 x 40 m²) at 3-10 meters depth, by recording each colony of hard coral’s lifeform and genus that was affected by coral disease or compromised health [7] (Table 1).

Table 1. Coral disease and compromised health categories.

Symptoms	Type	Code	Category
Tissue Loss - Predation	<i>Crown of Thorns Starfish</i>	COTS	Compromised Health
	<i>Coralliophila</i>	COR	Compromised Health
	<i>Drupella sp.</i>	DRU	Compromised Health
	<i>Fish Bites</i>	Fish	Compromised Health
Tissue Loss - Non-Predation	<i>Skeletal Eroding Band</i>	SEB	Disease
	<i>Black Band Disease</i>	BBD	Disease
	<i>Brown Band Disease</i>	BrB	Disease
	<i>Atramentous Necrosis</i>	AtN	Disease
	<i>Ulcerative White Spots</i>	UWS	Disease
	<i>White Syndromes</i>	WS	Disease
Tissue Discoloration - White	<i>Bleaching</i>	BL	Disease
	<i>Focal Bleaching</i>	FBL	Disease
	<i>Non-Focal Bleaching</i>	NFBL	Disease
Tissue Discoloration – Non-White	<i>Pigmentation Response</i>	PR	Compromised Health
	<i>Trematodiasis</i>	TR	Compromised Health
Growth Anomalies	<i>Invertebrate Galls</i>	IG	Compromised Health
	<i>Irregular White Plaques</i>	IWP	Compromised Health
	<i>Enlarged Structures</i>	ES	Disease
Other Reef Organisms/factors	<i>Aggressive Overgrowth</i>	AgO	Compromised Health
	<i>Flatworm Infestation</i>	RW	Compromised Health
	<i>Sediment Damage</i>	SD	Compromised Health
	<i>Crustose Coralline Algae</i>	CCA	Compromised Health

Type of coral disease and compromised health identified by looking at the symptoms or the cause that affected coral colonies. The abundance of coral disease and compromised health (colonies/10 m²) were calculated by dividing the number of colonies that were affected by either a type of disease or compromised health with the study area.

3 Results

3.1 The Abundance of Coral Lifeforms Abundance Affected by Diseases and Compromised Health

Nine coral lifeforms affected with the disease were found in six observation sites (Figure 2). The Coral Massive (CM) lifeform is the only lifeform that is always found to be affected with the coral disease at each observation site. CM was also the dominant lifeform affected with the disease (colonies/10m²) in six observation sites including Hollat (0.29 ± 0.03), Fako (0.42 ± 0.02), Ngefuit Bawah (0.46 ± 0.03), Kilwait (0.83 ± 0.08), Ohoifau (1.75 ± 0.05), and the highest abundance value of affected CM in all observation sites were found in Weduar (1.96 ± 0.14).

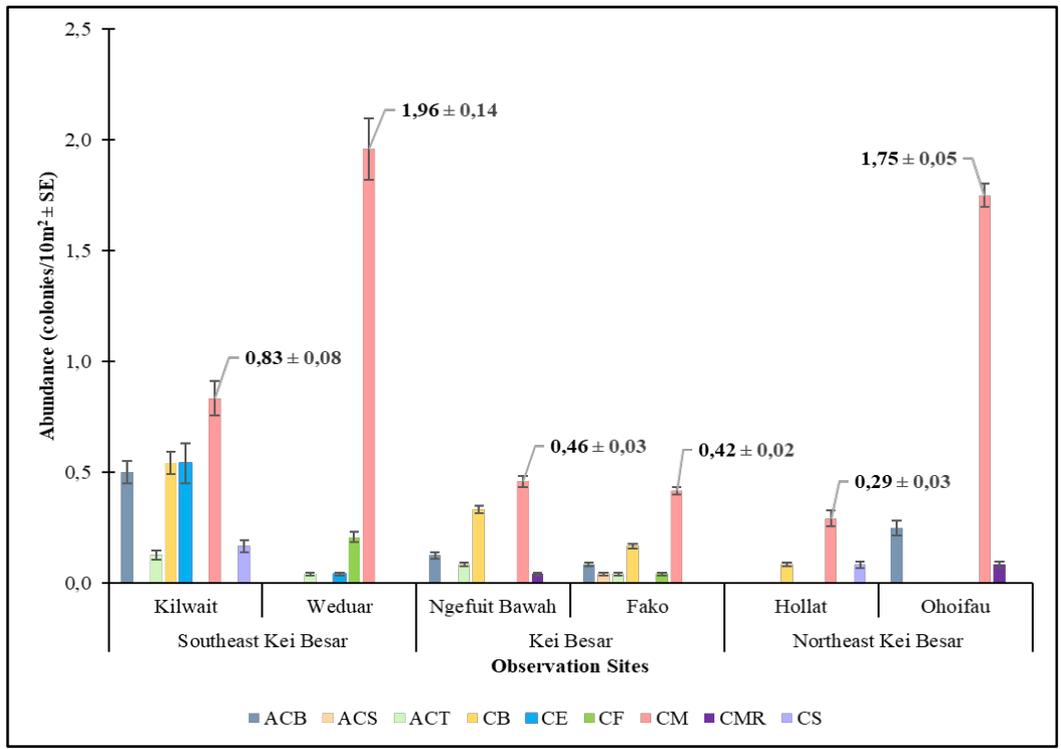


Fig. 2. The abundance of affected coral lifeform with coral disease in the observation sites. Coral lifeforms that are affected with disease include Acropora Coral Branching (ACB), Acropora Coral Submassive (ACS), Acropora Coral Tabulate (ACT), Coral Branching (CB), Coral Encrusting (CE), Coral Foliose (CF), Coral Massive (CM), Coral Mushroom (CMR), and Coral Submassive (CS).

Eleven coral lifeforms affected by compromised health were found in six observation sites (Figure 3). Six coral lifeforms are always found at each observation site, namely Acropora Coral Branching (ACB), Coral Branching (CB), Coral Encrusting (CE), Coral Foliose (CF), Coral Massive (CM), and Coral Submassive (CS). CM is a lifeform that has the highest abundance value affected by compromised health (colony/m²) at six observation sites including Kilwait (4.58 ± 0.22), Hollat (6.42 ± 0.08), Weduar (7.13 ± 0.18), Ngefuit Bawah (9.92 ± 0.36), Fako (10.46 ± 0.32), and the highest CM abundance value affected by compromised health in all observation sites were found in Ohoifau (10.63 ± 0.34).

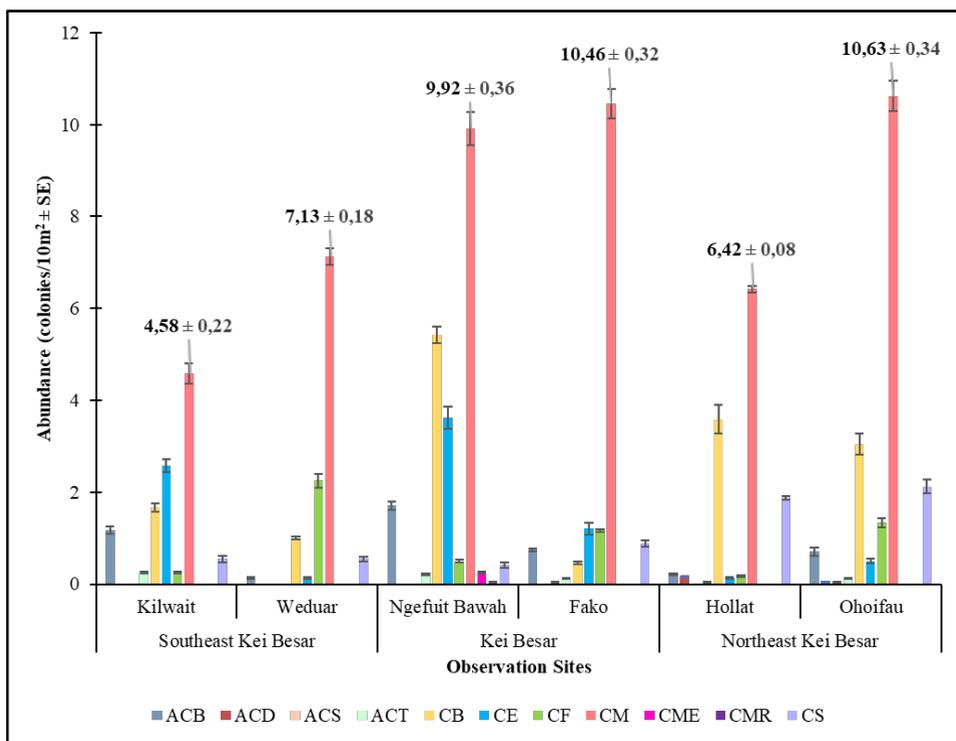


Fig. 3. The abundance of affected coral lifeforms by compromised health in the observation sites. Coral lifeforms that are affected by compromised health include *Acropora Coral Branching* (ACB), *Acropora Coral Digitate* (ACD), *Acropora Coral Submassive* (ACS), *Acropora Coral Tabulate* (ACT), *Coral Branching* (CB), *Coral Encrusting* (CE), *Coral Foliose* (CF), *Coral Massive* (CM), *Coral Millepora* (CME), *Coral Mushroom* (CMR), and *Coral Submassive* (CS).

3.2 The Abundance of Hard Coral Genera Affected by Disease and Compromised Health

In total, 19 genera of hard corals were found to be affected with coral disease. *Porites* affected with coral disease had the highest abundance value of 4.58 ± 0.09 colonies/10m². The genus of corals affected with the coral disease with the second-highest abundance, namely *Acropora* (1.29 ± 0.8 colonies/10m²) then followed by, *Favia* (0.71 ± 0.03 colonies/10m²), *Montipora* (0.54 ± 0.06 colonies/10m²), *Pocillopora* (0.54 ± 0.03 colonies/10m²), *Seriatopora* (0.38 ± 0.01 colonies/10m²), *Favites* (0.21 ± 0.03 colonies/10m²), *Stylophora* (0.17 ± 0.03 colonies/10m²), *Ctenactis* (0.13 ± 0.01 colonies/10m²), and *Goniastrea* (0.13 ± 0.01 colonies/10m²) (Figure 4). The ten genera of hard corals belong to the six coral families of the order Scleractinia including Poritidae (*Porites*), Acroporidae (*Acropora* and *Montipora*), Faviidae (*Favia*), Pocilloporidae (*Pocillopora*, *Seriatopora*, and *Stylophora*), Merulinidae (*Favites* and *Goniastrea*), and Fungiidae (*Ctenactis*).

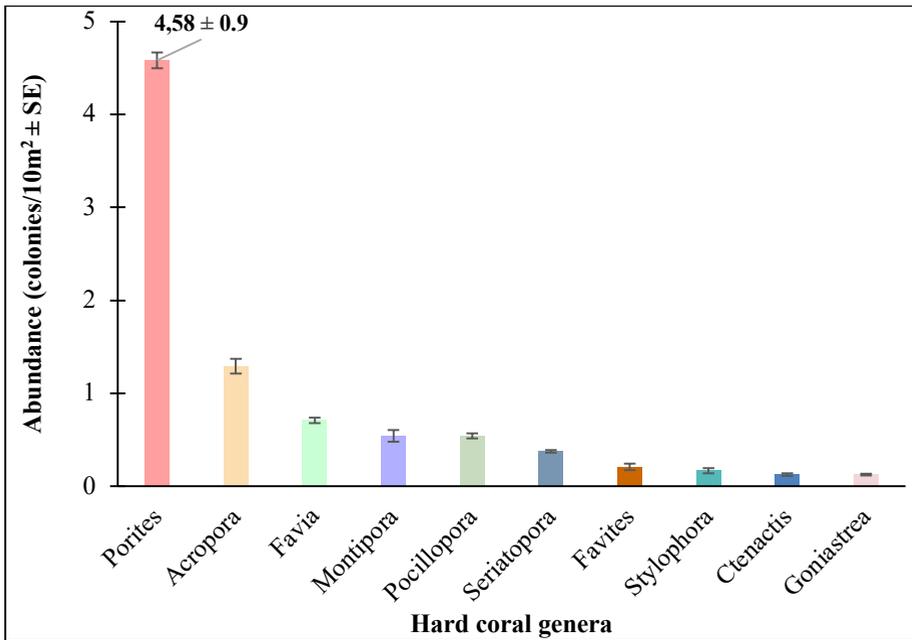


Fig. 4. The abundance of ten hard coral genera affected with coral disease with the highest abundance values.

In total, 46 genera of hard coral were found to be affected by compromised health. *Porites* affected by compromised health had the highest abundance value of 47.83 ± 0.77 colonies/10m². The genus of hard coral affected by compromised health with the second-highest abundance was *Acropora* (5.71 ± 0.23 colonies/10m²), followed by *Montipora* (5.00 ± 0.09 colonies/10m²), *Pocillopora* (4.58 ± 0.26 colonies/10m²), *Stylophora* (2.83 ± 0.16 colonies/10m²), *Favia* (2.63 ± 0.07 colonies/10m²), *Seriatopora* (2.46 ± 0.13 colonies/10m²), *Favites* (2.17 ± 0.09 colonies/10m²), *Pachyseris* (2.08 ± 0.17 colonies/10m²), and *Isopora* (1.92 ± 0.04 colonies/10m²) (Figure 5). The ten genera of hard corals belong to the six coral families of the order Scleractinia including Poritidae (*Porites*), Acroporidae (*Acropora*, *Montipora*, and *Isopora*), Pocilloporidae (*Pocillopora*, *Stylophora*, and *Seriatopora*), Faviidae (*Favia*), Merulinidae (*Favites*), and Pachyseridae (*Pachyseris*).

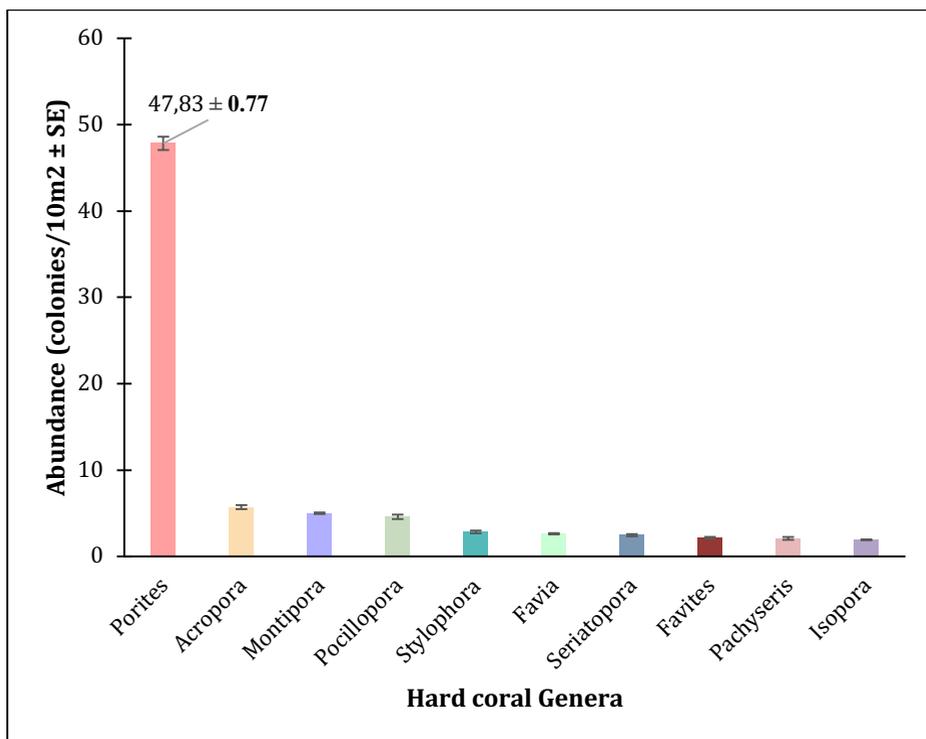


Fig. 5. The Abundance of ten hard coral genera affected by compromised health with the highest abundance value.

3.3 The Distribution of Coral Disease Types

Six types of coral disease were found which affected 224 hard coral colonies in all observation sites. The coral diseases found consisted of Atramentous Necrosis (AtN), Bleaching (BL), Enlarged Structures (ES), Focal Bleaching (FBL), Ulcerative White Spots (UWS), and White Syndromes (WS). There were differences in the number of coral disease types found at each observation site, namely at Weduar only two types of disease were found (FBL and UWS), three types of Hollat and Ohoifau (BL, FBL dan UWS), four types of Kilwait (BL, ES, FBL, and UWS), five types of Ngefuit Bawah (BL, ES, FBL, UWS, and WS), as well as the six types of coral disease were found in Fako. The abundance of coral disease at the observation sites has a smaller value than the existing compromised health. FBL was the dominant type of disease in five observation sites and had the highest abundance in Kilwait of 2.33 ± 0.02 colonies/10m². UWS was the dominant disease type in Fako with a value of 0.29 ± 0.02 colonies/10m² and the highest UWS abundance was found in Ohoifau of 0.83 ± 0.07 colonies/10m² (Figure 6). Type of coral disease FBL and UWS are two types of disease found in six observation sites.

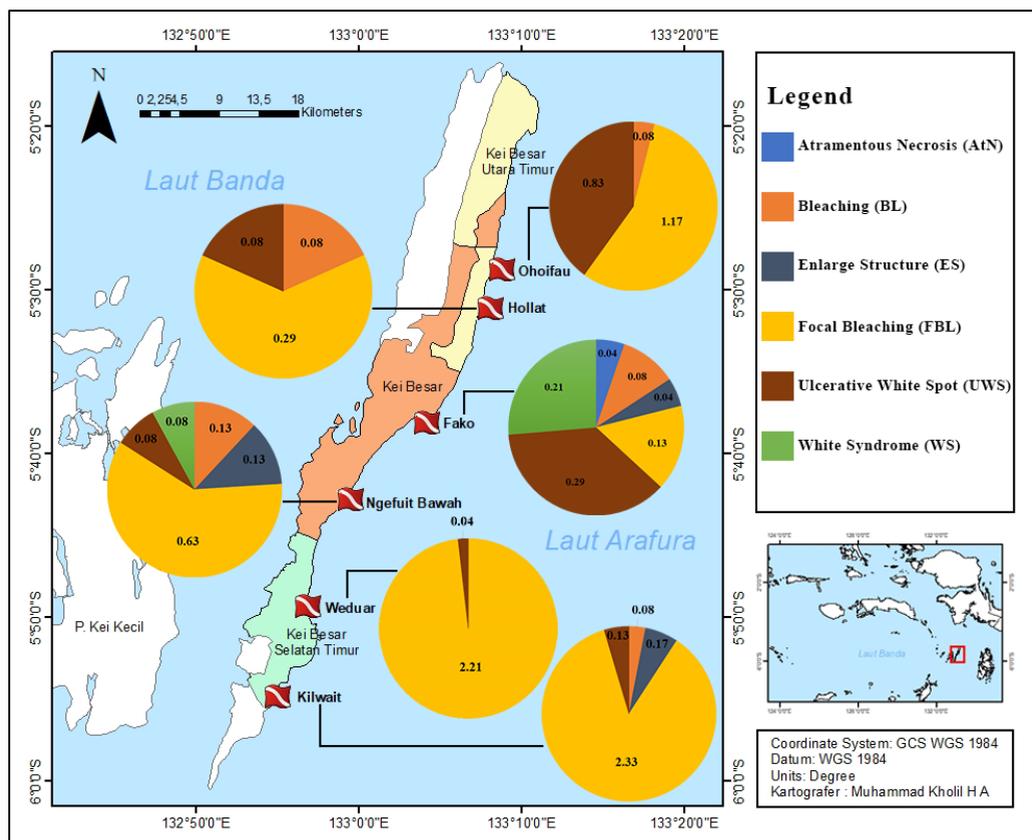


Fig. 6. The distribution of coral disease type in observation sites. The types of coral diseases found were Atramentous Necrosis (AtN), Bleaching (BL), Enlarged Structures (ES), Focal Bleaching (FBL), Ulcerative White Spots (UWS), and White Syndromes (WS).

3.4 The Distribution of Compromised Health Type

Nine types of compromised health were found which affected 2172 hard coral colonies in six observation sites. Four types of compromised health are always found from six observation sites, namely Aggressive Overgrowth (AgO), *Drupella* sp. (DRU), Invertebrate Galls (IG), and Sediment Damage (SD). Of the four types of disease, two types always had the highest abundance values in each observation site, namely SD which is dominant at five observation sites and second dominant in Kilwait (4.96 ± 0.25 colonies/10m²) and the second-highest at five other observation sites. The highest abundance value of compromised health with the SD type was found in Ohoifau of 11.42 ± 0.58 colonies/10m². Meanwhile, the highest abundance value of compromised health in IG type was found in Ngefuit Bawah of 6.71 ± 0.34 colonies/10m² (Figure 7). IG type also has the second-highest abundance in other five observation sites. AgO type has the highest-abundance in Ngefuit Bawah than other five observation sites. The compromised health of SD and IG types most commonly affected the *Porites* genus with the CM lifeform.

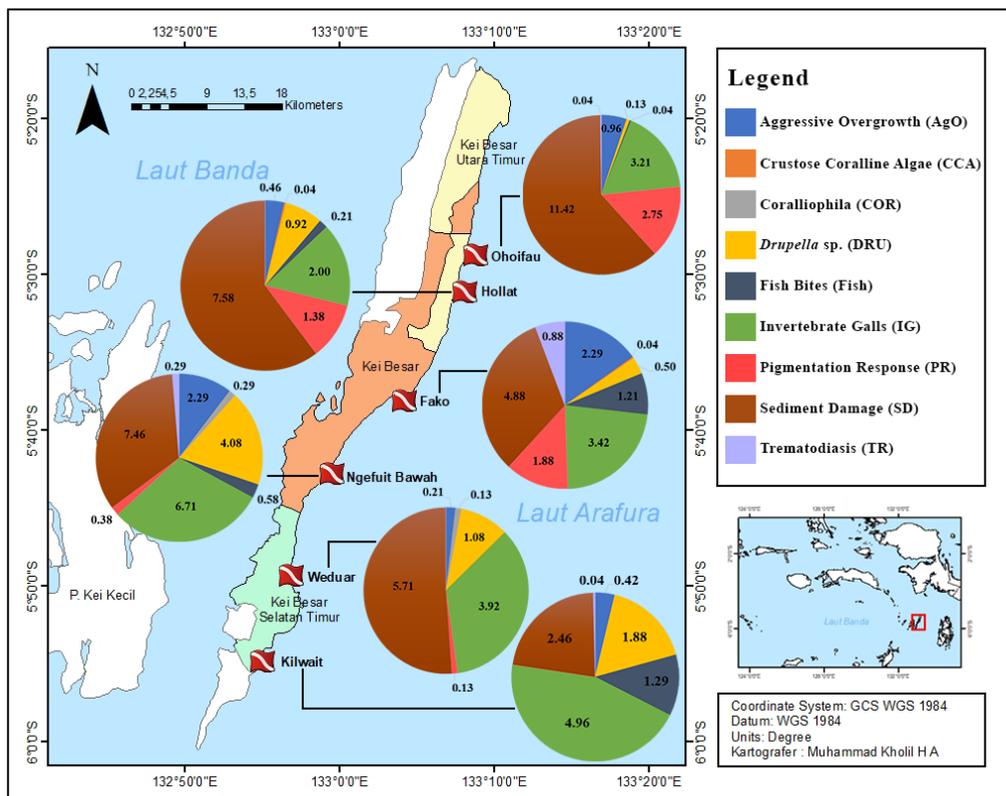


Fig. 7. The distribution of compromised health in observation sites. The types of compromised health found were Aggressive Overgrowth (AgO), Crustose Coralline Algae (CCA), Coralliophila (COR), *Drupella* sp. (DRU), Fish Bites (Fish), Invertebrate Galls (IG), Pigmentation Response (PR), Sediment Damage (SD), and Trematodiasis (TR).

4 Discussion

Morphology and behaviour of corals are among the factors influencing pathogen exposure in aquatic environments [10]. The Coral Massive (CM) lifeform is the most susceptible to coral diseases and compromised health among all the observed colony types. It also exhibits the highest abundance at each observation location (Figures 3 and 4). Larger and slower-growing forms like CM have greater tolerance to disruptive variables in disturbed ecosystems [11; 12]. Although CM colonies have greater tolerance, larger diameters that CM have are more vulnerable to disturbances from coral predators such as fish and invertebrates, as well as environmental factors like sediment [13] and algae [14]. Apart from the CM lifeform, the Coral Branching (CB) lifeform is the second most affected in terms of coral disease and compromised health. This might be due to the larger surface area of CB growth that exposed to water-borne pathogens compared to CM, increasing its potential for being affected by pathogen transmission from the water [10]. However, CB lifeform has a faster recovery rate compared to CM lifeform [15].

The families of Poritidae, Acroporidae, and Pocilloporidae were discovered to have the greatest number of colonies affected by diseases. *Porites* of the family Poritidae is the most common genus found at depths of 1-20 metres, with the distribution of one of its growth types (Coral Massive; CM) dominating in the Indo-Pacific Ocean [16; 13]. Additionally, according to the data gathered during the observation, CM *Porites* has the highest percentage of colonies that

are affected by coral diseases and compromised health. This could be due to the wide diameter of CM *Porites* which makes it easier for invertebrates and sediments to disturb. Moreover, through asexual reproduction or accretion, *Porites* can recover from disturbances quicker than any other genus [13].

Coral disease can spread across coral colonies through a direct transfer, transmission from other biotas, and transmission through waterways [10]. FBL is the most prevalent coral disease across five observation sites and has the greatest abundance value in the Kilwait site. According to [6], FBL, a type of multifocal coral bleaching that affects an entire coral colony, is a sign of the early stages of AtN and UWS diseases. FBL can be brought on by sedimentation, environmental stresses, and bacterial infections [8]. FBL may occur from the feeding behaviour of numerous fish species such as *Exallias brevis* and *Lutjanus unilineatus*, and it can also lead to multifocal bleaching lesions with living coral tissue.

The types of health problems caused by sedimentation (Sediment Damage; SD) dominate at five observation locations with the highest abundance value at the Ohoifau observation site. SD is a common and major problem that can affect the health of coral reefs [17]. The Kei Islands are located between three seas in Indonesia, namely the Halmahera, Banda, and Arafura Seas. SD can be caused by terrestrial run-off and strong currents in coastal waters [18; 17] so these two things can increase the prevalence of coral disease [19]. Contact between coral and sediment can significantly increase the incidence of coral disease symptoms such as symptoms of white plaque lumps which can remove hard coral tissue [20]. IG was one of the health problems that predominated after SD at five observation locations, with the highest abundance value at the Kilwait site. IG is a wound on coral reefs that can be caused by invertebrates. Invertebrates are benthic biota that are widely found in coral reef ecosystems and have a symbiotic relationship of mutualism, commensalism, and parasitism with coral reefs. Polychaete invertebrates are one type of invertebrates that can harm corals. However, several invertebrate species can protect corals from predators and slow down coral disease infections [17].

5 Conclusion

Six types of coral disease and nine types of compromised health were found which fall into six symptom categories. There are nine types of coral lifeforms from 19 genera affected by coral disease and eleven types of hard coral life forms from 46 genera affected by compromised health. Coral Massive *Porites* is the lifeform and genus of hard coral with the highest coral disease or compromised health abundance. CM lifeform have greater tolerance and larger diameters that CM have are more vulnerable to disturbances from coral predators such as fish and invertebrates, as well as environmental factors like sediment and algae. FBL and SD were most dominant type of coral disease and compromised health in observation sites. High abundance of sediment damage that affected coral colonies can be a notion of high abundance of FBL disease in observation sites. Kilwait is an observation location that has the highest abundance of hard coral colonies affected by the coral disease, while the Ngefuit Bawah observation location has the highest abundance of hard coral colonies affected by compromised health.

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