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LEMBAR HASIL PENILAIAN SEJAWAT SEBIDANG ATAU *PEER REVIEW* KARYA ILMIAH : JURNAL ILMIAH BEREPUTASI TERINDEK SCOPUS

Judul Jurnal Ilmiah (Artikel) : **Water quality impact to coral compromised health prevalence of prigi bay, East Java, Indonesia**

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Water quality impact to coral compromised health prevalence of Prigi Bay, East Java, Indonesia

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ABSTRACT

An epizootic of scleractinian coral became high attention by the scientist in these 3 decades. The environment factor changing altered the number of microbes in coral and compromising their health. Prigi Bay has been located in southern Java and connecting with the Indian Ocean. Many compromising health factors that are causing diseased coral such as competition (red filamentous algae, cyanobacteria, sponge, and flatworm), sedimentation damage and raising sea temperature (bleaching). The survey was conducted in 3 stations using belt transect 100 x 1 m in 7 m depth. Coral health data was obtained by underwater photography. The result showed that high cover percentage of coral was be found in station 2 (48.16%), the highest coral compromised health relevancy was 75.69% in station 3 that caused by sediment damage. The Pearson Correlation value for NO_3 was 0.520, NO_2 was 0.630 and sedimentation was 0.343. These environmental factors have a strong correlation to the compromised health prevalence.

Key words : *Sediment damage, Red filamentous algae, Cyanobacteria, Sponge, Pigmentation response*

Introduction

The coral compromises health has contributed to the declining coral cover through coral disease. Compromised health associated with water quality, such as increasing sea surface temperature, the load of nutrients and sedimentation (Nugues & Roberts, 2003). Coral compromised health is an unhealthy condition of coral that was not infectious but will leave a wound on coral that potentially damage the host. (Beeden *et al.*, 2008a) gave 5 categories of coral compromised health they were: pigmentation response, unusual bleaching patterns, competition and aggressive overgrowth by another benthic organism, sediment damage and flat infestation (Beeden *et al.*, 2008a; Raymundo *et al.*, 2008). The sediment from terrestrial suggested can bring bacteria that identified as the cause of necrosis on coral tissue (Nugues and Robert, 2003). Other biotic and abiotic factors such as chemicals, nutrient imbalances, UV radiation, predation, overgrowth, and infectious diseases are becoming the coral compro-

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mised health (Harvell *et al.,* 2007), and these factors can synergize in a reduction of coral cover (Hughes *et al.,* 2003).

The number of nutrients in the sea waters are also an indicator of environmental health. Nutrients are needed for primary productivity in the sea waters but high nutrients in sea waters such as nitrates can lead to increased algal growth (Bricker *et al.,* 2008). Nutrients also have a direct influence on corals. The higher nutrients will increase the growth of algae that can disrupt coral recruitment to cause habitat degradation (Box and Mumby, 2007). High phosphate in sea waters can affect the success rate of coral fertilization (Harrison and Ward, 2001). Nitrate is also known to affect corals by reducing the calcification rate of coral skeleton (Marubini and Davies, 1996).

The presence of sediments on surface coral colony will interfere with the coral metabolism due to coral polyps covered by sediment. The sediment damage caused by high sedimentation rates can also interfere with coral reproduction (Beeden *et al.,* 2008a). One research on *Acropora digitifera* showed that high sedimentation on corals affects the success of coral fertilization and disrupts coral larvae attachment to the substrate (Gilmour, 1999). The process of fertilization of *Acropora milepora* was also influenced by sediment (Humphrey *et al.,* 2008). Turbid sea water that contained high sediment in the water column also affects the growth rate of Porites and Acropora corals (Crabbe and Smith, 2005).

Competition among benthic species also became the coral compromised health and can affect coral colony death. The benthic competitor and became a threat of coral were sponge, flatworm, cyanobacteria and red filamentous algae (Beeden *et al.,* 2008a). The coral colonies that overgrow with algae and sponges will suffer bleaching and impact on coral mortality, while flatworms can cause loss of living tissue on corals (Beeden *et al.,* 2008a).

Coral disease prevalence indicates the number of diseased coral colonies by a number of all coral colonies in a certain area. High prevalence means high pathogen-host, changing environmental from normal condition and stress of coral by increased a surface mucopolysaccharide layer. The coral disease prevalence in the world is different but the Caribbean' s sea still become a hot spot area with the prevalence was more 20%, in Australia, Palau and East Africa less for 5% while in Philippine was 8% (Harvell *et al.,* 2007). The prevalence in Indonesia described in Lembata, West Nusa Tenggara was 40%, with the type of coral compromised health was sediment damage and competition-overgrowth (Nugues and Roberts, 2003). In East Java coral compromised health reported from nature reserve Pulau Sempu about 15%, with types of compromised health was competition and flatworm infestation (Luthfi *et al.,* 2014). North part of Indonesia, Pulau Barrang Lompo, south of Sulawesi the prevalence was lesser from another area about 6,09%. Pigmentation response was a common type of coral compromised health (Massinai *et al.,* 2012).

The Prigi Bay administratively was in Trenggalek, East Java. The coral reef was adhering in reef edge that surrounds this location such as Pulau Rembang, Pasir Putih, Pantai Damas, Umbokarno and Karang Malang (Wibowo and Adrim, 2014). Coral in Prigi Bay may under the treat due to high tourism activity, fish harbor activities and sedimentation came from the river that outfall in Prigi Bay. During preliminary research, a lot of coral rubble and high seawater turbidity be found in all stations. The purpose of this study was to determine the prevalence value of coral health disruption and the effect of environmental parameters on the prevalence of coral health problems in Prigi Bay.

Materials and Methods

Sites of Research and Surveys

Coral compromised health survey was conducted in situ at 3 stations on Prigi Bay, the locality showed in Figure 1. The coral data were collected by using a belt transect 1 x 100 m, a measuring tape (100 m

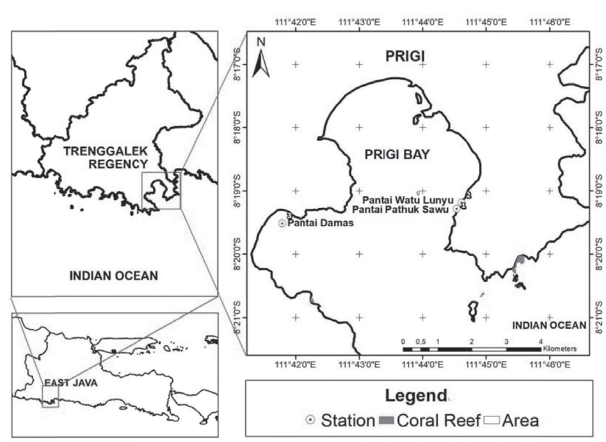

Fig. 1. Localities of stations in this study that indicated by a yellow dot in the map.

long) was laid in 3-5 m depth parallel with shoreline than a quadrat transect 1 x 1 m rolled along 100 m tape. A quadrat transects divided into 4 sub-plots 50 x 50 cm in size, scleractinian coral within sub-plot photographed using underwater camera Canon G-16 (Japan) and identified to genus (Kelley, 2009). The status health, diseased and compromised of coral colony was followed a protocol by (Beeden *et al.,* 2008b).

Water Quality Data Collection

The water quality such as salinity, turbidity, and chlorophyll-a were quantified using AAQ 1183-IF (Japan). Sea temperature and dissolved oxygen (DO) were quantified by DO Meter AZ 8403, while nitrate (NO_3), nitrite (NO_2), and phosphate (PO_4) analyzed in Marine Science Laboratory University of Brawijaya each 1 week. The sedimentation rate obtained from sediment trap made from 5 x 12 cm of PVC that laid nearby coral ecosystem and measured every 2 weeks.

Coral Cover Analysis

The coral cover was estimated from digitized images of each coral colony within sub-plot using ImageJ (NIH-USA) by calculating coral surface area of coral by total area of belt transect. To check the detail physical lesions in coral the digital image was corrected in Photoshop CS 6 to adjust contrast and the brightest of a digital image. The percent of coral cover was calculated as follows (van Woesik *et al.,* 2009; English *et al.,* 1997):

$$L = \frac{Li}{N} \times 100\% \quad .. (1)$$

Where:
L = Percentage of hard coral cover
Li = Total hard coral area in sub-plot (cm^2)
N = Total transect area (cm^2)

Prevalence of Coral Compromised Health Analysis

The prevalence of compromised health on scleractinian corals is calculated using the formula (Raymundo *et al.,* 2008), as follows:

$$P = \frac{a}{A} \times 100\% \quad .. (2)$$

Where:
P = prevalence of compromised health
a = number of compromised coral
A = total coral colony in transect

Statistical Analysis

We used correlation Pearson to analyze the effect of the environment to the prevalence of coral compromised health. The results of the analysis can be determined by looking at the value of significant if > 0.05 it means no significant influence of the independent variable to the dependent variable. The normality data was tested by the Shapiro-Wilk method if Sig > 0.05 the data were assumed normal in distribution. Statistical analysis was also performed to see the relationship between among type of compromised health of sediment damage, cyanobacteria, red filament algae, and sponge using Spearman rank correlation two-tailed if the value of sig or p-value <0.05 means the variable has a significant correlation.

Results and Discussion

Live Coral Cover And Its Composition

The total number of scleractinian coral was surveyed were 5,057 colonies that came from 10 families and 19 genera (Table 1). Acroporids coral was dominated in all stations where the highest number of those colonies were in station 3. Other dominant corals are massive and branching Poritids where found nearby Acroporiids colonies. The dominant Acroporids coral was genus Montipora that has faster growth rate than other coral and also this type of coral is one of successful scleractinian that can make a good adaptation in the shallow water area, high water turbulence and high level of light (Gomez *et al.,* 2011). Montipora also called a pioneer that has long live planulae (Veron, 2000; Luthfi, 2009). Porites has slower skeleton extension rate than Acroporids coral, 1.5 cm/yr. Not like fast-growing coral, Porites has the ability to live in high sedimentation water (Lough and Barnes, 2000).

Figure 2 showed the percentage of coral life coverage in 3 stations, the highest was found in station 2 (48.16%). The percentage of life cover in station 1 and 3 were 32.84% and 39.52% respectively. The coral cover in Prigi Bay categorized as a good condition (Gomez and Yap, 1988), while in general coral coverage has been divided into 4 categories as poor (0-25%), medium (26-50%), good (27-75%) and very good (76-100%). High domination scleractinian coral in substrate shown the healthy condition of coral reef, where thousands of marine creatures are

Table 1. Scleractinians coral in Prigi Bay

No.	Family	Genus	Station 1	Station 2	Station 3
1	Acroporidae	*Acropora*	29	4	6
		Montipora	888	706	1648
2	Agariciidae	*Pavona*	0	1	75
3	Dendrophylliidae	*Turbinaria*	1	0	4
4	Faviidae	*Coelastrea*	284	13	235
		Cyphastrea	0	0	153
		Favia	3	0	8
		Favites	23	3	366
		Leptastrea	0	1	8
5	Fungiidae	*Fungia*	4	1	1
		Sandalolitha	0	1	0
6	Merulinidae	*Merulina*	0	0	3
		Hydnopora	0	1	15
7	Mussidae	*Lobophyllia*	0	0	1
8	Oculinidae	*Galaxea*	2	0	19
9	Pocilloporidae	*Pocillopora*	1	0	1
10	Poritidae	*Porites*	18	85	444
Total	10	17	1254	816	2987

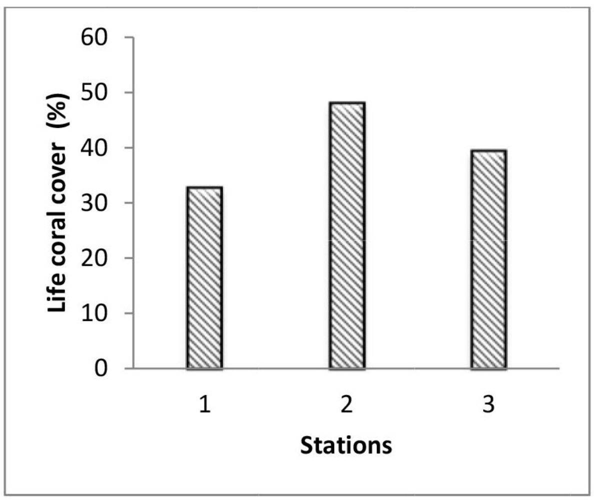

Fig. 2. Coral cover in all stations at Prigi Bay

reef dependence (Vroom, 2011).

Coral cover in station 3 is lower than station 2 even though the number of colonies in this station is triple than station 2. Two explanations for this problem first from analyzing of photo transects in both stations, the size coral colonies in station 3 are smaller than station 2 that was resulted in a high number of the colony but lower in coral cover percentage. Second, naturally, the upper area of station 3 is mangrove forest that load high sedimentation during the rainy season or mixed of mangrove substrate during high tide and increasing suspended particle in sea water. Coral growth influenced by environmental factors such as water clarity, sedimentation, salinity, and sea temperature. High sedimentation will effect on coral lower growth rate coral Acropora and non-Acropora, change the coral morphology and in long term will influence coral diversity and their abundance (Crabbe and Smith, 2005). Dominance Montipora branching and foliose in station 2 and 3 suggested that both genera were well adapted in high turbid water.

Compromised Health

The result of this survey showed that 5 types of coral compromised health, sediment damage (CH-SD), competition with sponge (CH-SP), competition with cyanobacteria (CH-CY), red filamentous algae (CH-RFA) and pigmentation response (CH-PR) or others stated as tissue discoloration (TD-PR). Sediment damage was dominant in station 1-3, their prevalence was 80.34%, 84.44% and 93.69% (Figure 4). Competition with the sponge was higher in station 2 (4.89%) than the other. Red filamentous algae and pigmentation response were high prevalence in station 1 (7.25% and 8.59%). The competition red filamentous algae in station 2 were 6.52% higher than station 3 that only 1.89%.

Sediment and eutrophication have become a global threat for the coral reef in the world (Wesseling *et al.*, 1999; Victor *et al.*, 2006; Weber *et al.*, 2012). After and during the rainy season the sediment from terrestrial carried out into the sea and settle into the surface of coral that can bleach or kill the coral's tissue. A large amount of sediment in the water column also reduce the light needed by zooxanthellae for photosynthesis. Sediments also enrich with organic material such as fecal pellets, detritus and microorganism (Weber *et al.,* 2012). The coral mortality by sediment was an indirect process, sediment that rich with organic matters lead a microbial consumed lot of oxygen from the coral a make it anoxia and make the environment of coral acid that causing of coral death within half until two days (Weber *et al.,* 2012).

Competition on space that becomes compromised health to coral is caused by sponge, in this location sponge active aggregate and colonize the healthy coral (Figure 3a). The excavating sponge from Clionidae has been reported to be the strongest competitors for coral and became abundant in the Caribbean sea (Rützler, 2002; ChavesFonnegra and Zea, 2011). The sponge has the ability to displace coral live tissue within 1-4 days using chemicals compound called clionapyrrolidine A and N-acetylhomoagmatine. Those of kind chemicals were produced by Cliona sponge during direct contact with coral (ChavesFonnegra and Zea, 2011). The compromised health was also coming from red filamentous alga (RFA) (Figure 3c). The prevalence of this competition was 7.25, 6.52 and 1.88 in station 1,2 and 3. RFA colonized massive Porites coral in the top of the colony in many form pattern. Algae may from *Anotrichium tenue* and some of the mixed turf algae. *A tenue* reported has an aggressive way to kill and overgrowth directly on coral rather than tissue damage or coral stress (Jompa and McCook, 2003).

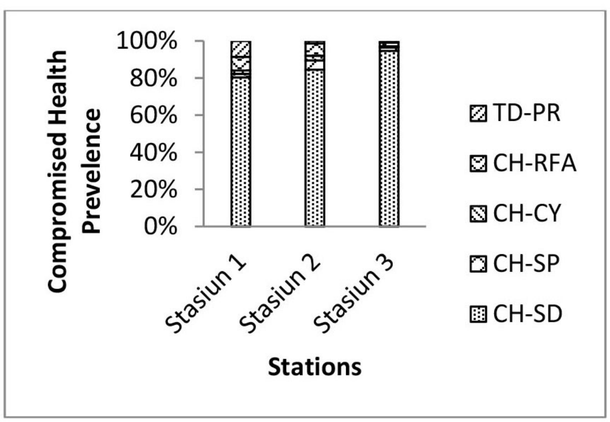

Fig. 3. The composition of Compromised Health in all stations

Individual regression using Spearman rank, as shown in Table 2, showed that sediment damage has a positive correlation with red filamentous algae (correlation value 1), and had a strong correlation with sponge. While sediment damage vs cyanobacteria and sediment damage vs pigmentation response have no significant correlation (sig > 0.05). Red filamentous algae such as *A. tenue* was abundance in coral mucus and sediment, they can present in underneath of sediment and accelerate coral tissue lysis along with sediment (Jompa and McCook, 2003). Algae, in general, have a role to accumulate sediment preventing them from resuspension in the water column and enhance the overgrowth of another benthic biota such as coral (Birrell *et al.,* 2005). Sponge has good adaptation behavior into turbid water, higher abundance and species richness were found in high-level sediment in North East Atlantic (Bell *et al.,* 2015). A large number of sponges in the turbid area or in high sedimentation site suggested that sponge has a passive adaptation in change their morphological and structural modification. Others sponge (*Oceanapia oleracea* and *O. peltata*) develop tube-like siphons to continue suck water under complete burial sediment (Bell *et al.,* 2015).

Prevalence of Coral Compromised Health

All coral compromised health prevalence in all stations was shown in Figure 5, where the highest prevalence was found in station 3 (75.69%). Variation value of compromised health prevalence on scleractinian coral has been shown in many West Pacific area such as at Koh Tao, Thailand was 32.3%

Table 2. Results of correlations statistical analysis between types of coral compromised health

			CH_SD	CH_SP	CH_CY	CH_RFA	CH_PR
Spearman's rho	CH_SD	Correlation	1.000	1.000**	.500	1.000**	-.500
	Sig. (2-tailed)	Coefficient	.	.	.667	.	.667
		N	3	3	3	3	3

**. Correlation is significant at the 0.01 level (2-tailed).

(Lamb, 2013), Sempu Island, Indonesia was 15.24% (Luthfi *et al.*, 2014), Lembata island, East Nusa Tenggara was 56.67% (Abrar *et al.*, 2012), and at Barrang Lompo, South Sulawesi was 6.09% (Massinai *et al.*, 2012). And if the percentage of prevalence is more than 10%, it was categorized as high prevalence (Ruiz-moreno *et al.*, 2012). In this research, the average of compromised health in Prigi Bay was 60.34% that was dominated by sedimentation (Figure 4). Sedimentation came from a terrestrial area where was disembogues into the Prigi Bay.

A research was conducted at Western Australia shows how sedimentation and turbidity have an influence on coral diseases that high sedimentation can have a doubling effect in coral disease prevalence (Turley, 2016), also decreasing water quality combine with sedimentation can have a direct impact on coral mortality (Fabricius, 2005). High nutrient loaded into sea water also support the coral

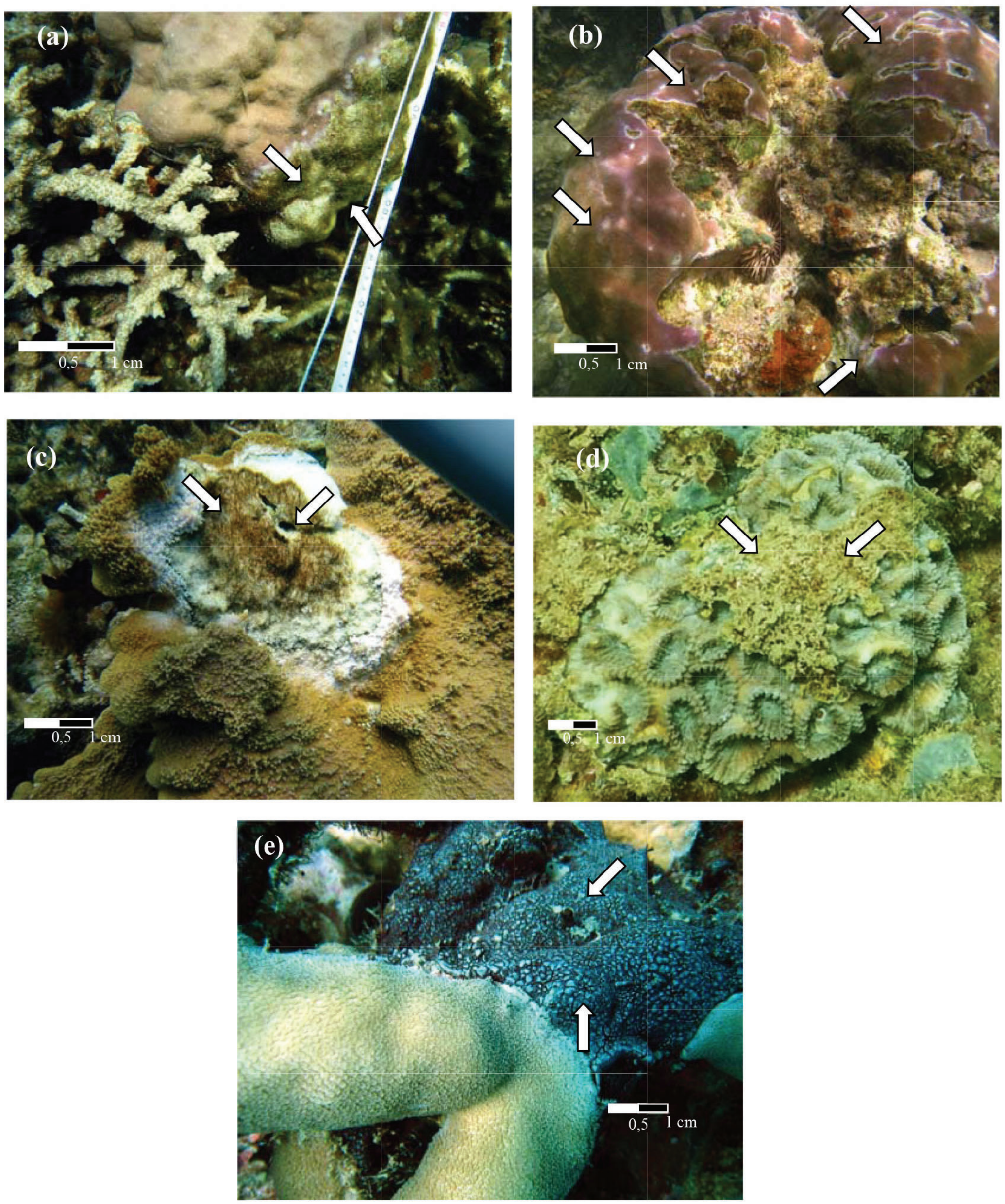

Fig. 4. Types of coral compromised health (CH): (a) Cyanobacteria, (b) Pigmentation Response, (c) Red Filamentous Algae, (d) Sediment Damage, (e) Sponge.

Table 3. Results of statistical analysis of the correlation between aquatic parameters and prevalence of compromised health

	Prev.	Temp.	Tur.	Sal.	pH	DO	Chlo.	NO_3	NO_2	PO_4	Sed.
Prevalensi-	1	.059	.250	.025	-.319	.207	.311	.520**	.630**	.221	.343*
Pearson		.386	.105	.452	.053	.151	.057	.003	.000	.133	.040
Correlation	27	27	27	27	27	27	27	27	27	27	27
Sig. (1-tailed) N											

Prev.: Prevalence; Temp.: Temperature; Tur.: Turbidity; Sal.: Salinity; Chlo.: Chlorophyll-a; Sed.: Sedimentation**. Correlation is significant at the 0.01 level (1-tailed).*. Correlation is significant at the 0.05 level (1-tailed).

competitor such as algae and sponge that was associated with a coral cover decrease (Rogers and Miller, 2006). Poor water quality can affect coral susceptibility by facilitating host-pathogen interactions. Increased prevalence of coral disease is also associated with eutrophication and sedimentation (Bruno *et al.,* 2003; Kaczmarsky *et al.,* 2005).

The compromised health prevalence on coral is also influenced by the number of coral genera that are susceptible to environmental conditions. In station was dominated by Porites from the family Poritidae and Montipora from the family Acroporidae that both of those genera was the most vulnerable genus (Couch *et al.,* 2014). Porites are a genus of coral that can host many lesions and disorders, and are most affected (Raymundo *et al.,* 2005). Nearly close to 90% of all studies on diseases and compromised health (bleaching and other pigment changes, predation, and competition overgrowth) carried out are from the family Acroporidae and Poritidae (Page *et al.,* 2009).

Correlation Between Water Quality and Prevalence of Coral Compromised Health

The Pearson correlation test in Table 3 was conducted to find the effect of environmental parameters on compromised health prevalence. The results of the normality test using the Shapiro-Wilk method showed data were normally distributed (Sig> 0.05). Pearson correlation test produced a significant value of <0.05 for the parameters NO_3, NO_2, and sedimentation rates. The correlation value obtained from the Pearson Correlation test is $R = 0.520$ for NO_3, $R = 0.630$ for NO_2, and $R = 0.343$ for the sedimentation rate. Correlation coefficient shows the parameters of nitrate, nitrite, and sedimentation rate are strongly correlated with prevalence values.

The Pearson correlation test has been done to find out the effect of environmental parameters on the compromised health prevalence showed that nitrate, nitrite, and sedimentation rates are positively correlated with prevalence values. Sedimentation related to turbidity has an influence on coral diseases and health problems even areas with high sedimentation can have a prevalence of up to twice (Turley, 2016). Decreasing water quality can worsen coral health and sedimentation can have a direct impact on coral mortality (Fabricius, 2005). Sedimentation is one of the most common disorders found in areas with high sedimentation (Turley, 2016). The entry of nutrients into seawater can support the growth of coral algae and is associated with a decrease in the number of herbivores (Hughes *et al*., 2003; Rogers and Miller, 2006). Increased prevalence of coral disease is also associated with eutrophication and sedimentation (Bruno *et al.*, 2003; Kaczmarsky *et al.,* 2005).

Conclusion

High compromised health of scleractinian coral (60.34%) in Prigi Bay may response from environmental factors such as nitrite, nitrate, and sedimentation. Various lesions in the surface of the coral colony that became epizootic on sediment damage (SD), sponge (SP), cyanobacteria (CY), red filament algae (RFA), and pigmentation response (PR). As a utilization zone, coral on this area may threat affected on coral diseases and stress so inhabit their growth and coral abundance in the future.

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