International Journal of Innovation, Creativity and Change. www.ijicc.net
Volume 15, Issue 9, 2021

Comparison Structure of Life-Form Hard Corals at Aquaculture and Non-Aquaculture Sites as Biomonitoring at Karimunjawa Islands, Indonesia

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This study on hard coral life-forms in relation to anthropogenic activities was carried at the marine utilization zone near Menjangan Besar, Karimunjawa Islands National Park, Central Java, during July 2019. The goal was to assess the structure of corals at aquaculture and non-aquaculture coastal areas of Menjangan Besar Island. Sampling was carried out using the Line Intercept Transect (LIT) method at two underwater aquaculture stations at 10 m deep. The coordinates of Station I (Aquaculture) and Station II (Non-Aquaculture Waters) were 5° 52'54,3 "LS 110° 25'41.29" EL and 5° 52'26,22 "LS 110° 25'12,10 "BT respectively. The coral classification was based on the form of growth (life-form). Observations were made with tools in the form of a SCUBA set and a 50 m transect tape stretched over the coral reef cover. The transect position was parallel to the shoreline on the left side of the transect and was at a constant depth. The observation data of coral cover were analyzed using the in situ proportion approach to live coral cover. The biotic cover of coral reefs at Station I was dominated by Dead Coral with Algae (37.5%), Non-Acropora Foliose (30.5%), Acropora Branching (12.2%), Non-Acropora Encrusting (11.0%). Meanwhile, the diversity of coral reef biotic cover at Station II was dominated by Non-Acropora Foliose (17.3%), Acropora Branching (19.2%), Acropora Encrusting (13.2%), and Acropora Digitate (16.0%). Life-form corals found in the non-aquaculture site were slightly higher when those in the aquaculture siteThe ordinates on the PCA-graph of environmental conditions of the aquaculture and non-aquaculture zone are discussed. Further analysis indicated that soluble phosphate concentration and water clarity (p=0.771, BIOENV) as the strongest abiotic factors influencing the abundance of life-form corals.

Key words: *Life-form hard corals, Karimunjawa Islands, biomonitoring, aquaculture site, Non-aquaculture site, Water clarity, phosphate.*

INTRODUCTION

Karimunjawa National Park, Jepara Regency is one of the seven marine national parks and 51 national parks in Indonesia. It is officially under the management of the Karimunjawa National Park Agency (BTNKJ). Located in the north of the island of Java, Karimunjawa National Park has an area of 111,625.0 ha, covering 22 islands with a total area of 507.7 ha and waters covering 110,117.30 ha. Due to numerous non-conservative activities in the area, the entire Karimunjawa National Park area has been divided according to five zones, one of them is the utilization zone, that aquaculture, tourism, and catch fisheries are permitted (Balai TNKJ, 2004). The Karimunjawa Islands have long been a populated area with various activities in various sectors. Mariculture/aquaculture is one of the main supporting sectors for the life of the local community. The abundance of biodiversity both on land and waters of Karimunjawa prompted the government through the Minister of Forestry to legalize Karimunjawa's status as a national park in 2001. Since then, all activities that are usually carried out in Karimunjawa should follow various regulations.

The main highlight of Karimunjawa National Park regarding conservation is the underwater ecosystem. Coral reefs play a major role in the survival of the underwater biota of Karimunjawa waters (MDI TNKJ, 2018). Coral growth has a certain pattern with various forms, or commonly referred to as life-forms. The majority of corals that dominate the seabed belong to the phylum Scleractinia or stony corals. Coral reefs have valuable ecosystem services and play an important role in the marine ecosystem as they provide shelter and spawning grounds for a wide range of ocean life. They maintain carbon dioxide at a natural balance level, and they may protect the environment, especially shorelines, from strong ocean currents and high waves (Kelley, 2009; Rosset *et al*, 2017). Several studies on coral reef community at Karimunjawa National Park have been reported (Edinger *et al*, 1998; Yusuf, 2013; Sulisyati *et al*, 2014, Nadia *et al*, 2018; Ariyani & Kismartini, 2018; Kusuma *et al,* 2018; Akhmad *et al*, 2018; Kennedy *et al*, 2020; Prasetya *et al*, 2020). However, only a few studies focused on the impact of anthropogenic activities on coral life-forms, especially aquaculture/mariculture. Most of the references focused on the tourist activities and other resources, such as coral fish (Sulisyati *et al*, 2014; Nadia *et al*, 2018; Yusuf, 2013), the impact of the increase in the number of tourists and snorkeling activity on coral cover and the carrying capacity of marine tourism (Prasetya *et al*, 2020; Akhmad *et al*, 2018). Sulisyati *et al* (2014) related to the diversity of coral fish associated with coral reef diversity at tourist utilization zone of Karimunjawa National Park, 18 families of fish from shallow to deep water were observed inhabiting various coral diversity, suggesting that ecotourism utilization zone required good management depending on the diversity of both corals and coral reef fish communities as a tourist attraction.

In general, the main factors that limit coral reef development may include water temperature, salinity, depth, light, and sedimentation. These factors can be influenced by climate change and a range of anthropogenic pressures (Hoegh-Guldberg *et al*, 2007; Hughes *et al*, 2007). Thus, nutrient environment plays a defining role in determining coral reef resilience (D'Angelo and Wiedenmann, 2014; Brodie *et al*, 2012), especially dissolved inorganic nitrogen to phosphorus. The N:P ratio in the marine environment may have an important role in photosynthetic primary production by the availability of nitrogen or phosphorus (Rosset *et al*, 2017). The waters around Menjangan Besar island, Karimun Jawa Islands, are the scope of this study, where there is a growing coral reef population. However, the relationship between the diversity of life-form hard corals community and water and sediment quality is not clearly understood. This study was conducted to compare the structure of this coral reef community with several objectives, *i.e.* to determine the differences in species diversity in coral reef ecosystems in the marine cultivation and non-aquaculture site of Menjangan Besar Island, Karimun Jawa Islands.

METHODS

Sampling sites and procedures

This study was carried out in June 2019, located at a marine ecosystem near Menjangan Besar Island, Karimunjawa National Park, Jepara Regency. Before carrying out data collection, appropriate locations were selected based on the aims of the study. The coordinates of the sampling activity stations were located at two underwater stations with a depth of 10 m, representing aquaculture and non-aquaculture water zones. The coordinates were marked after a surface survey to select a representative location, i.e., Station I (aquaculture site) at 5°52'54,3"SL,110° 25'41.29" EL, and Station II (Non-aquaculture site) at 5 ° 52'26,22 "SL 110 ° 25 '12, 10 "EL, as shown in **Fig. 1.**

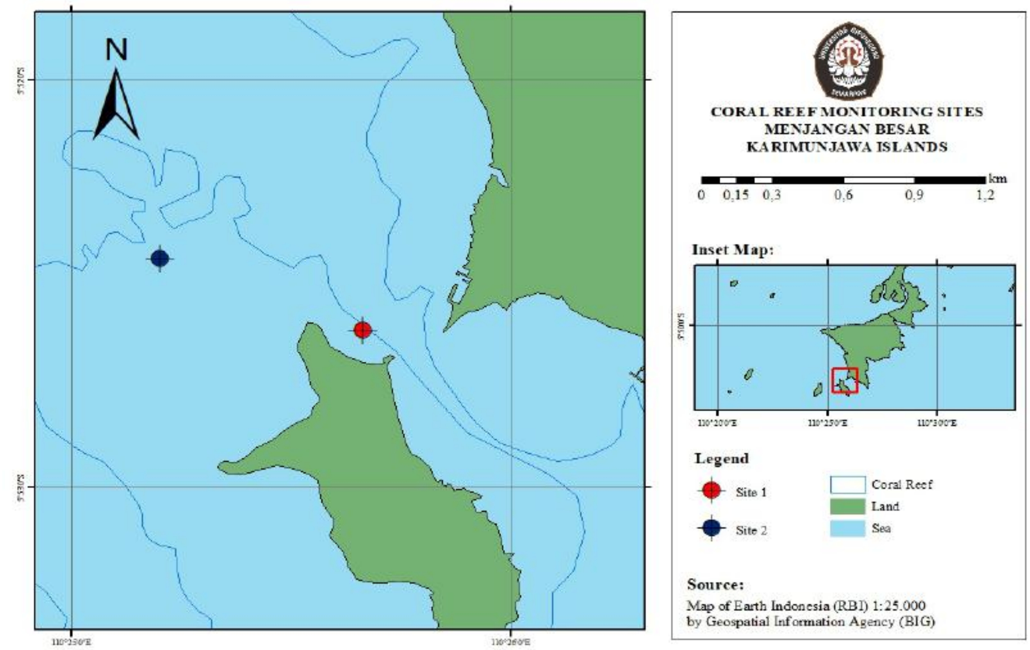

Figure 1. Map of the coordinates of the sampling sites located at water ecosystem close to Menjangan Besar Island, Karimunjawa National Park, Jepara Regency.
Notes: Site 1= Station I (Aquaculture site); Site 2= Station II (Non-aquaculture site)

Field sampling was done by taking primary data in the form of coral populations using the Line Intercept Transect (LIT) method. This method is commonly used to describe the structure of coral reef communities by looking at the cover of live corals, dead corals, algae, and other types of substrates and biota (English *et al*, 1994). Observations were made with tools in the form of a SCUBA set and a 50 m transect tape stretched over the coral reef cover. The transect position is parallel to the shoreline on the left side of the transect and is at a constant depth. The Underwater Photo Transect (UPT) method was used for coral reef surveys according to the Coral Reef Health Monitoring Guidelines (Giyanto *et al*, 2015). Photographs were taken along coral reef cover at a depth of 10 m. The location of the second transect was determined randomly. The interval for taking photos was 1 m starting from the starting point so that in one station, 2 × 25 photos of the substrate were obtained. The classification of corals used is based on their form of growth (life-form). Coral reefs as the main object in this study were categorized in the form of hard corals which were divided into two categories, Acropora and non-Acropora and algae that grew on dead corals, or dead corals with algae (Colin & Arneson, 1995; Kelley, 2009). The abiotic parameters of waters and sediments included soluble nitrates and phosphates concentration, salinity, DO, temperature, TDS, water clarity, water current, as well as substrate grain composition.

Data analysis

The results of coral reef cover observations as primary data were recapitulated in tabulated form. The recapitulation data was then analyzed using the percentage of live coral cover in the coral reef ecosystem determined by the following formula (Saputra, 2015):

$$ni = \frac{li}{L} \times 100\%$$

where: *ni* = percentage of coral cover of the *i* (%),
li = Length of coral life-form type of the *i* (cm), and
L = total length of transect (cm).

Referring to the Decree of the Minister of Environment No. 4 of 2001, the percentage categories of coral reefs are shown in **Table 1.**

Table 1. The criteria of live coral as percentiles, as per the Decree of the Minister of Environment of Indonesian Government No. 4, 2001.

% cover of live corals	Criteria
0–24.9	Heavy Damage
25–49.9	Moderately Damaged
50–74.9	Good
75–100	Very Good

The degree of correlations between physical-chemical water and sediment properties and the abundance of life-form corals were analyzed using BIO-ENV (Primer 6.1.5). The raw biotic data of 13 variables were transformed using log (X+1) and then were tested using the similarity to have the Bray Curtis matrix. A square root transformation was applied to the chemical-physical water and sediment quality as abiotic data. The result of the transformation in the first normalization was then analyzed using Euclidean distance of resemblance measure and stepwise Spearman rank correlation method to measure the most abiotic factors influencing the structure of life-form corals as a biotic factor. Furthermore, the distance matrix using Euclidean Distance was used to perform 2-dimensional Principal Component Analysis (PCA). The circle projected onto the ordination diagram was displayed to estimate the importance of individual of 13 abiotic variables. The radius is calculated as √(d/p), where d is the number of displayed PCA axes (d=2) and p is the number of 13 variables. The descriptor with a vector of the same length as the circle radius contributes equally to all axes in PCA, whilst vectors extending the circle radius make a higher contribution than average to the current display.

RESULTS AND DISCUSSION

Composition of Coral Cover: aquaculture versus non-aquaculture sites

Based on observations at two stations, both aquaculture and non-aquaculture sites, there are various types of coral cover. The biotic coral cover observed was in the form of hard corals which were divided into two categories, Acropora and non-Acropora, and algae that grew on dead corals, or dead corals with algae. Apart from hard corals, several segments were also covered with soft corals.

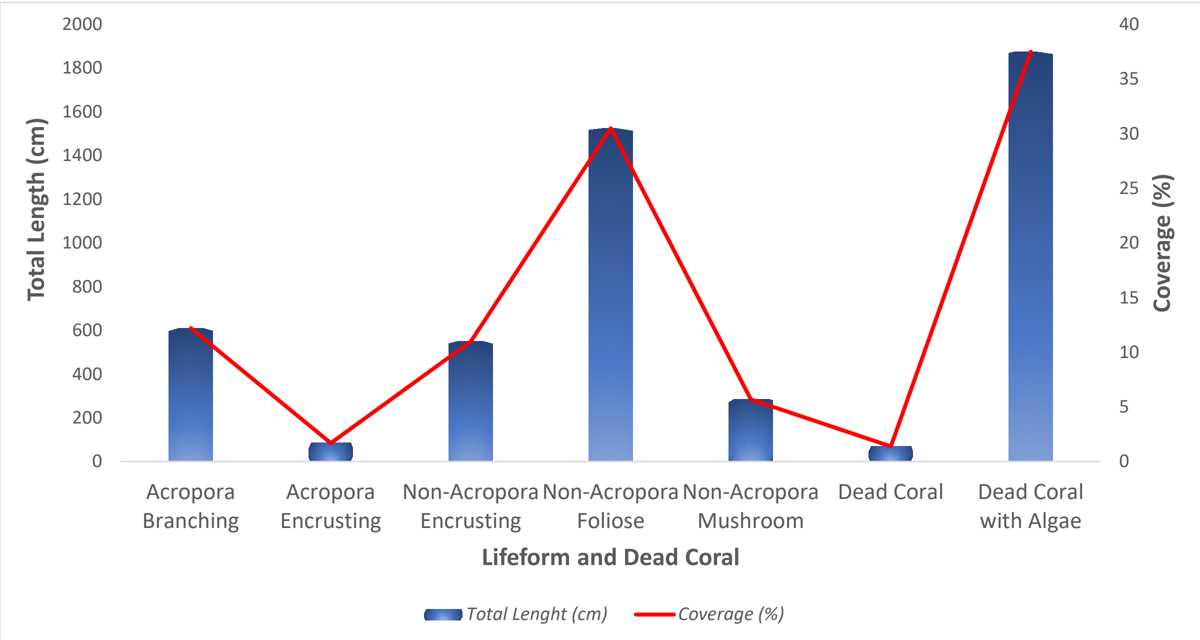

Figure 2. The biotic coverage of coral reefs in total length (cm) and coverage (%) at the aquaculture site (Station I).

Meanwhile, the abiotic cover composition of the two stations consisted of several segments of dead coral. The biotic coverage of coral reefs in the aquaculture site (Station I), live corals in the forms of non-Acropora foliose, Acropora branching, non-Acropora encrusting, non-Acropora mushroom, and Acropora encrusting were found, with the highest proportion of non-Acropora foliose (30.5%), as shown on **Fig. 2**. The composition of live corals was double compared to dead coral, as shown in Table 2.

Table 2. The proportion of live and dead corals in the forms of the total length of transect and percentage at Station I.

Population	Total Length of Transect (cm)	Percentage (%)
Live Coral	3,725	61.1
Dead Coral	1,945	38.9

On the other hand, the diversity of life-form corals at Station II consists of Non-Acropora Foliose, Acropora Branching, Acropora Encrusting, but Non-Acropora Encrusting and Non-Acropora Mushroom were not found, as they were present at Station I. Life-form Acropora branching was dominated (19.2%).

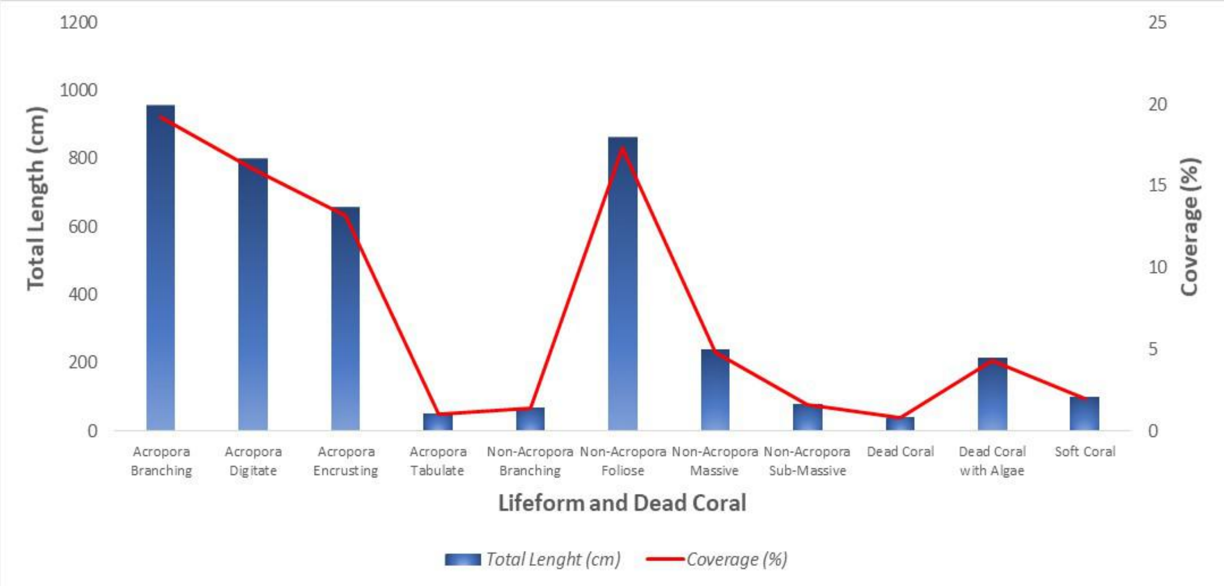

Figure 3. The biotic coverage of coral reefs in total length (cm) and coverage (%) at the Non-aquaculture site (Station II).

Other life-form corals found at this station were Acropora Digitate, Acropora Tabulate, Non-Acropora Massive, Non-Acropora Submassive, and Soft Coral, with the proportion as shown in Figure 3. In general, the composition of the cover of life-form corals was three times more than dead corals, as shown in Table 3. As seen on the Fig. 2 and Fig. 3, life-form corals found at the non-aquaculture site are slightly higher when they compared to the aquaculture site. This may be due to fish farming practices which involve overfeeding the cultured biota which results in deposition of unfed pellets into the sediment.

Table 3. The proportion of life and dead corals in the forms of total length of transect and percentage at Station I.

Population	Total Length of Transect (cm)	Percentage (%)
Life Coral	3,055	76.5
Dead Coral	1,945	23.5

Organic matter that dissolves during activities can also reduce the clarity of the water, which can affect the composition and vitality of the coral community. It has been reported that organically rich sediments underneath farm facilities and the consequent depletion of oxygen in the sediment pore water resulted in changes in infaunal assemblages, in particular, polychaetes exhibited differences both in number of taxa and abundance between the farm and reference site (Putro *et al*, 2020; Putro, 2010). However, further study on physical-chemical water and sediment properties to coral reef may need to be carried out, considering many other factors may contribute to the coral community.

Figure 4. External anatomy of dominant life-form corals at sampling sites of Karimunjawa's marine ecosystem. (A) *Acropora* sp. (Scleractinia: Acropodiidae); (B) *Pachyseris* sp. (Scleractinia: Agaricidae); (C) *Favia* s (Scleractinia: Faviidae): (D) Foliose coral *Montipora* sp. (Scleractinia: Acropodiidae).

Sulisyati *et al* (2019) wrote that the zoning system is the main part of the management of the Karimunjawa National Park (TNKJ) area. During its time as a national park, TNKJ has undergone revisions in 2005 and 2010. The last revisions were made in 2012 and approved by Decree of the Director-General of PHKA No. 29 / IV-SET / 2012. The final result of the revision divides the entire Karimunjawa area into several zones, one of which is the mariculture zone, including Menjangan Besar Island.

Based on data of life-form hard corals collected at both sampling areas, we found some dominant life-form corals at sampling sites of Karimunjawa's marine ecosystem, i.e., *Acropora* sp. (Scleractinia: Acropodiidae), *Pachyseris* sp. (Scleractinia: Agaricidae), *Favia* sp. (Scleractinia: Faviidae), Foliose coral *Montipora* sp. (Scleractinia: Acropodiidae). *Acropora* is a genus of small polyp stony coral known as table coral, elkhorn coral, and staghorn coral. *Acropora* species are some of the major reef corals responsible for building the immense calcium carbonate substructure that supports the thin living skin of a reef. This genus is usually highly susceptible to bleaching and disease, with an individual's low ability to recover from environmental stressors (Loya *et al*, 2001). *Favia* is a genus of reef-building stony corals in the family Muscidae. Members of the genus are massive or thickly encrusting colonial corals, either dome-shaped or flat, and a few are foliaceous. It has been reported that high flow, low light, and the presence of planktonic prey induce expansion of stony coral *Favia favus* after being exposed to different flow speeds and levels of light. Under conditions of high light, expansion may lead to a decrease in overall photosynthetic rate and an increase in coral metabolic rate, resulting in a net loss of energy. However, these results may not be applied to high algal density-corals that would benefit from expansion when light levels are high (Levy *et al*, 2001).

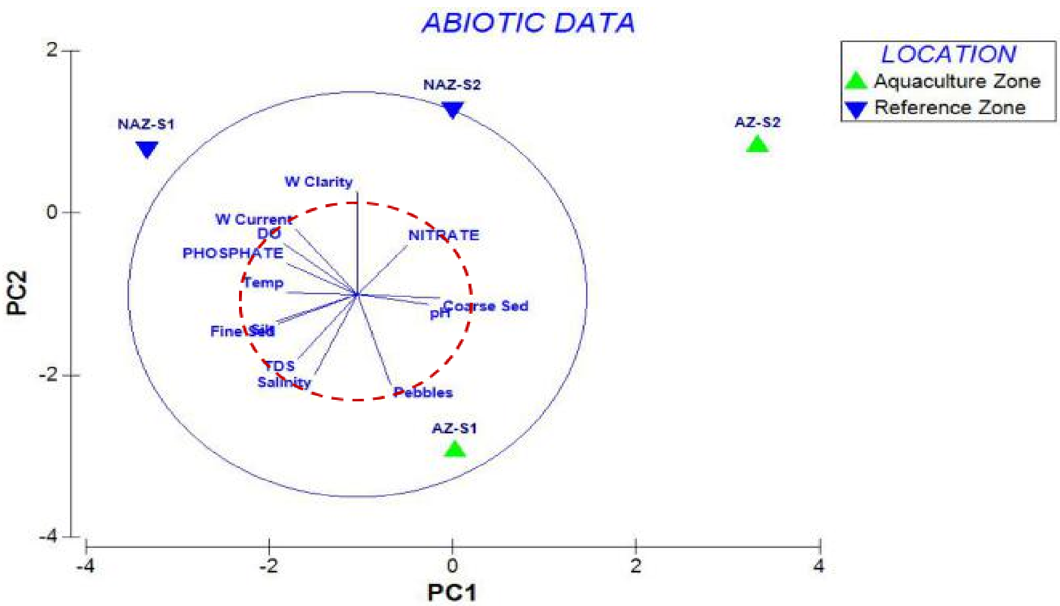

Figure 2. Graph of 2-dimensional Principal Component Analysis (PCA) to estimate the importance of individual of 13 abiotic variables influencing the position of each station on the ordinates, comparing aquaculture site and non-aquaculture site (reference zone).

The PCA-graph of environmental conditions in the non-aquaculture/reference zone and aquaculture zone was made using Euclidean Distance Index equations. As shown in Figure 2, the ordinates of the non-aquaculture/reference zone are more likely influenced mainly by water clarity, water current, DO, and phosphate, whilst the aquaculture site's ordinates are influenced mostly by sediment grain size (pebbles) and TDS, and salinity. Further analysis using BIO-ENV (Primer 6.1.5 software) was done to assess the relationship between the biotic and abiotic components of the sampling locations, as seen in Table 2.
Table 2 shows the highest correlation value of the abiotic factors that have the strongest influence on the abundance of live corals were soluble phosphate concentration and water clarity (p=0.771). This indicates that these two environmental factors are factors that may determine the fertility and vitality of coral reefs concerning the availability of adequate light and food sources, especially phosphate to support the formation of the skeleton of hard corals.

Table 2. Results of analysis of the relationship of biotic and abiotic components.

No	Correlation Value	Selected Variables
1	0.771	2, 8
2	0.771	2, 6, 8
3	0.714	4, 5, 8
4	0.657	4, 8, 11
5	0.600	4, 5
6	0.600	2, 4, 8
7	0.600	2, 4, 5, 8

Notes: 1) Nitrate, 2) Phosphate (PO4), 3) pH, 4) DO, 5) Salinity, 6) TDS, 7) Temperature, 8) Water Clarity, 9) Water Current, 10) Pebbles, 11) Coarse Sediment, 12) Fine Sediment, 13) Silt.

Water clarity is a measure of the number of particles in the water or the extent to which light can travel through the water. Suspended sediments, algal growth, runoff, shoreline erosion, wind mixing/upwelling, and tannic and humic acids from wetlands can all affect water clarity. It often fluctuates seasonally and can be affected by storms, wind, climate change, and normal cycles in the food webs of the water ecosystem. A study on coral reefs in Bengkoang Island, Karimunjawa, suggested that water visibility is an important factor for coral growth and coral fish diversity (Nadia *et al*, 2018). Furthermore, slightly lower water clarity indicated by increased turbidity and chlorophyll has influenced the increasing prevalence of disease on coral reefs of Florida Bay, together with higher dissolved inorganic nitrogen (Kim and Harvell, 2002). The need for light for coral growth can be related to the depth in the habitat in which they live. In some cases, corals respond positively to the presence of water-rich dissolved nutrients, which means that water clarity decreases. In shallow water, irradiance can reach levels that can be destructive for corals, thus a reduction in light capture may be required. Whilst in deep water, light is the main limiting factor in controlling coral morphology, thus flattening it may enhance light capture (Ow and Todd, 2010). A study on the effects of light limitation and reduced water quality of shallow turbid waters in the inshore Burdekin region, GBR, showed a reduction in photosynthesis and light calcification rates of the coral *Acropora tenuis* by up to 70% and 50%, respectively (Strahl *et al*, 2019).

Coastal water quality and light attenuation can detrimentally affect coral health. Nutrient availability is one of the main factors in supporting the growth of hard corals, apart from other environmental factors. The two main elements of nutrients that determine its growth are nitrogen and phosphate. Long term experiment done by Rosset *et al* (2017) by exposing corals to imbalanced N:P ratios had severely disturbed the symbiosis due to undersupply of phosphate. A further effect of deficiency of nutrient intake, especially phosphate is the loss of coral biomass, owing to malfunctioning of algal photosynthesis and bleaching of the corals. Research carried out by Wiedenmann *et al* (2013) in the experiment of high nitrate concentrations in combination with low phosphate availability resulted in phosphate starvation of the algal symbiont and increased susceptibility of corals to heat- and light-stress-induced bleaching. However, the opposite condition occurs when the corals tolerated an undersupply with nitrogen at high phosphate concentrations without negative effects on symbiont photosynthesis, suggesting a better adaptation to nitrogen limitation (Rosset et al, 2017). In terms of the etiology of coral disease, Kuta and Richardson (2002) reported orthophosphate as one of the five factors that exhibited statistically significant relationships with black band disease of corals, including water temperature, water depth, coral diversity, and concentrations of nitrite. Furthermore, Haese *et al* (2007) reported the depletion of dissolved inorganic phosphorus after the bloom of phytoplankton which was initially triggered by an increase in nitrogen levels. This follows the results of Rosset *et al* (2017), which highlighted the key role of phosphorus in supporting zooxanthellae numbers and coral biomass as well as the proper functioning of symbiont photosynthesis.

CONCLUSION

The biotic cover of coral reefs at Station I was dominated by Dead Coral with Algae (37.5%), Non-Acropora Foliose (30.5%), Acropora Branching (12.2%), and Non-Acropora Encrusting (11.0%). Meanwhile, the diversity of coral reef biotic cover at Station II was dominated by Non-Acropora Foliose (17.3%), Acropora Branching (19.2%), Acropora Encrusting (13.2%), Acropora Digitate (16.0%). The percentage of live corals at Station I was slightly lower (61.1%) than at Station II (76.5%), while the percentages of dead corals at Station I and Station II were 38.9% and 23.5%, respectively. This implies that fish farming activities may influence the total percentage of life-form corals. Further spatial and temporal sampling procedures need to be carried out on a larger scale to have a better understanding of the relationship between environmental variables, especially phosphate and organic matter soluble in waters and sediments on the diversity of living corals.

ACKNOWLEDGEMENTS

This research was funded under the scheme of Applied Research funded by Directorate Research and Community Service – Ministry for Research and Technology/ National Research and Innovation Agency (DRPM-Kemenristek/BRIN) Republic Indonesia, contract No. 187-58/UN7.6.1/PP/2021. We would like to thank the Head of the Central Java Fisheries and Maritime Affairs Office, the Head of Karimunjawa Village, and all parties who have supported the field sampling process to testing and data analysis.

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