Health Status of Coral Reef in Tunda Island, Banten Province, Indonesia

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Abstract

Coral reef is an important underwater ecosystem supporting people's lives in coastal areas. One of the communities depending on the coral reef ecosystem for its food, livelihood, shoreline protection, and recreation needs is a community in Tunda Island. This research aims to analyze and determine the health status of coral reef in the island using a survey method. It was conducted in July 2018 and July 2019. Underwater photography transects were established at two depth areas of ± 3-4 m (shallow water) and ± 10-11 m (reef slope). Analysis of the results of live coral cover was divided into eight categories of groups based on CPCe output series 4.1. The values of coral reef cover at first depth (± 3-4 m) were 64.86% (east side of the island), 55.76% (north toward east side), and 32.22% (west side). The values of coral reef cover at second depth (± 10-11 m) were 36.36%, 25.00%, and 23.63% on the north toward east, east, and central north sides of the island, respectively. In shallow waters of Tunda Island, the coral reef health is classified as moderate to good, mostly those located on the east and the north toward the east sides. At reef slope, the coral reef health is classified as damaged to poor, particularly those located on the south and the south toward the west sides. The difference in the health values implies that most corals occur in shallow waters while deep corals differ from those near the surface and are not safe from impacts of the activities in the coastal area of Tunda Island.

Keywords: *coral reef cover, coral reef health, coastal area, ecosystem services, habitat, Tunda Island*

Introduction

Tunda Island is one of the seventeen small islands in the Serang District area (BPS Serang District, 2018). It is located in Wargasara Village, Tritayara Sub-District, Banten Province, Indonesia. Based on the plan of zoning of the coastal areas and small islands in Serang District from 2013-2033, Tunda Island is included in a development program for marine tourism zone (Regional Regulation of Serang District No. 2/2013). Tunda Island is a diverse marine and coastal area. It is an attractive site for ecological research and tourism, and has an abundance and diversity of coral reef and reef fish (Zamani, 2015).

The development of marine tourism areas is a resource management strategy that would be beneficial for businesses and the community in Tunda Island in terms of sustainable management, protection, preservation and utilization of ecosystem services of marine and fishery resources. Currently, the abundant underwater property in Tunda Island has enough potential to be developed as a marine tourism area for diving, snorkeling, and fishing tour (Alam *et al*., 2017). Tunda Island has three important ecosystems along the beach and coastal area: coral reef, seagrass, and mangrove forest. Of which, the coral reef ecosystem is the basis for the development of marine tourism in the island.

Existing coral reef ecosystem is used as an indicator of environmental change because it is more sensitive to physical and chemical changes in the marine environment (Guzman and Jimenez, 1992; Al-Rousan *et al*., 2007; Jayaraju *et al*., 2009; Riska *et al*., 2015). This change is seen from the health and physiology of coral polyp (Esselemont *et al*., 1999; Chan *et al*., 2014) and physical and chemical characteristics on its skeleton (Abelson *et al*., 2005; Riska *et al*., 2015). Coral reefs are formed from massive sediments of calcium carbonate ($CaCO_3$)

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produced by reef organisms, which form coral hermatypic reef) from phylum Cnidaria. Scleractinia order builds themselves a hard skeleton and lives in symbiosis with zooxanthellae, and a little addition of calcareous alga and other organisms that secrete calcium carbonate (Dhiecho *et al*., 2015).

The numerous and varied benefits of a coral reef ecosystem can be direct or indirect. Direct benefits include the availability of fish another biota as habitat, and marine tourism. Meanwhile, the indirect benefits are abrasion barrier and breakwaters. A coral reef is one of the important marine ecosystems providing crucial ecosystem services, such as base food source for some commercial biota/organism, marine tourism support, beautiful sand on the beach, and barrier of waves and erosion (Westmacott *et al*., 2000; Dhiecho *et al*., 2013; Nugraha *et al*., 2017).

At present, tourism activities in Tunda Island need a regulation especially the activities on the beach and coral reef waters. The regulation must be proper, well planned and adhere to the principles and goals of sustainable development. This research aims to analyze and determine the health status of coral reefs in Tunda Island The increasing impact of human activities is endangering the survival of this ecosystem and learning about the coral reefs will help the government, the community and other stakeholders understand what is needed to protect.

Materials and Methods

Samplings were done in July 2018 and July 2019 in Tunda Island waters, Serang District, Banten Province (see Figure 1.) by Rapid Reef Assessment. This assessment combined the methods of manta tow, Line Intercept Transect (LIT), and Underwater Photo Transect (UPT) (Jonker *et al*., 2008) where the length of the transect line used was 50 meters. UPT combines underwater digital camera and computer software developed by P2O-LIPI (Giyanto *et al*., 2014). Subsequently, the generated pictures were analyzed using CPCe (*Coral Point Count with Excel extensions*) Software version 4.1 to obtain quantitative data. Observation and collection of data were done in 2 depths, *i.e*. ±3-4 m (shallow water) and ±10-11 m (reef slope). Placement of line transects and transect quadrates was done from 0 m to 50 meters in the bottom waters (sea). The value range of ±3-4 m and ±10-11 m were used because in coral reef habitats it is difficult to get final values. Mujiyanto and Syam (2014) found that in bottom waters, producing a fixed value to place the line transects and transect quadrates was difficult.

Results of the percentage of reef colony cover were grouped into thirteen based on CPCe output (Kohler and Gill, 2006) which was developed and modified by P2O-LIPI (Giyanto *et al*., 2014). These include Live Coral (LC), Acropora (AC), Non Acropora (NA), Dead Coral (DC), Dead Coral with Algae (DCA), Soft Coral (SC), Gorgonians (G), Zoanthids (Z), Sponges (S), Fleshy Seaweed (FS), Other (OT), Other Live (OT), Coraline Algae (CA), Rubble (R), Sand (S), Silt (SI) and Rock (RK). Analysis of coral health was carried out according to quality of coral health by the Ministry of Environment of Republic of Indonesia No. 4/2001 concerning the standard criteria for damaged coral reefs.

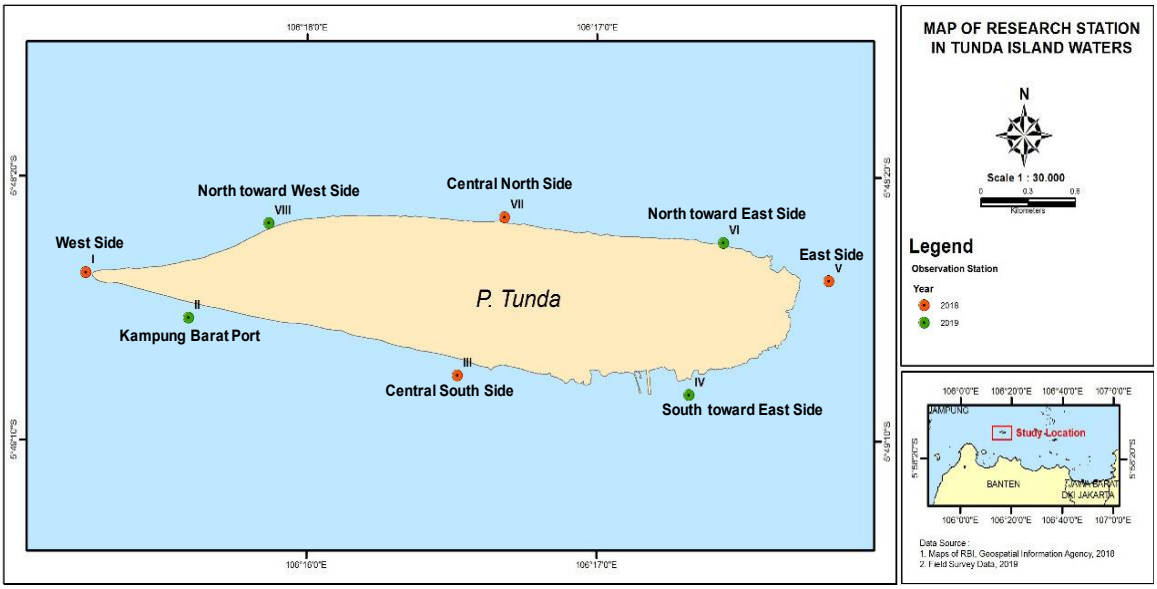
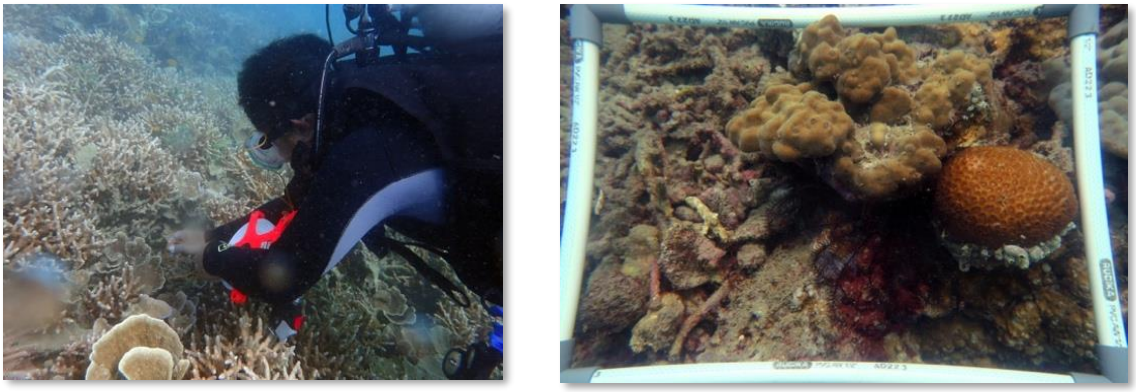


Figure 1. Map of research stations in Tunda Island waters



Preparing to put the transect line | transect quadrates of 58x44 cm

Figure 2. Collection of data on coral reef health

Analysis to find out the similarity between stations based on the cover percentage of coral reef was done by cluster. The method used to measure the similarity of the object was Complete Linkage (Hidayatullah and Perihatini, 2016). This method an overall group distance from all stations including a cluster with all stations in another cluster. The analysis was performed using Minitab 15 software.

Results and Discussion

Percentage of live coral cover in shallow water

The percentage of live coral cover observed at ±3-4 meters on 8 stations showed a high level of healthy corals. Station 5 (East Tunda Island Side) had the highest coral cover at 64.86%. The level results from the calculation of category groups included Live Coral (LC) at 55.10%, Gorgonians (G) at 0%, Sponges (S) at 0%, Zoanthids (Z) at 0%, Other Live (OL) at 9.76%, and Coralline Algae (CA) at 0%. The range of percentages of coral health at 3-4 meters on 8 stations was 11.82% -42.12%. In addition, the highest value was found on the North Side of the island while the value for the North toward the East Side was 55.76%. The result of the analysis with a focus on the LC category was benthic life composition life coral from Acropora and non-Acropora type. Coral reef conditions can be based on the percentage of coral cover life from hard coral type (Acropora and non-Acropora) (Adriman *et al*., 2014).

The health of the reef in shallow waters in all stations can be classified as moderate to good. These are located on East Side (Station 5) and North toward East Side (Station 6.). Meanwhile, reef health on other sides are classified as damaged to poor, including those on the Central North Side (Station 7.) and North toward West Side (Station 8.) (Table 1).

The percentage value of healthy coral cover on the East Side and on the North toward the East Side has been dominated by massive and branching live corals. Other types have also been found, such as a mixture of Other Live (OT) and Coralline Algae at 9.76% on the Central North Side and 8.18% on the North toward the East Side). The percentage of reef health on the North and East sides can be classified as good because of the fewer fishing activities in the area. The East Side also has high waves and currents (Prameswara and Suryawan, 2019). Meanwhile, the Central North Side and the Central South Side have damaged to poor coral cover because the locations are being used as snorkeling area, for fishing with a spear gun, and for other activities performed by Tunda people and tourists. The poor condition in these locations is caused by destructive fishing activities, including the use of fishing gears that damage coral reef, and by coral mining that takes out live corals for use as building materials (Hermansyah *et al*., 2017).

The percentage of live coral cover were also used in the identification of the type of damage based on the following category groups: Dead Coral (DC), Fleshy Seaweed (FC), Dead Coral with Algae (DCA) and Sand (S), Rubble (R) and Rock (RK). At ±3-4 m depth at 8 sampling stations, the highest level of coral reef damage observed was located on the South Side Station near Kampung Barat Port and on the North Side of Centre Part (Station 2.). The percentage values on the South Side close to Kampung Barat Port and the North Side (Station 7.) were 7.58% and 9.09 %, respectively.

Fishing is the main source of livelihood for the people in Tunda Island. Tunda Island people work as traditional fishermen and their major fishing location is the coral reef ecosystem (Nugraha *et al*., 2017). High dependence on the fish resource is due to the direct benefit of the coral reef ecosystem in coastal areas. In terms of occupation, around 80% of Tunda

people are fishermen while the rest are workers (10%) or with other jobs (10%) (insert source). Based on the level of economic prosperity, most of the 200 families belong to the underprivileged and prosperous group 1. Considering the link between their livelihood and economic welfare conditions, it is reasonable to assume that the livelihood of people as fishermen in the region has not been able to provide adequate welfare for their families. Coral reef ecosystem is one part of the coastal ecosystem that is very important as food resource, habitat for some fish and other commercial organism, marine tourism support, sand provider for the beach, and breakwater and barrier of beach erosion (Westmacott *et al*., 2000; Dhiecho *et al*., 2013; Nugraha *et al*., 2017).

Percentage of live coral cover at reef slope

The results showed that the level of coral reef health at all stations has a range of 1.82 to 33.36%, with Station 6 having the highest percentage at 33.36 %. The dominant value of reef health at the depth of ±10-11 meters has a range of 1.82 to 22.00%. The lowest percentages of coral cover were found at Station 4 (1.82%), Station 3 (9.09%), and Station 2 (17.27%). Station 2 is located near the Tourist Port (South Side of Tunda Island waters), Station 3 is near the Kampung Barat Port, and Station 4 is close to the Central Port of Tunda Island.

Based on the results of the analysis from all stations, there is no range of reef health percentage at ±10-11 meters that has been categorized as damaged to moderate (Ministry of Environment Regulation No. 4/2001). The moderate category was found on the North Side toward the East Side and on the East Side, while the poor category was found on the South Side, specifically at the front of Kampung Barat Port (Station 2). According to the result of the research of Hermansyah *et al*. (2017), the condition of coral reef in Tunda Island waters at >8 m depth is categorized as in poor condition at 4 stations (West Side, Tourism Port, East Side and North Side). These stations are different from this research. The calculated values of live reef health in this research on the South Side was about 8%, 9% at Station 1 (West Side), 12% at Station 7 (Central North Side), and 12% at Station 5 (East Side). These values are

Table 1. Percentage of live coral cover at research stations in shallow water

No.		Major Category	St. 1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	St. 8
1.	LC	Live Coral (AC+NA)	31.48	14.67	7.58	38.18	55.10	47.58	2.73	6.97
		AC = Acropora	28.34	12.47	5.47	33.29	37.18	42.78	1.79	5.41
		NA = Non Acropora	3.14	2.20	2.11	4.89	17.92	4.80	0.94	1.56
2.	DC	Dead Coral	12.22	0	0	0	0	0	1.00	1.21
3.	DCA	Dead Coral With Algae	44.07	37.67	24.85	36.36	24.85	25.15	51.82	44.85
4.	SC	Soft Coral (G+Z)	0	0	0	0	0	0	3.94	0
		G = Gorgonians	0	0	0	0	0	0	3.94	0
		Z = Zoanthids	0	0	0	0	0	0	0	0
5.	S	Sponges	0	0	0	0	0	0	0	0
6.	FS	Fleshy Seaweed	12.22	5.33	7.88	3.64	0	6.97	7.58	6.06
7.	OT	Other (OT+CA)	0.74	1.33	0.00	3.94	9.76	8.18	2.42	4.85
		OT = Other Live	0.74	1.33	0	3.94	9.76	8.18	1.52	3.64
		CA = Coraline Algae	0	0	0	0	0	0	0.91	1.21
8.	R	Rubble	8.25	34.17	34.13	13.35	6.17	6.26	13.65	18.23
9.	S	Sand	2.25	3.11	15.53	2.88	1.05	2.26	7.16	8.61
10.	SI	Silt	0.98	3.72	10.04	1.65	3.06	3.60	9.80	9.22
11.	RK	Rock	0	0	0	0	0	0	0	0
The total number (%)			100	100	100	100	100	100	100	100
The health of coral reef (%) = LC + SC + S + OT			32.22	16.00	7.58	42.12	64.86	55.76	9.09	11.82

categorized as poor. The result of research conducted by Soedharma *et al*. (2017) in Tunda Island using the LIT method at 7-8 m depth showed that the live reef percentage on the South Side was 25,5%, which is categorized as moderate. Comparing the North and South sides from 2012 until 2017, the coral reef ecosystem has decreased with the poor condition of live coral cover (Hermansyah *et al*., 2017).

Based on the coral reef composition of the group of categories as the output of CPCe software, the dominance of composition habitat on the South Side was Dead Coral with Algae (DCA) and Sand (S), Rubble (R), and Rock (RK). The value was taken from the highest category group of the DCA category. It is located on the North Side of Tunda Island, precisely at Station 6 (40.30%), Station 7 (50.03 %), and Station 8 (37.33%). Coral reef composition found on the Central South Side of Tunda Island was categorized into Sand (S), Rubble (R) and Rock (RK) with the values of 78.48%, 56.97%, and 72.73% at stations 2, 3, and 4, respectively. The values of coral cover by category and by research station are presented in Table 2.

Central South Side in Tunda Island waters is classified as water condition with very low transparency level and high turbidity. On the Central South side, it was observed that the water is susceptible to people's activities. The settlement of people in Tunda Island will have impact to surface and underwater ecosystems around, especially the coral reef ecosystem. According to Burke *et al*. (2002), environmental pressures due to land activities can reduce biodiversity in coral reef areas by 30-60%. Increasing activities of the people also can relate directly to the coral reef ecosystem. It has a significant contribution to the occurrence of sedimentation and physical damage to the coral reef. Due to the high levels of sedimentation, the shape of colonies in sequence will tend to be massive, branchy and foliose (Rahmitha *et al*., 2015). De Meesters *et al*. (2002) stated that Porites can adapt in a water environment with high turbidity to carry out active metabolism. Therefore, turbid water with low salinity is likely to have Porites as the dominant coral.

Table 2. Percentage of live coral cover at research stations at reef slope

No.		Major Category	St. 1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	St. 8
1.	LC	Live Coral (AC+NA)	13.33	4.85	8.18	0.91	19.33	33.03	13.03	15.67
		AC = Acropora	7.37	3.16	5.38	0.91	15.67	28.79	9.25	12.7
		NA = Non Acropora	5.96	1.69	2.80	0	3.66	4.24	3.78	2.97
2.	DC	Dead Coral	0	0	0	0	0	0	0	0
3.	DCA	Dead Coral With Algae	38.79	15.76	25.45	24.55	35.00	40.30	53.03	37.33
4.	SC	Soft Coral (G+Z)	3.33	0	0.30	0.91	0	0	7.58	0
		G = Gorgonians	1.82	0	0	0	0	0	7.58	0
		Z = Zoanthids	1.52	0	0.30	0.91	0	0	0	0
5.	S	Sponges	0	0	0	0	0	0	0	0
6.	FS	Fleshy Seaweed	15.76	0.91	8.48	0.91	23.33	0	0.91	0
7.	OT	Other (OT+CA)	0.61	0	0.61	0	5.67	3.33	3.03	6.33
		OT = Other Live	0.61	0	0.61	0	5.67	3.33	3.03	6.33
		CA = Coraline Algae	0	0	0	0	0	0	0	0
8.	R	Rubble	25.17	45.25	46.78	56.35	27.36	15.28	15.29	31.94
9.	S	Sand	0.67	31.56	7.44	13.02	- 13.65	4.59	1.86	6.38
10.	SI	Silt	2.34	1.67	2.75	3.36	2.96	3.46	5.27	2.35
11.	RK	Rock	0	0	0	0	0	0	0	0
The total number (%)			100	100	100	100	100	100	100	100
The health of coral reef (%) = LC + SC + S + OT			17.27	4.85	9.09	1.82	25.00	36.36	23.64	22.00

The condition of coral reef at ±10-11 meters' depth is a manifestation of the impact of fishing activities in the past few years. In the past few years, fishing activities used compressors and anchor ship. They are still rife in Tunda Island because of the absence of regulation. The complexity of coral reef provides protection, which is important for reef fishes (Alvarez *et al*., 2011). Besides, coral reefs are threatened by local community activities like fishing that is not environmentally friendly and pollution (Sandin *et al*., 2008). Meanwhile, Tunda Island is a small island with a lot of human activities and has a coral reef ecosystem around coastal waters (Zamani, 2015). Riegl *et al*. (2012) explained that the coral reef ecosystem located near the community settlement will be the more accessible to people and tend to be most at risk of degradation. Several local threats come from the boats, anchors, destructive fishing, and tourism activities on the coral reef ecosystem in Tunda Island (Zamani, 2015; Fahlevi *et al*., 2017).

The similarity between the percentage of coral reef among stations

The results of the analysis of the similarity level of coral health among stations in shallow water (± 3-4 meters depth) show that four groups had the closest similarity level in terms of coral health. These are: a) Station 5 and 6, b) Station 7 and 8, c) Station 1 and 4, and d) Station 2 and 4. All four groups had the same distance at a value of similarity >75 %. The research stations at a depth of ±3-4 meters with proximity values >90% were stations 5 and 6, as well as stations 7 and 8 (See Figure 3.).

These groups have same health value tendency due to the fact that the four stations are all located on the North Side of Tunda Island. This side of the island has little activities because people's activities are still concentrated on the South Side of Tunda Island. Gladfelter *et al*. (1980) stated that the similarity of coral reef habitat is possibly due to the position of the reefs, especially concerning the degree of exposure to ocean current, water depth, and proximity to the main reef barrier that play a role in determining the composition of fish as reflected in the similarity fauna.

Grouping of similarity values between the percentages of coral cover and stations at the reef slope (±10-11 m depth) shows on highly similar group, composed of stations 2 and 4. Meanwhile, the similarity values >75% were found at stations 1 and 5, stations 6 and 7, and stations 2, 4 and 3 (See Figure 4.).

The water conditions were the same as the conditions at a depth of 3-4 meters. The level of similarity can be explained by the fact that the area is being used as a fishing location dominated by the use of destructive fishing equipment. The fishing method involves the use of some fishing gear that are not environmentally friendly (Mulyani *et al*., 2017). Therefore, coral reefs experienced some level of damage as Station 4 becomes the location of the development of fishing boat docks. Fachry and Pertamasari (2011) identified five main human activities that threaten the preservation of coral reef, including fishing with poisonous materials, fishing with explosives, rock extraction, sedimentation, and pollution.

The condition of coral reefs in Tunda Island is not secure because of excessive coral reef exploration and mining of materials for the construction of settlement foundations (Dedi *et al*., 2017). The community also dispose household waste to the water, which will cause damage to the

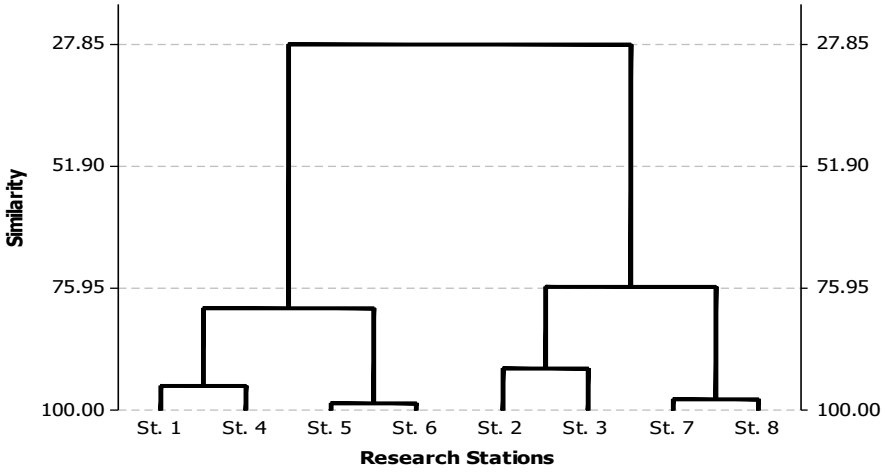


Figure 3. Dendrogram/hierarchical clustering for shallow water using Complete Linkage Method

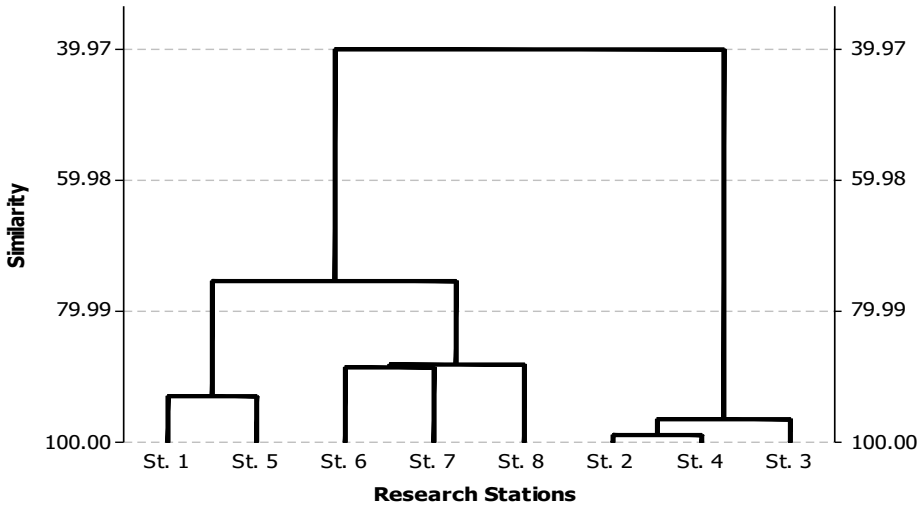


Figure 4. Dendrogram/hierarchical clustering for reef slope using Complete Linkage Method

surrounding environment. Riska *et al*. (2015) reported that heavy metals accumulation in Tunda Island waters is increasing as seen from an annual band of *Porites lutea* corals. Zamani (2015) also explained that the decrease in the percentage of coral reefs in Tunda Island is caused by boat activities, such as boat anchoring and perching or grounding of local tourism boats. The dead coral has been overgrown with algae as a result of pressure from human activities and long-standing environmental factors.

Conclusion

In shallow waters in Tunda Island, the health of the corals on the East Side and North toward the East Side is classified as moderate to good. Those located on the Central North Side and North toward West Side is categorized as poor to moderate. Meanwhile, the coral reef health at reef slope in Tunda Island waters is classified as damaged to poor. The moderate category is located on the North toward East Side, while the damaged to poor one is on Central South and South toward West Side.

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