



## The escalation of coral growth by biorock technology applied in Sabang marine ecotourism

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**Abstract.** This study was carried out in sea ecotourism park (Taman Wisata Alam Laut-TWAL), Rubiah Island, Sabang, from July to September 2017. The aim of this study was to evaluate the coral transplantation using biorock technique. Biorock is capable of producing minerals by applying a low voltage direct electrical current, which is commonly recognized as mineral accretion. The study used following materials, i.e. iron stick, titanium mesh, power supply, wire, cable ties, water quality tester, underwater stationery, diving equipment and coral fragments. Field experiment of biorock was applied in two depth levels: 3 m and 8 m. A total of 3 biorock structures and 1 control (non-biorock) were applied in each depth level. Each of the transplantations contained 10 fragments of *Acropora* and *Pocillopora*. Parameters observed included absolute growth, coral growth rate, survival rate, and water quality, and all those parameters were observed monthly. The results exhibited that absolute growth ratio of *Acropora* and *Pocillopora* was 4:1 (biorock:control), while the growth rate of both corals under biorock treatment was higher than that of corals under control treatment. For both genera, the survival rate reached more than 75%, while it reached only 70% under control treatment at 8 m depth level. No adverse changes in water quality were observed in the experimental location.

**Key Words:** mineral, fragments, growth, biorock.

**Introduction.** Coral reefs in Weh Island, Sabang, have been reported to be in good condition (Ardywijaya et al 2009). Their presence is remarkably meaningful for fishery industries with various fishing tools applied in both coastal area and for commercial pelagic fishery. Weh Island has a sea ecotourism park (Taman Wisata Alam Laut-TWAL), governmentally stated through the Minister of Agriculture Decree (No. 928/Kpts/Um/12/1982, 27 December 1982), which covers 2,600 ha. The park offers several attractive activities such as snorkeling and SCUBA diving. These tourism activities provided a great contribution to coastal communities other than agriculture, business and government (Baird et al 2005).

In response to the decline of coral reefs, the effective and rapid conservation strategies are required. Seaman (2000) stated some strategies of rehabilitation including management and technological approaches. One of technological approaches is development of artificial reefs in which natural reef-like structures are installed at the bottom of seawater. Rehabilitation of coral reefs should regard materials that construct the structure, as well as its effects on biodiversity.

Coral reef ecosystem could be rehabilitated by mineral accretion technology. This technique has been developed since 1980 and promoted in Pemuteran, Bali, Indonesia by Tom Goreau and Wolf Hilbertz in 2000 (GCRA 2004). Goreau (2014) stated that biorock process can accelerate the coral growth and resistance to environmental stress factors. Moreover, the restoration can be used by this technique in a short time where there is no natural recovery.

## Material and Method

**Study site.** The study was carried out in the sea ecotourism park (Taman Wisata Alam Laut-TWAL), Rubiah Island, Sabang (Figure 1) from July to September 2017. Structure for mineral accretion was made from non-galvanized iron stick (designed to form open prism) as cathode, titanium mesh as anode, power supply (battery charger), wires, cable ties and coral fragments from *Acropora* and *Pocillopora* genera. Complementary devices included diving equipment, coral cutter, underwater stationery; underwater camera and caliper were also used.

The environmental parameters were monthly observed namely lightness, temperature, current, dissolved oxygen, salinity, and pH. All parameters can provide information about the limiting factors on coral growth. The data has been compared with the standard data that has been issued by Ministerial Decree of the environment for Sea Quality Standard for Marine Biota No. 51 year 2004, attachment III.

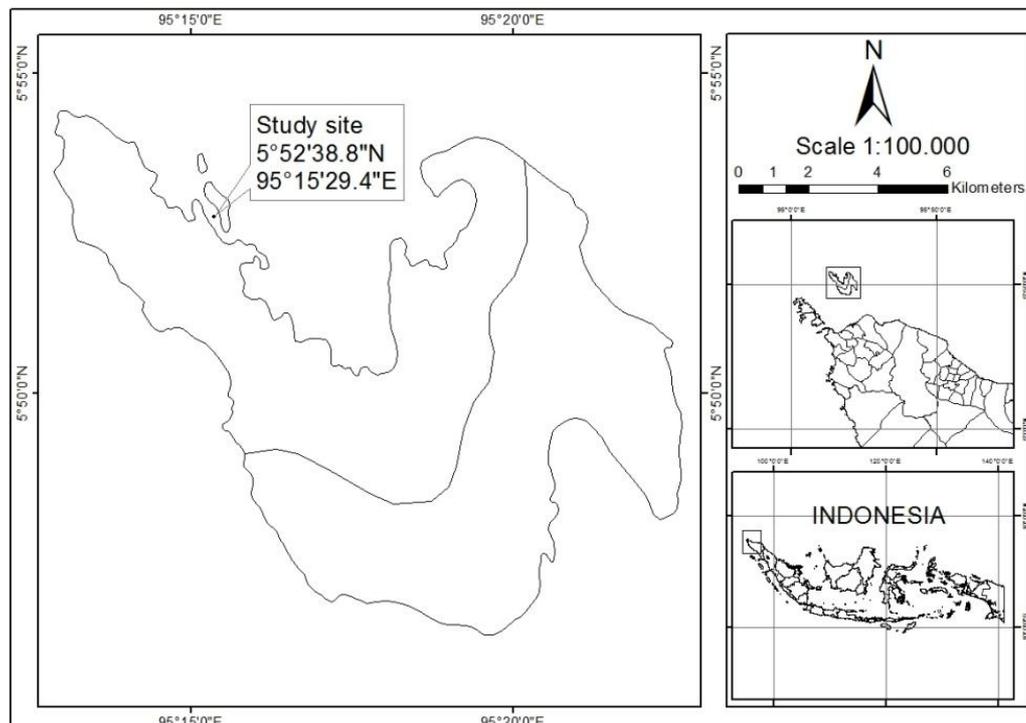


Figure 1. Map of experimental location

**Biorock module.** The main principle of the biorock technique is to generate mineral crystal attached in iron sticks. The mineral complex consisted of calcium carbonate and magnesium hydroxide, in which calcium carbonate concentration was expected to be higher and insoluble (Hilbertz 1992). The iron skeleton served as cathode, which supplied electron to ion in the solution for inducing chemical reaction. This electrode functioned as a site for mineral settlement (sea cement). Titanium mesh was used as anode set nearby the iron skeleton. Both anode and cathode were connected using wire with power supply, a source of electrical current (DC, 6 Volts). This experiment used 8 structures of skeleton which had similar shape and size. The structure of mineral accretion was also designed to have the same rate of mineralization. A total of 4 skeletons (3 for biorock treatment, 1 for control) were installed in each depth level (3 m and 8 m), parallel to the coastline. The skeleton was set on sand substrate, and far away from natural existing coral reefs. Coral genera *Acropora* and *Pocillopora* were transplanted in the iron bars (10 coral fragments for each skeleton), yielding 20 coral fragments in each skeleton.

**Monitoring and observation.** Coral growth (vertical height and diameter) was monthly observed using caliper, while at the end of experimental period, survival rate was determined. Water quality (lightness, temperature, current, salinity, pH, dissolved oxygen) was also monthly observed *in situ* together with coral growth measurement. All data were tabulated in Microsoft Excel 2016. Growth of coral was measured using the following formula:

1. Absolute growth of diameter and height (Effendi 1979):

$$\beta L = L_t - L_o$$

where:  $\beta L$ : absolute growth of diameter and height (mm);  
 $L_t$ : average height and diameter at t month (mm);  
 $L_o$ : average height and diameter at initial period (mm).

2. Coral growth rate (Effendi 1979):

$$\alpha = \frac{L_{i+1} - L_i}{t_{i+1} - t_i}$$

where:  $\alpha$ : growth rate of height/diameter (mm/month);  
 $L_{i+1}$ : average (height, diameter) at time i+1 (mm);  
 $L_i$ : average (height, diameter) at time i (mm);  
 $t_{i+1}$ : observation period i+1 (month);  
 $t_i$ : observation period i (month).

3. Survival rate (Effendi 1979):

$$SR = \frac{N_t}{N_o} \times 100\%$$

where: SR: survival rate (%);  
 $N_t$ : number of coral at the end of experimental period;  
 $N_o$ : number of coral at initial of experimental period.

**Results.** The results exhibited that height and diameter of coral fragments under biorock and control treatment showed a less desired condition. Coral height and diameter was dissimilar according to initial condition, colony shape, branching, as well as fragment size as they were prior to transplantation. Veron (1993) reported that the corals could have dissimilar growth rate when planted in different sites, although they were from the same genus. The coral growth in branch height is depicted in Figure 2.

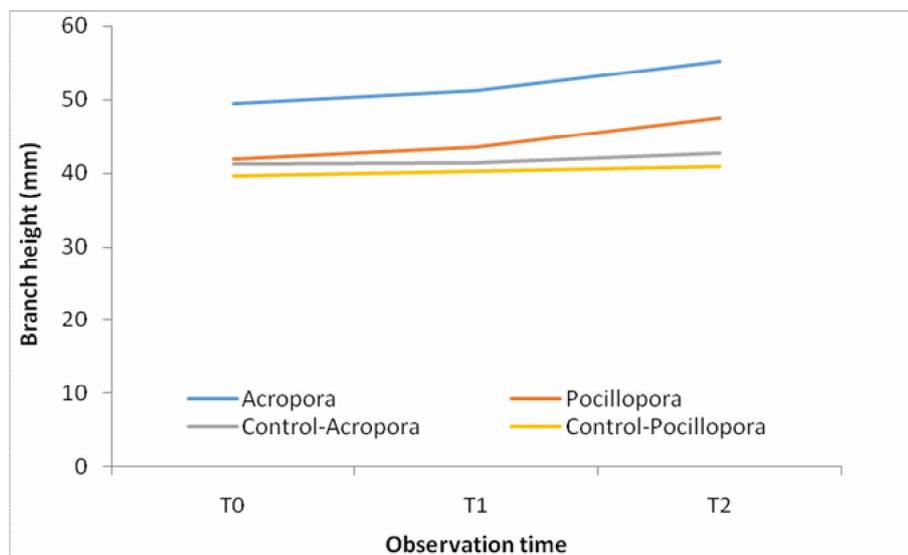


Figure 2. Changes in branch height of *Acropora microphthalmia* and *Pocillopora verrucosa* under biorock and control treatment at 3 m depth.

The results demonstrated that the growth of *Acropora* under biorock treatment at 3 m depth reached 5.83 mm in height and 4.2 mm in diameter, which was higher than *Acropora* under control treatment (height 1.52 mm and diameter 1.12 mm, respectively). This suggests that application of biorock technology has an important effect on coral growth. As reported by Goreau (1996), the use of biorock for transplanted coral could enhance their growth 3-5 faster than normal condition. Furthermore, Aspari (2009) showed that transplanted coral at electrochemical reef construction (ERCON) or biorock had absolute growth of 5.25 mm in height and 1.44 mm in diameter for four months monitoring. In case of *Pocillopora*, the coral under biorock treatment at 3 m depth has reached 5.47 mm in height (Figure 2) and 4.53 mm in diameter (Figure 3). Under control treatment, *Pocillopora* tends to have similar growth compared to *Acropora*. However, with application of biorock, the growth of *Acropora* shows to be higher than *Pocillopora*, resulting in a different height of 0.36 cm. Harriot & Fisk (1988) reported that the most appropriate coral genus for transplantation was *Acropora* branched due to its better survival rate, faster growth, and higher adaptability in response to environmental changes.

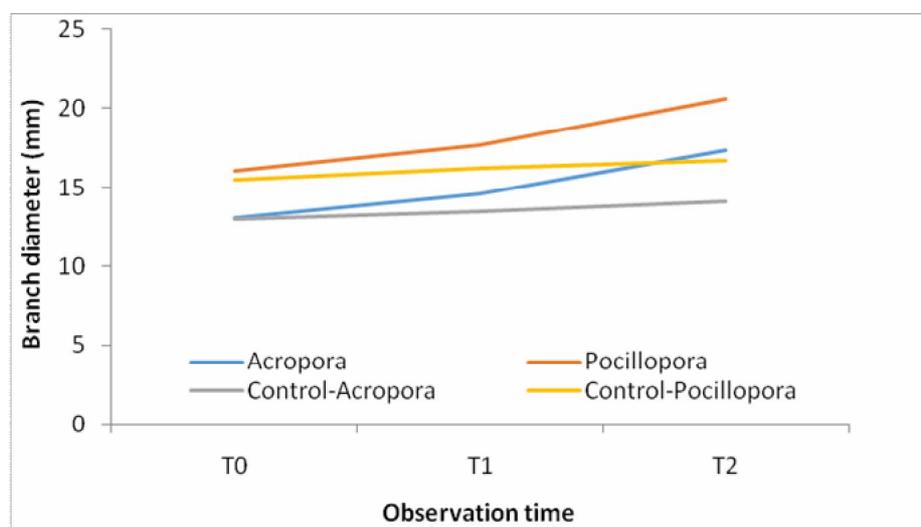


Figure 3. Changes in branch diameter of *Acropora microphthalmalma* and *Pocillopora verrucosa* under biorock and control treatment at 3 m depth.

At 8 m depth, the application of biorock resulted in better growth performance of corals compared to control treatment. During experimental period, the height and diameter of *Acropora* under biorock treatment was 5.97 mm (Figure 4) and 3.09 mm (Figure 5), respectively, while under control treatment their growth was 1.28 mm in height and 1.10 mm in diameter. Similar, Jose (2006) found that growth of transplanted coral using biorock technique was about 4 times faster. Nevertheless, the growth at 8 m depth was less than at 3m depth. Nybakken (2000) reported that the difference might result from varying intensity of light exposure and existence of wave current, affecting the coral growth. We have found that the difference in coral growth under biorock and control treatment was at ratio of 4:1. Furthermore, the coral growth was almost similar in various levels of depth. Morphology of coral reef ecosystem may differ as a result of dissimilar current speed and turbulence around waters. In our experiment, *Acropora* mainly revealed a vertical growth, while *Pocillopora* predominantly showed a horizontal growth.

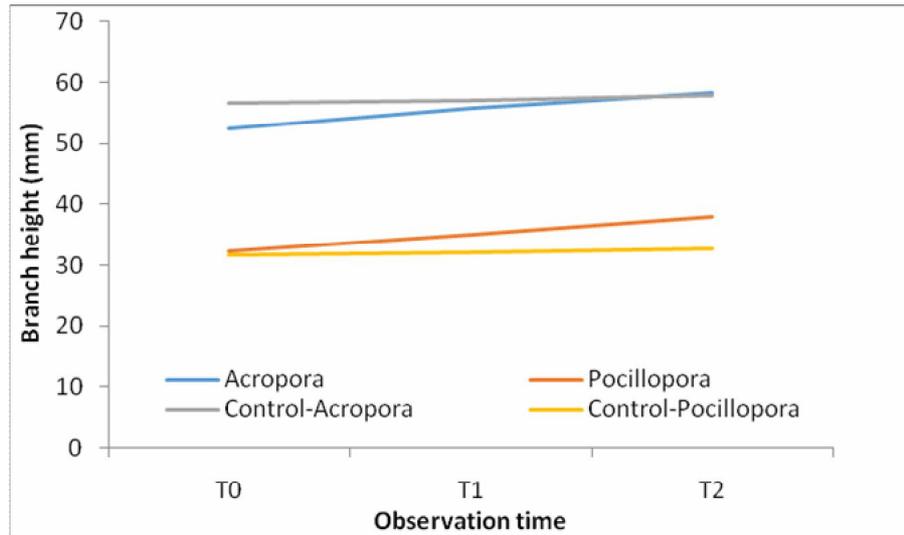


Figure 4. Changes in branch height of *Acropora microphthalmal* and *Pocillopora verrucosa* under biorock and control treatment at 8 m depth.

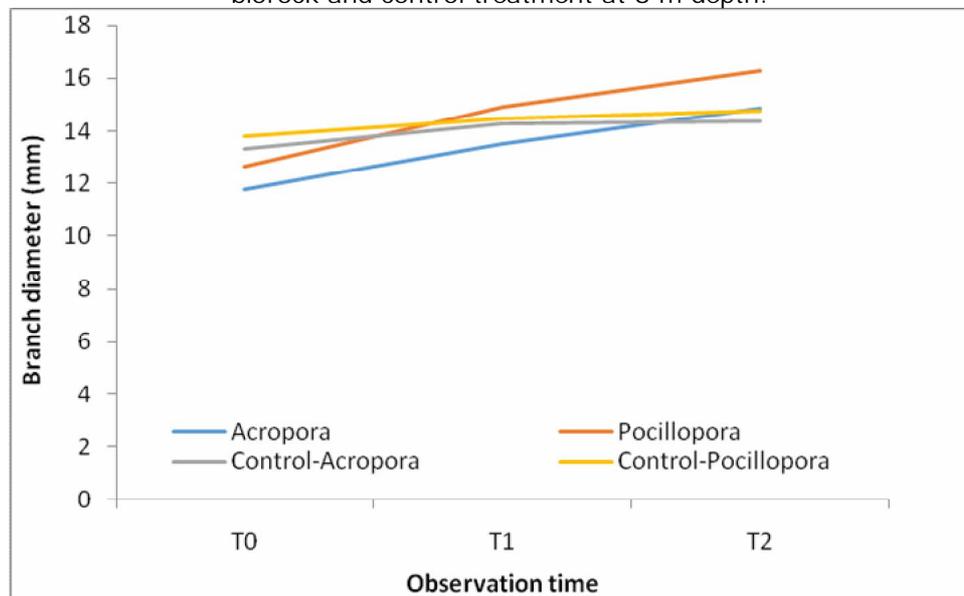


Figure 5. Changes in diameter of *Acropora microphthalmal* and *Pocillopora verrucosa* under biorock and control treatment at 8 m depth.

### **Growth rate of corals**

*Height growth rate.* Changes in coral height and diameter were investigated. The results showed that there was a difference in coral growth between biorock and control treatment as exhibited in figure below. Figure 6 shows that there was no significant difference in absolute height of both corals under biorock treatment at 3 m depth in the first and second month. Similar result was also found in control groups.

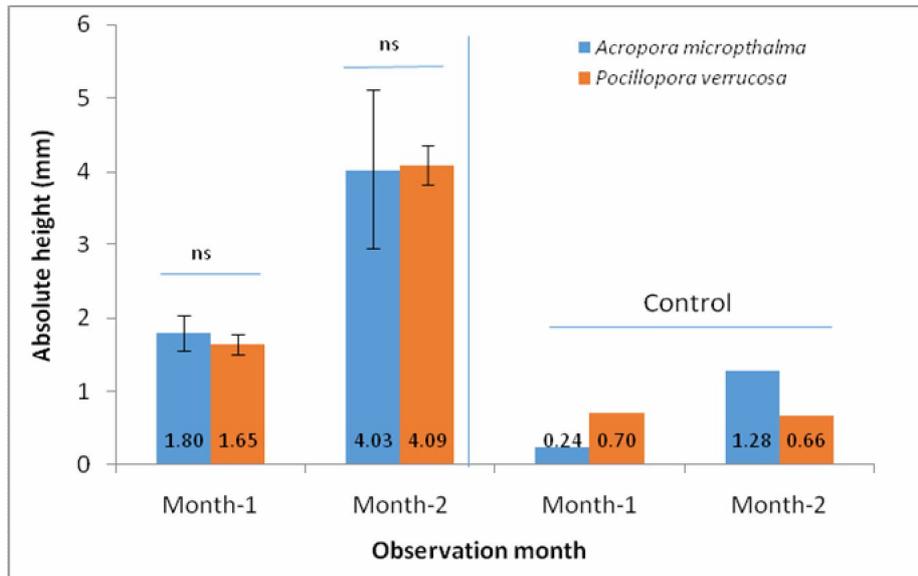


Figure 6. Increase in absolute height (mm) of *Acropora microphthalma* and *Pocillopora verrucosa* under biorock and control treatment at 3 m depth. The ns notation above bars indicates non-significant difference based on t-student test at  $\alpha = 5\%$ .

Figure 7 shows that no significant difference was observed in absolute height between *Acropora* and *Pocillopora* under biorock treatment. Additionally, similar results were also observed in control group. The results also revealed that absolute growth of corals treated with biorock was much higher than that of control group.

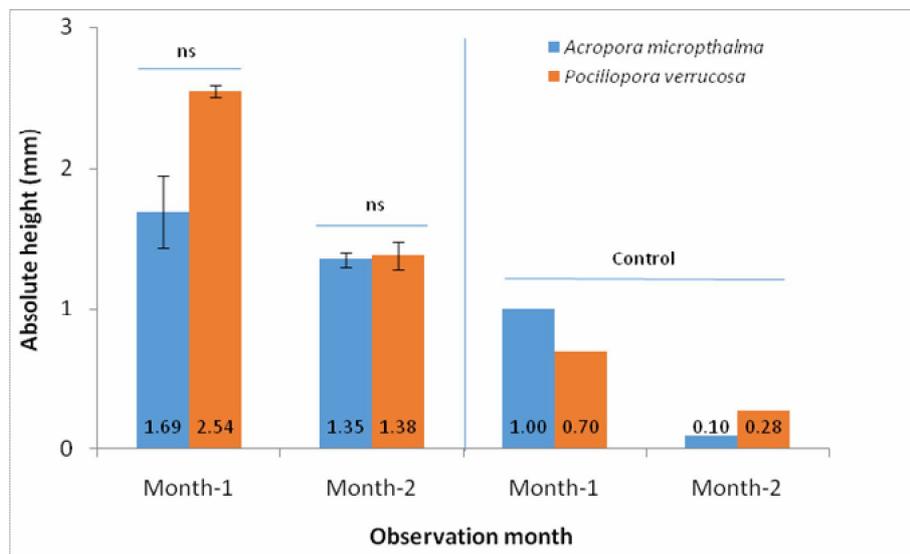


Figure 7. Increase in absolute height (mm) of *Acropora microphthalma* and *Pocillopora verrucosa* under biorock and control treatment at 8 m depth. The ns notation above bars indicates non-significant difference based on t-student test at  $\alpha = 5\%$ .

Figure 8 exhibited that there was a slight difference in absolute height of *Acropora* and *Pocillopora* between biorock and control treatments at 3 m depth. However, the results of absolute growth of corals are quite different between the two conditions.

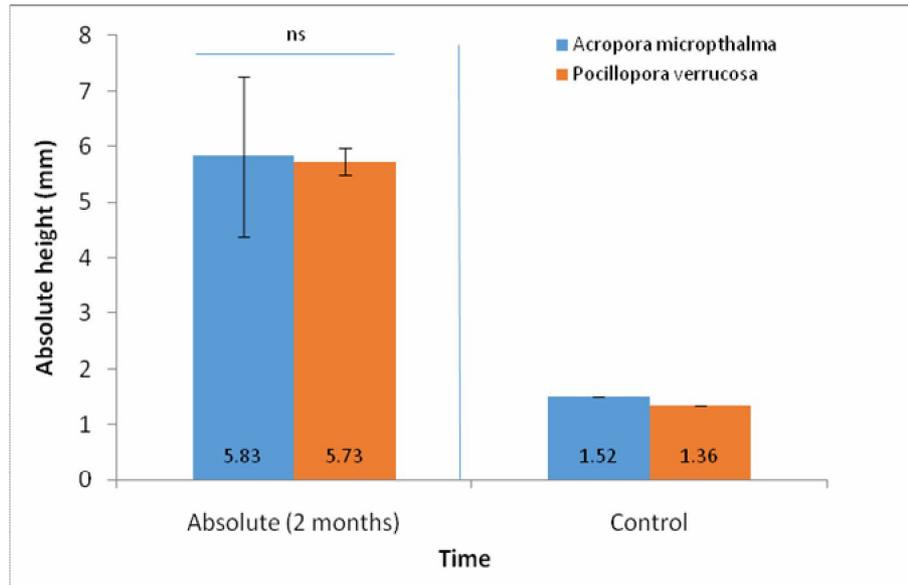


Figure 8. Changes in absolute height (mm) of *Acropora microphthalma* and *Pocillopora verrucosa* for 2-month experiment under biorock and control treatment at 3 m depth. The ns notation indicates non-significant difference based on t-student test at  $\alpha = 5\%$ .

As exhibited in Figure 9, there was no significant difference in absolute height between *Acropora* and *Pocillopora* under biorock treatments. The similar result was also found in control group.

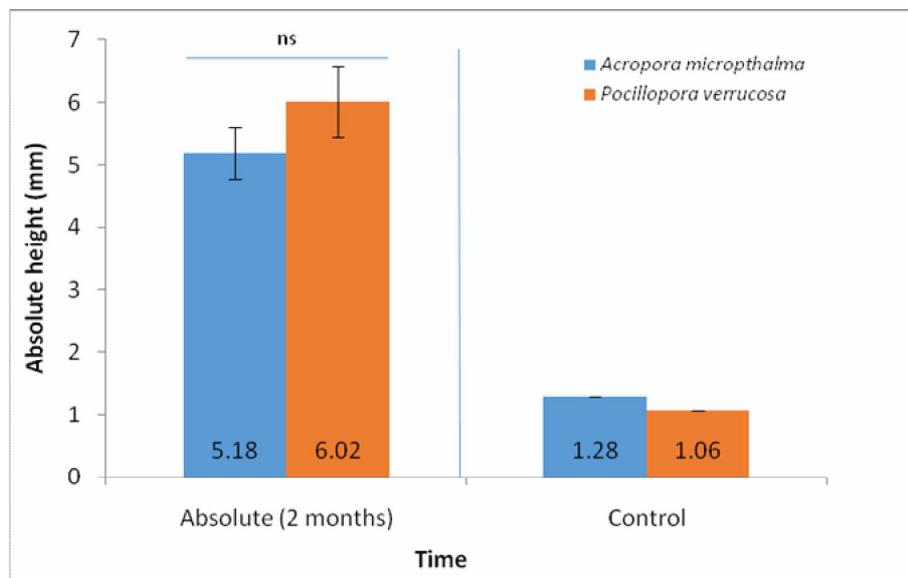


Figure 9. Changes in absolute height (mm) of *Acropora microphthalma* and *Pocillopora verrucosa* for 2-month experiment under biorock and control treatment at 8 m depth. The ns notation indicates non-significant difference based on t-student test at  $\alpha = 5\%$ .

Figure 10 exhibited that absolute diameter of *Acropora* and *Pocillopora* under biorock treatment at 3 m depth between first and second month was not significantly different. Similarly, the diameter did not significantly differ in the case of control treatment.

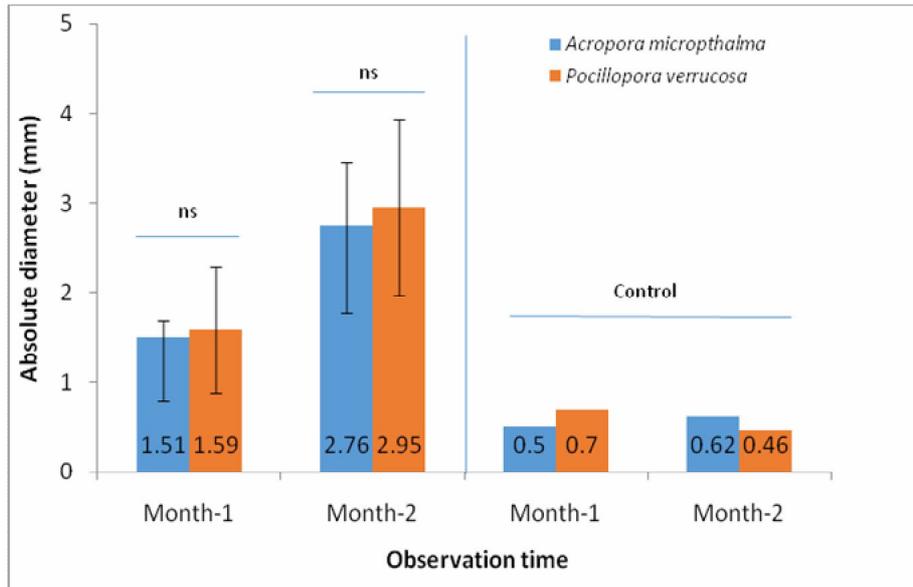


Figure 10. Increment of absolute branch diameter (mm) of *Acropora microphthalmalma* and *Pocillopora verrucosa* under biorock and control treatment at 3 m depth. The ns notation indicates non-significant difference based on t-student test at  $\alpha = 5\%$ .

In the case of 8 m depth (Figure 11), *Acropora* and *Pocillopora* had no significant difference in absolute diameter under biorock treatment. Although the absolute diameter of both corals also did not significantly differ under control treatment, it was much lower in comparison with absolute diameter under biorock treatment.

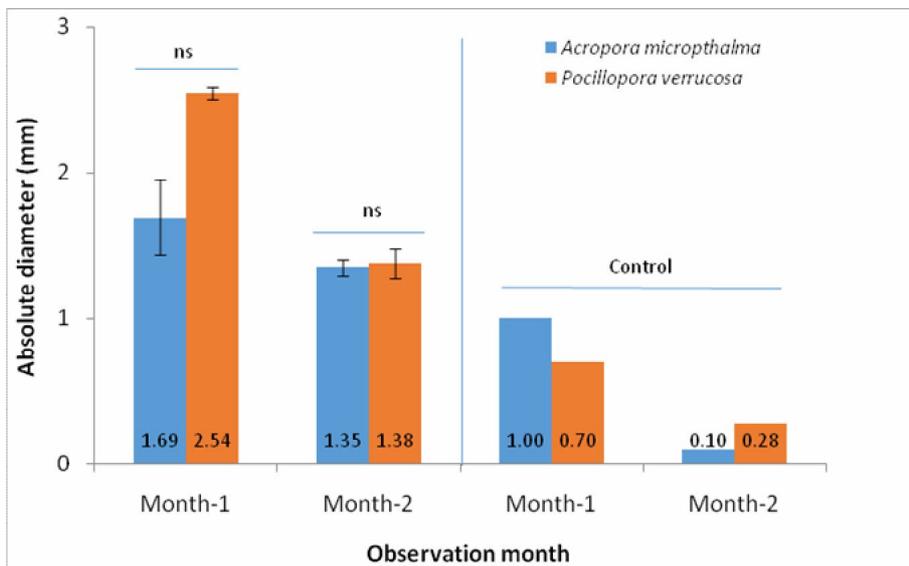


Figure 11. Increment of absolute branch diameter (mm) of *Acropora microphthalmalma* and *Pocillopora verrucosa* under biorock and control treatment at 8 m depth. The ns notation indicates non-significant difference based on t-student test at  $\alpha = 5\%$ .

Figure 12 (a) exhibited that absolute diameter of *Acropora* and *Pocillopora* showed no significant difference under biorock and control treatment at 3 m depth. However, the coral diameter treated with biorock was higher than control. In the case of 8 m depth, both transplanted coral showed a similar absolute diameter both in biorock and control treatment, as exhibited in Figure 12 (b).

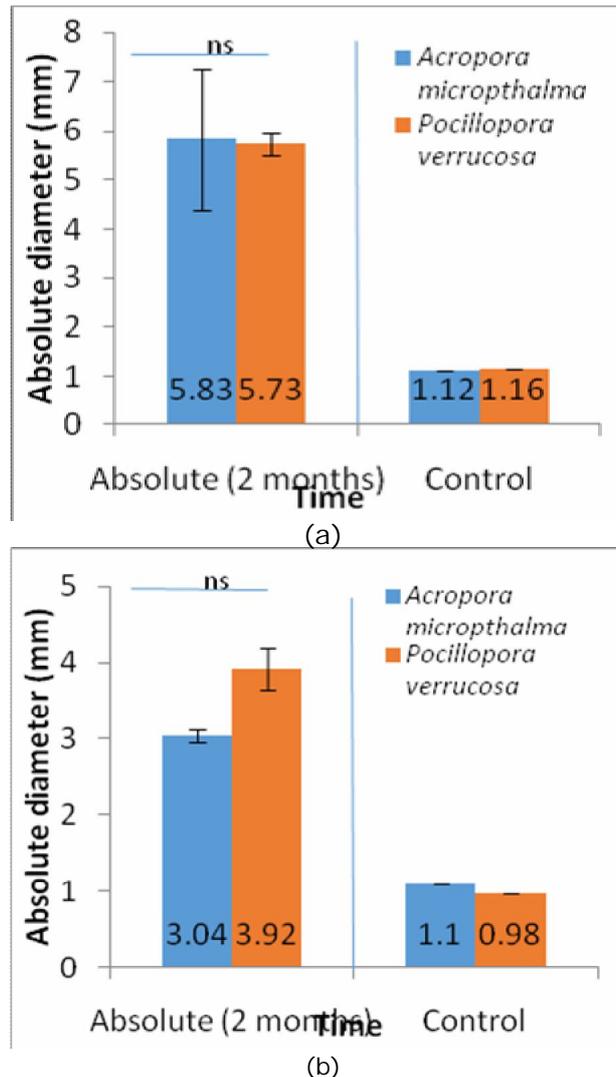


Figure 12. Increment of absolute branch diameter of *Acropora microphthalmalma* and *Pocillopora verrucosa* for 2-month experiment under biorock and control treatment at 3 m depth (a) and 8 m depth (b). The ns notation indicates non-significant difference based on t-student test at  $\alpha = 5\%$ .

Under biorock treatment, growth rate of *Acropora* reached 2.91 mm in height after 2 months and a diameter of 2.1 mm in 2 months, while growth rate of *Pocillopora* reached a height of 2.73 mm in 2 months and diameter of 2.27 mm. *Acropora* predominantly grow up vertically, while *Pocillopora* grow up mainly horizontally (Pratama 2005). In absence of biorock treatment, the coral growth (height and diameter) was less than 1 mm in 2 months for both genera.

Growth rate of *Acropora* under biorock treatment was 2.98 mm in height after 2 months while for diameter the mean values were 1.55 mm; growth rate of *Pocillopora* reached 2.84 mm after 2 months in height and 1.83 mm in diameter. In the case of control treatment, the growth rate (less than 1 mm in 2 months) was almost similar compared to previous condition. Such data may suggest the incapability of the coral fragments to adapt when the environmental conditions changes. Furthermore, presence of microalgae also affects coral growth. Nugraha (2008) found that young coral utilized the energy generated by photosynthesis only for their growth. Meanwhile, mature coral consumed a lot of energy for some activities such as competing for space with its neighbors and cleaning the sediments that blocked its huge polyp. This behavior may also suggest that the coral shows a slow growth at the initial stage.

Growth rate of corals between biorock and control treatment showed a significant difference in both 3 m and 8 m depth. Presence of electrical current enables corals to absorb more calcium. The irreversible reaction in this system promotes oxidation reaction

in anode, while reduction reaction could form calcium and magnesium sedimentation on cathode. The use of low voltage electrical current (6V) can generate sedimentation of calcium and magnesium in cathode, contributing to better effects on coral growth (Jose 2006). Furthermore, Borneman (2000) stated that application of biorock resulted in growth rate of 99 mm in a year for *Acropora palmata*. They concluded that biorock-treated coral had a greater growth in comparison to natural existing corals.

Figure 13 exhibited that there was no significant difference in growth of *Acropora* for both 3 m and 8 m depths. However, a high increase of *Acropora* growth was observed in 3 m depth. In the case of *Pocillopora*, there was a significant difference between two depth levels in the first month, although this did not occur in the second month.

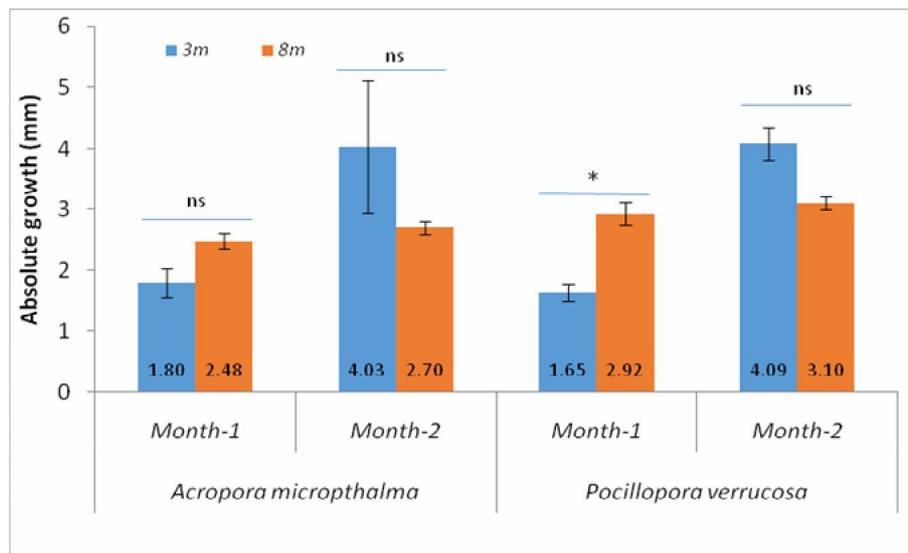


Figure 13. Absolute branch growth of *Acropora microphthalmalma* and *Pocillopora verrucosa* under biorock treatment at 3 m and 8 m depths. The ns notation indicates insignificant difference, while \* notation indicates a significant difference based on t-student test at  $\alpha = 5\%$ .

As depicted in Figure 14, there was no significant difference in the absolute growth of *Acropora* between 3 m and 8 m depths. The similar result was also observed in *Pocillopora*. Interestingly, we found that the growth of both corals at 3 m depth was slightly higher than that of at 8 m depth.

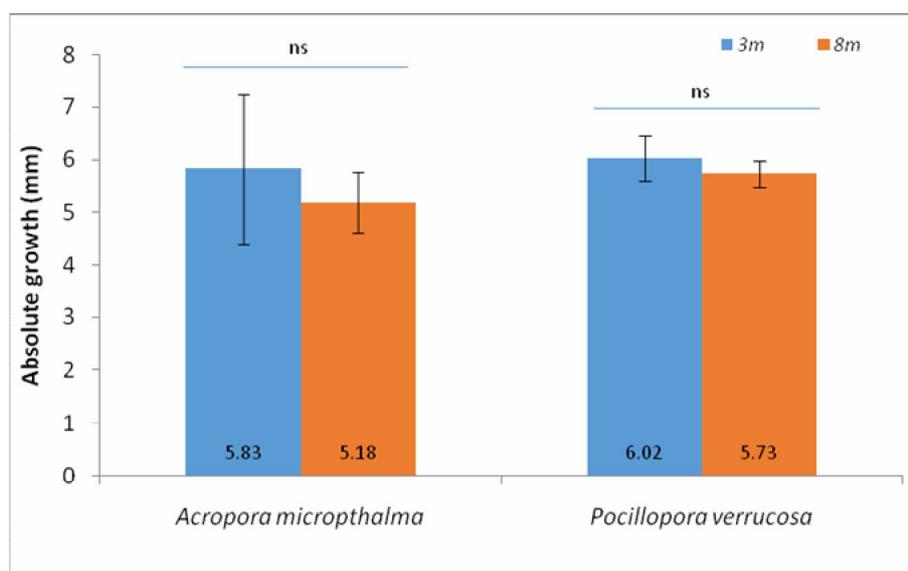


Figure 14. Absolute branch growth of *Acropora microphthalmalma* and *Pocillopora verrucosa* under biorock treatment at 3 m and 8 m depths for 2-month experiment. The ns notation above bars indicates insignificant difference based on t-student test at  $\alpha = 5\%$ .

The results showed that varying depth levels resulted in significant difference in the diameter growth of *Acropora* in the second month (Figure 15). In this case, the diameter growth of *Acropora* at 3 m depth was higher than that of 8 m depth. Nevertheless, there was no significant difference in the diameter growth of *Pocillopora* between two depth levels both in the first and second month. Furthermore, we found that the diameter growth of *Pocillopora* at 3 m depth seemed to be higher than at 8 m depth.

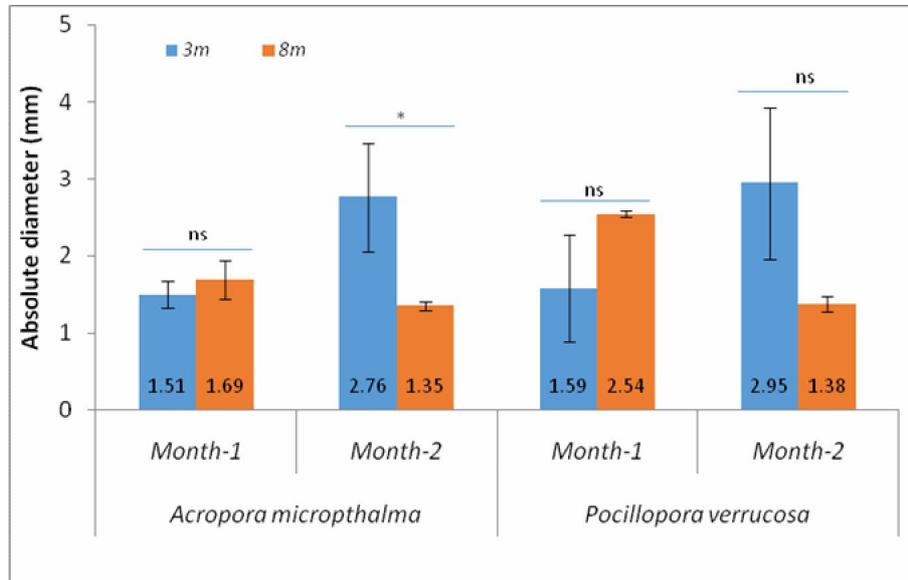


Figure 15. Absolute branch diameter growth of *Acropora microphthalmalma* and *Pocillopora verrucosa* under biorock treatment at 3 m and 8 m depths. The ns notation above bars indicates insignificant difference, while the symbol \* indicates significant difference based on t-student test at  $\alpha = 5\%$ .

Absolute diameter growth of both corals demonstrated a significant difference between two depth levels. Diameter growth of *Acropora* at 3 m depth (5.3 mm) was higher than at 8 m depth (3.04 mm) as exhibited in Figure 16. The similar result was also found in *Pocillopora*; the growth at 3 m depth was 5.73 mm, while the growth at 8 m depth was 3.92 mm.

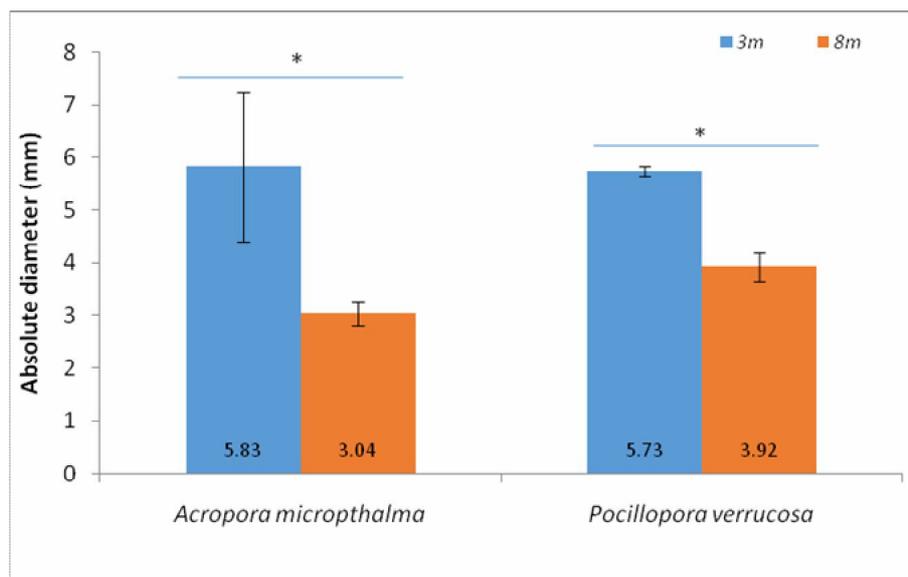


Figure 16. Absolute branch diameter growth of *Acropora microphthalmalma* and *Pocillopora verrucosa* under biorock treatment at 3 m and 8 m depths for 2-month experiment. The symbol \* above bars indicates a significant difference based on t-student test at  $\alpha = 5\%$ .

**Survival rate.** Survival rate is the number of corals alive after a specified time interval, and expressed as percentage (%). In general, the experimental corals showed a better survival rate at 3 m depth. This may correlate with the intensity of light exposure. At a deeper level, less light intensity has penetrated to the corals. The light is used by *Zooxanthellae*, which is symbiotic with corals to promote photosynthesis. Additionally, Supriharyono (2007) stated that corals generally live in coastal and marine waters shallow level where the penetration of sunlight still reaches at the bottom waters. Table 1 presents survival rate of corals for 3-month experiment.

Table 1

Survival rate of corals

Location	Genus	Survival rate (%) per month		
		July	August	September
<b>3 m depth</b>				
Biorock	<i>Acropora</i>	100	87	77
	<i>Pocillopora</i>	100	83	80
Non-biorock	<i>Acropora</i>	100	90	70
	<i>Pocillopora</i>	100	100	90
<b>8 m depth</b>				
Biorock	<i>Acropora</i>	100	83	77
	<i>Pocillopora</i>	100	87	83
Non-biorock	<i>Acropora</i>	100	100	70
	<i>Pocillopora</i>	100	80	70

In the case of 3 m depth under biorock treatment, survival rate of *Acropora* reached 77%, which was lower than that of *Pocillopora* (80%). Prior to transplantation, seed corals need to protect against the extreme temperature changes, and they should be always submerged in seawater. The location in which seed corals are taken should be close to the transplantation site (Kudus & Wijaya 2002). The coral seeds used in this study were about 5 cm in length, which may reduce the coral mortality. Coral size for transplantation affects its survival rate. As previously reported by Herdiana (2001), the use of small corals was associated with higher mortality.

In addition, similar result was also observed in 8 m depth under biorock treatment. The survival rate of *Acropora* was 77%, while *Pocillopora* showed a higher survival rate (83%). This result indicates that survival rate of experimental corals is acceptable. Harriot & Fisk (1988) found that survival rate of 50% was regarded as successful for coral transplantation.

In the case of control treatment, both corals at 3 m and 8 m depths also showed a good survival rate, which was greater than 70%. This may indicate that the water conditions in the experimental site were desirable for transplantation. However, unacceptable conditions for corals may promote stress condition, indicated by production of mucus (Supriharyono 2007). Presence of microalgae around existing corals could negatively correlated with their survival rate (Burke et al 2011).

**Water quality.** Parameters of water quality are presented in Table 2, including physical properties (lightness, temperature, current) and chemical properties (DO, pH and salinity).

Based on the data, seawater in Rubiah Island offered a desirable water quality for growth of transplanted corals using biorock technology. We found that the lightness in the study site reached 10 m (100%), which most likely improved coral growth. The lightness is closely related to the wind condition and sea wave. The research site was located near the mainland by approximately 400 m. The lightness was also associated with photosynthesis activity by *Zooxanthella*. Coral growth highly depends on the existence of *Zooxanthella* as biota that provided nutrient for coral. Furthermore, the temperature was recorded at 29°C, which was within a good range for coral growth. Supriharyono (2000) found that temperature as a limiting factor was 25-29°C, while the

maximum temperature was 36°C. Increasing temperature could induce *Zooxanthella* moving to other sites that had more ideal conditions for their growth. Meaningful changes in the temperature would affect food response, attenuate reproduction, produce mucus and retard photosynthesis (Haris 2001). The current speed within our experiment was recorded to be about 12 m s<sup>-1</sup>. This parameter highly affected coral's life through providing oxygen and better nutrition (zooplankton). Its presence was also meaningful in removing sediments present on the corals.

Table 2  
Parameters of water quality

<i>Parameters</i>	<i>Unit</i>	<i>Value</i>	<i>Standard *</i>
<i>A. Physical properties</i>			
Lightness	m	10	> 5
Temperature	°C	29	28-30
Current	m s <sup>-1</sup>	0.12	-
<i>B. Chemical properties</i>			
DO	mg L <sup>-1</sup>	8.8	> 5
pH	-	7	7-8.5
Salinity	‰	33	33-34

\* Based on Ministerial Decree of the environment for Sea Quality Standard for Marine Biota No. 51 year 2004, attachment III.

Dissolved oxygen (DO) is an indicator used to evaluate water quality. In our experimental conditions DO was recorded to be about 8.8 mg L<sup>-1</sup>. Based on Ministerial Decree of the Environment, DO must be greater than 5.0. This finding suggests that water in Rubiah Island is good for growth of corals. In addition, pH was recorded at 7.0, which was also good for coral growth. The water with pH of 7.5-8.5 could have a high productivity in corals (Wahyuni 2017). Last, salinity observed in this site was 33‰, which was in accordance with the standard of Ministerial Decree of the Environment. Nevertheless, Nybakken (2000) found that coral reefs could still survive at salinity of 25-40‰.

**Conclusions.** Absolute growth of *Acropora*, both in height and diameter, was better than that of control, resulting in a ratio of 4:1. This ratio was also found for *Pocillopora*. In addition, we found that *Acropora* showed a faster growth in comparison with *Pocillopora*. Application of biorock technology also promoted better growth of both corals compared to control. Survival rate of both corals have a diverse percentage in the range of 70~90%. The water quality in study site showed an acceptable condition for growth of corals. All parameters of water quality were in range of standard of Ministerial Decree of the Environment.

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