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Growth rate and survival rate of coral *Acropora* sp. transplanted on the artificial dead coral substrate in the waters of Baai Island, Bengkulu, Indonesia

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Abstract. *Andika D, Purnama D, Negara BFSP, Kusuma AB, Tapilatu RF. 2020. Growth rate and survival rate of coral* Acropora *sp. transplanted on the artificial dead coral substrate in the waters of Baai Island, Bengkulu, Indonesia. Ocean Life 4: 17-23.* Coral reefs are organisms that live on the bottom of the waters that are capable of producing limestone. Transplantation is a technique to accelerate the regeneration of coral reefs that can be used to protect coastal areas and marine life and improve the quality of coral habitat. This study aims to determine the survival rate, growth, and growth rate of height and width of *Acropora* sp. reared using transplantation technology. The usefulness of this research is as one of the basic information about the use of transplantation in the maintenance of coral reefs. The research location is on Baai Island at a depth of 2 m. This study used an experimental method utilizing a transplant technique and five treatments. At the end of the study, the survival rate of coral reefs *Acropora* sp. at the end of the study was 92%. For three months, the growth of coral reef height *Acropora* sp. ranged from 0.87 to 0.90 cm, while the width ranged from 0.84 to 0.94 cm. The growth rate of the average height of coral reefs *Acropora* sp. ranged from 0.72 to 0.82 cm, while the average width was 0.72 to 0.76 cm. Based on the ANOVA statistical test results, there was no difference in the growth rate in either height or width for each type of substrate used.

Keywords: *Acropora*, coral, survival rate, transplant

INTRODUCTION

Coral reefs are bottom-dwelling organisms capable of creating limestone (Kordi 2010; Tuhumena et al. 2019). Corals thrive on dead coral substrates that are sufficiently light and warm. Corals may live in waters as bright as 10.6 m and as warm as 23-25ºC (Sudiono 2008). Corals are considered to be slow-growing creatures (Muhidin 2012). Corals can grow at six to eight centimeters per year (Prameliasari et al. 2012; Tuhumena et al. 2019). Branching corals grow far faster than huge corals (Hairunizar et al. 2015; Tuhumena et al. 2019). Coral reef ecosystems are coastal ecosystems that perform important tasks and serve critical services directly and indirectly (Fadli 2009; Aditiyana 2012; Peck et al. 2021).

Coral reef ecosystems provide a dual purpose of protecting the shoreline and providing habitat for various marine species. According to Suryanti et al. (2011), coral reefs act physically as a filter, ensuring the purity of water in coastal areas and wave absorbers. In addition, coral reefs serve as nurseries, feeding sites, and spawning grounds on an ecological level (Yunus et al. 2013; Algutomo et al. 2022). Coral reefs, on the other hand, are deteriorating at the moment. According to Wilkinson (2002), coral reef ecosystems have suffered a 10% to 50% decline in the last 50 years.

Coral reefs are harmed by coastal development activities such as agriculture, coastal dredging, and explosive fishing, which are the primary causes of coral reef degradation (Haruddin 2011; Algutomo et al. 2022; Sitanala et al. 2022). As a result, additional work is required to rehabilitate damaged coral reef ecosystems.

Rehabilitation is one method of repairing damaged coral reef ecosystems. According to Callista and Sriwarno (2013), rehabilitation is the process of restoring damaged coral reef ecosystems. In addition, Priyono (2004) noted that numerous rehabilitation procedures, such as transplantation, have been used to enhance the condition of damaged or destroyed coral reefs.

Coral transplantation is a technique for accelerating coral reef regeneration that can preserve coastal areas and marine life while also improving the quality of coral habitat (Pradana 2008). Coral reef transplantation has taken place in various locations, including Enggano and Tikus islands in Bengkulu Province, Indonesia.

Currently, Mukholladun et al. (2016) researched coral reef transplanting and reported that the growth rate of the coral reef species *Goniastrea* sp. is 16.33 mm/month. According to Subhan et al. (2014), the coral reef species *Acropora pocillopora* can grow up to 1.75 millimeters every month. However, no research on coral *Acropora* sp. transplantation using artificial dead coral substrate has been conducted on Baai Island, Bengkulu Province, Indonesia.

Baai Island, one of Bengkulu Province's ports, has the potential to provide waters for the rehabilitation of coral reef ecosystems. According to a preliminary survey, the outer right side of Baai Island features healthy coral reefs. This study aims to determine the growth rate and survival rate of coral *Acropora* sp. transplanted onto a dead coral substrate in the waters off Baai Island, Bengkulu, Indonesia.

MATERIALS AND METHODS

Study area

Coral reef transplantation was carried out on Lentera Merah Waters of Baai Island, Bengkulu City, Bengkulu Province, Indonesia (Figure 1). Data analysis was carried out at the Fisheries Laboratory, Department of Marine Science, Universitas Bengkulu, Indonesia.

Method

The method in this research was the experimental method. The experimental method is research conducted to reveal a causal relationship between two variables by controlling the influence of other variables (Afriandi et al. 2012). This study used two types of substrates, artificial substrates made from a mixture of cement: dead coral and a mixture of cement: sand. This substrate consisted of 5 treatments or 5 ratios, namely, 1:1 (A), 1:2 (B), 1:3 (C), 1:4 (D) (cement: dead coral reefs) and 1:1 (E) (cement: sand). The amount of cement used was equal, but the number of dead coral reefs differed. The control substrate was made of cement and sand, with the addition of 25-30% water (Tjokrodimulyo 2007). The measurement and the growth recording were performed once a month for 3 months, and the measurement of physical and chemical parameters of waters was done twice a month for 3 months. The research station was an open area located around Baai Bengkulu Island with a depth of 3 meters.

Coral transplantation on artificial media

Shelf making

The making of the shelves was adjusted to the water conditions and the selection of materials so that the shelves were not easily damaged or dragged by the current. The shelf size was 1 m^2 and a height of 40 cm with a capacity of 28 fragments/substrate. The iron used in making the shelves was 16 mm in diameter, and the space between one substrate to another was 20 cm (Figure 2).

Substrate making

The substrates were made of cement and dead coral reefs. The amount of water for mixing the substrate was 25-30% of the weight of the cement (Tjokrodimulyo 2007). The size of the substrate had a height of 2 cm and a diameter of 8 cm. The total number of substrates was 25 pieces, consisting of 5 pieces in a ratio of 1:1 (A), 5 pieces in a ratio of 1:2 (B), 5 pieces in a ratio of 1:3 (C), 5 pieces in a ratio of 1: 4 (D) and 5 control substrates made of cement and sand (Figure 3).

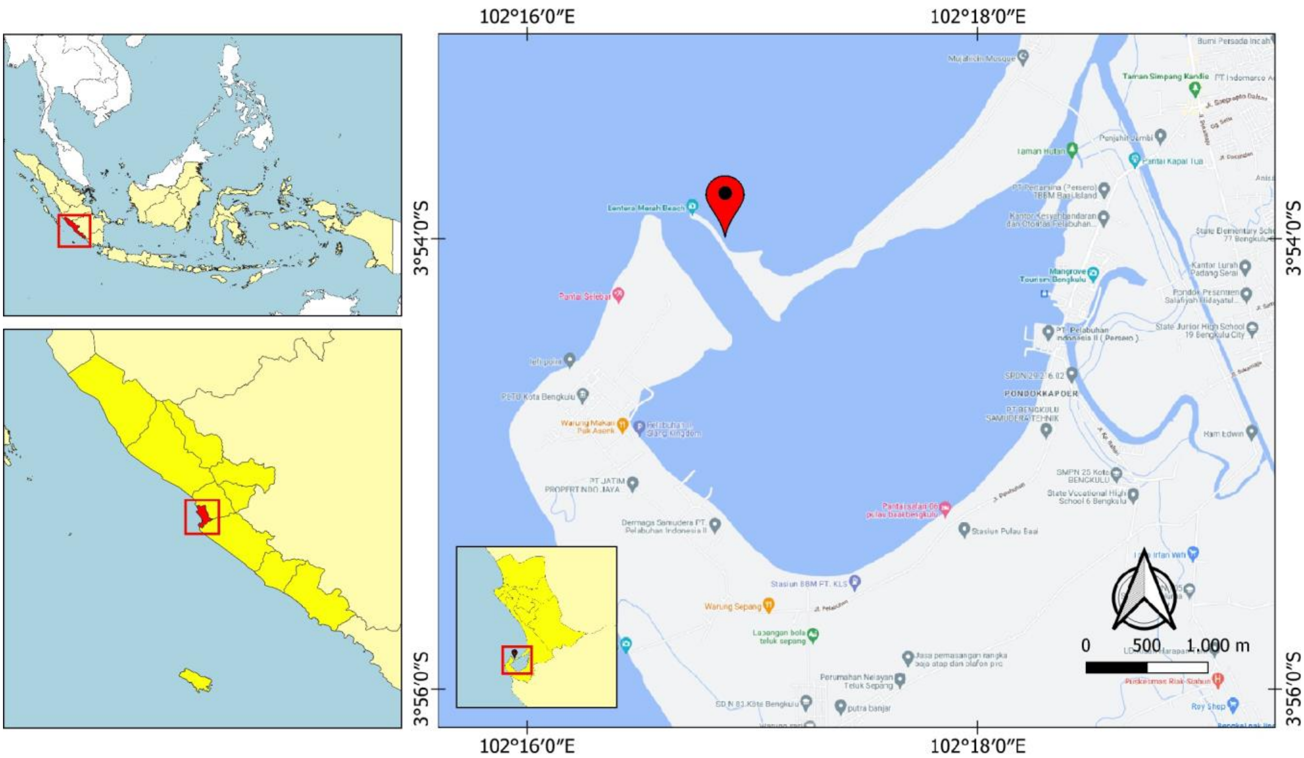

Figure 1. Map of the placement of *Acropora* sp. coral transplantation shelf transplanted on artificial dead coral reef substrate in the waters of Baai Island, Bengkulu, Indonesia

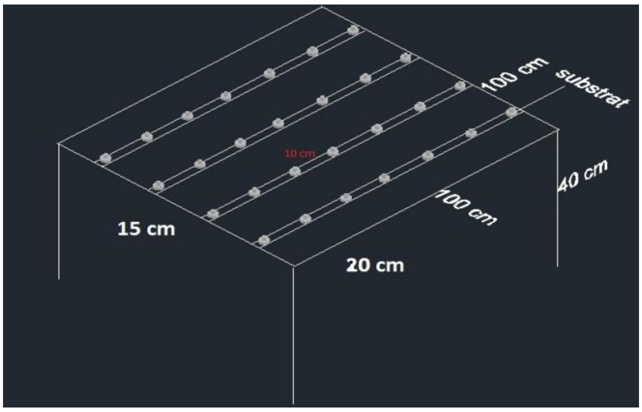

Figure 2. Transplantation shelf where the substrates of cement: dead coral and cement: sand were attached

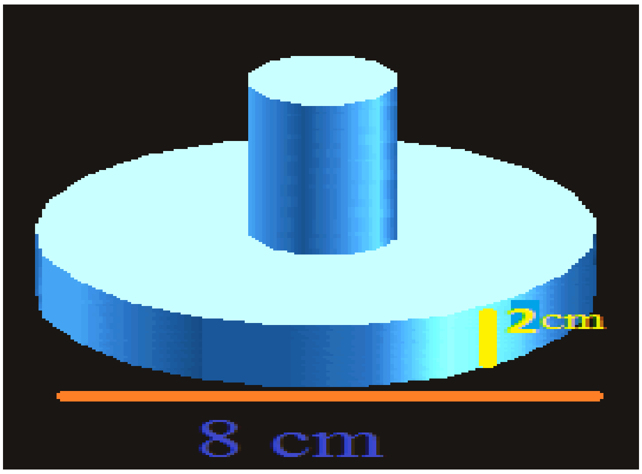

Figure 3. A substrate of a mixture of cement: dead coral reef and cement: sand

Seed retrieval

Coral seedlings were taken around the waters of Baai Island with a depth of 3 m. The studied coral reefs were *Acropora* sp.

Transplant seed attachment

The seeds were attached to the substrates of a mixture of cement: dead coral reef, and cement: sand and were tied with tirek to the pillars in the substrates so that the seeds could be arranged neatly and tightly bound.

Placement of transplant shelf

The placement of the transplant shelf at the study site was based on the availability of equipment on the transplant shelf using the SCUBA device so that there was no difficulty in performing the placement of the transplant shelf.

Measurement of coral reef growth and growth rate

Measuring growth on coral reef fragments/seedlings was carried out by measuring the growth rate consisting of the increase in the height and width of corals. Measuring the height and width of coral reefs used a vernier caliper. The width of the coral reef *Acropora* sp. was measured from the width of the growing branches. The measurement process is carried out directly in the water using the help of SCUBA equipment. Dead or bleached corals will be counted and recorded to measure coral survival. The interval of measurement of transplanted coral reefs was once a month, and the collection of the data on the growth of transplanted corals was conducted in three months (Figure 4).

Measurement of coral survival rate and growth rate

According to Sadarun (1999) to measure the growth rate and survival rate of transplanted corals uses the following formula:

Survival Rate (*SR*)

$SR = N_t / N_0 \times 100\%$

Where:

SR = Survival rate of hard corals (%),

N_t = number of transplanted corals at a certain time,

N_0 = number of transplanted corals at the beginning of the study.

Coral Reef Growth (β)

$\beta = L_t - L_0$

Where:

β = length/width growth of hard coral (cm)

L_t = length/width of hard coral at t time (cm)

L_0= length/width of hard coral at 0 time (cm)

Then the growth rate is calculated with the formula:

$$\alpha = \frac{(L_t + 1) - L_t}{(t_i + 1) - t_i}$$

Where:

α : growth rate of length or width of transplanted coral fragment

L_t+1 : average length or height of fragments at t+1 time

L_t : average length or height of fragments at i time

t_i+1 : observation at i+1 time

t_i : observation at i time

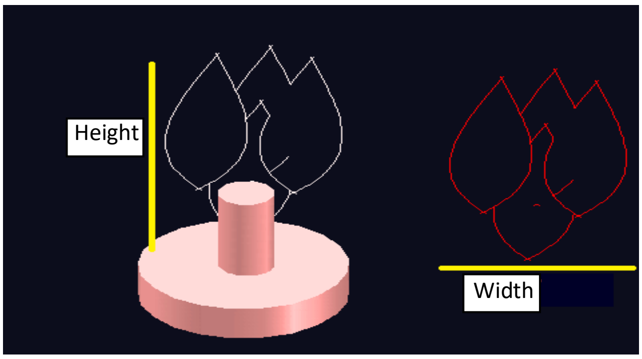

Figure 4. Measurement of coral reef growth and growth rate

Table 1. Water quality parameters

Parameter	Unit	Tool	Description
Temperature	ºC	Thermometer	In situ
Salinity	‰	Refractometer	In situ
Brightness	%	Secchi disk	In situ
Current	m/s	Parachute Meter	In situ
pH	-	pH meter	In situ
TSS	Mg/L	Filter paper	In situ

Water quality measurement

The measurement of water quality parameters is shown in Table 1.

Data analysis

In this study, the ANOVA test was used to determine growth differences between the types of treatments used in transplanting *Acropora* sp. The calculated parameters were the vertical and horizontal sizes of each fragment.

RESULTS AND DISCUSSION

Survival Rate (SR) of *Acropora* sp.

The study results on the survival rate of *Acropora* sp. showed 80% on substrates A and C and 100% on substrates B, D, and E (Figure 5). However, the release of fragments from their holder in treatments A and C caused the survival rate in these treatments to be lower than in treatments B, D, and E. The release of reef fragments corals from the module is thought to be due to strong currents and waves and human activities such as snorkeling, diving, and fishing using fishing rods. Supriharyono (2007a,b) explains that damage to coral reef ecosystems is influenced by various factors, namely biological factors, physical factors, and human factors.

Height and width growth of transplanted *Acropora* sp.

In each treatment, the measurement results of height growth of coral reef fragments of *Acropora* sp. showed an increase during three months of observation. At the end of the study, the average height growth of *Acropora* sp. ranged from 0.87-0.94 cm. The highest growth of *Acropora* sp. fragment height occurred in treatments B and C, 0.90 and 0.94 cm. In contrast, the lowest growth of *Acropora* sp. fragment height occurred in treatments D, A, and E with a size of 0.87 cm and 0.88 cm, respectively (Figure 6).

Growth rate of height and width of *Acropora* sp.

The measurement of the growth rate of coral reefs includes the growth rate of coral reef fragment height and growth rate of coral reef fragment width for three months. The results showed that the growth rate of the height and width of coral reefs *Acropora* sp. had the same increase pattern for all substrate types (Figure 7). Based on the data, the growth rate of height and width in the second month had the highest yield. Meanwhile, in the third month, the growth rate, both in height and width, decreased compared to the second month, but there was still an increase.

Water parameters

The physical characteristics of the waters play an important role in determining the suitability of the area for coral reef transplantation and are interrelated. Marine organisms have environmental requirements to live and grow well, the more suitable the conditions of the aquatic environment, the better the growth of an organism. Coral reefs are one of marine organisms that require environmental habitats to grow and reproduce. The growth of coral reefs is influenced by oceanographic factors such as physical and chemical parameters, as shown in Table 2.

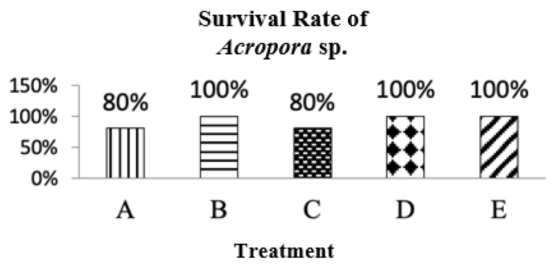

Figure 5. The survival rate of *Acropora* sp. in Lentera Merah Waters, Baai Island, Bengkulu, Indonesia; A=1:1, B=1:2, C=1:3, D=1:4 (cement: dead coral reefs) and E=1:1 (cement: sand)

Table 2. Observations of the physical and chemical conditions of Lentera Merah on Baai Island, Bengkulu, Indonesia

Parameters of the waters	Month				Average	Quality Standard
	I	II	III	IV		
Current (m/s)	0.04	0.08	0.04	0.06	0.05	-
Brightness (%)	100	100	100	100	100	-
Temperature (ºC)	32	27.3	32	31.6	30.08	28-32.5 (Syaifullah 2015)
Salinity (‰)	35.6	30.3	35.3	36	33.99	33-34 (Dhahiyat et al. 2003)
pH	7.63	8.3	7.8	8	7.93	7.7-8.4 (Supriharyono 2007a,b)
TSS (mg/L)	0.05	0.15	0.1	0.1	0.1	0.16-0.21 (Andaris et al. 2015)

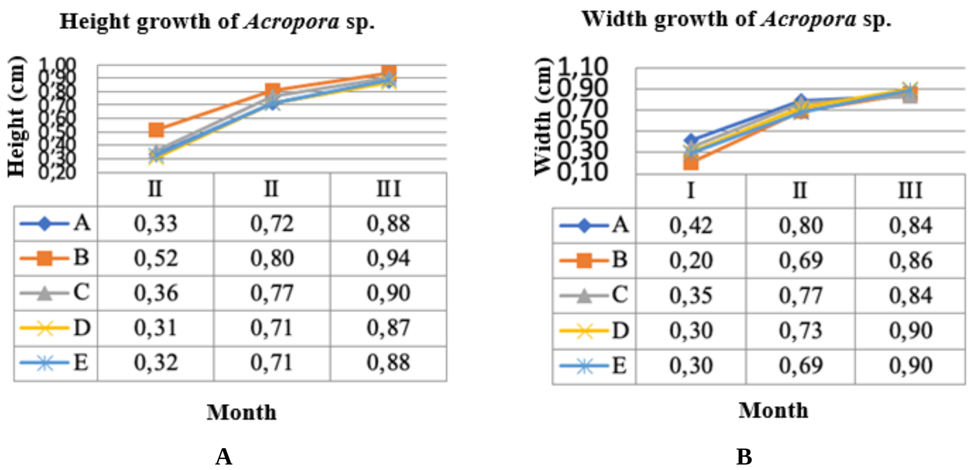

Figure 6. Growth of (A) height and (B) width of transplanted *Acropora* sp. in Lentera Merah Waters, Baai Island, Bengkulu, Indonesia

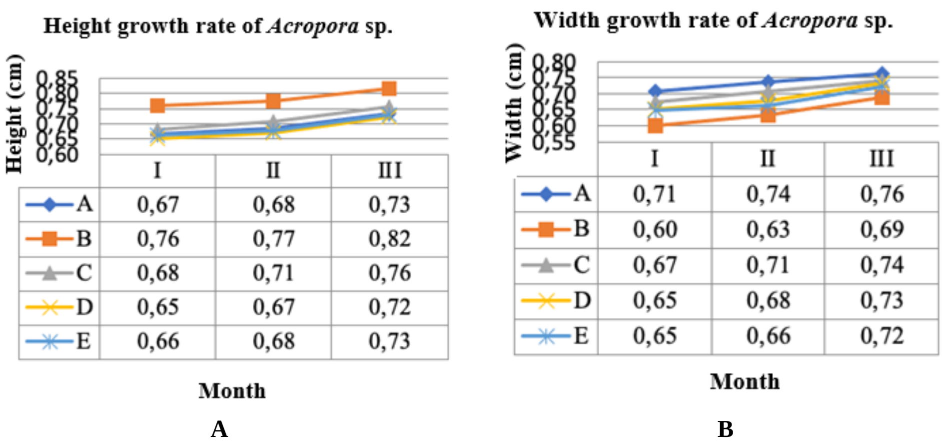

Figure 7. Growth rate of (A) height and (B) width of *Acropora* sp. in Lentera Merah Waters of Baai Island, Bengkulu, Indonesia

Discussion

Survival Rate (SR) of Acropora *sp.*

Overall, the survival rate of *Acropora* sp. of all types of treatment observed was still above 50%. Therefore, the transplant activity for coral reefs of *Acropora* sp., located in Lentera Merah, Baai Island, can be said to be successful. Harriot and Fisk (1988) in Pratama (2005) stated that coral transplantation was successful if the survival rate in most cases ranged from 50-100%, where corals were transplanted in the same or similar as their initial habitat. The survival rate of coral reefs transplanted in different habitats will be influenced by the ability of these coral reefs to adapt to their new environment.

The low survival rate of *Acropora* sp., namely 80%, in substrates A and C was caused by the detachment of the bonds of the transplanted coral fragments. It was possible because of the human factor that uses fishing gear around the research location. The results of field observations showed that many nets and fishing lines have tied up coral reef fragments. Supriharyono (2007a,b) explained that damage to coral reef ecosystems is influenced by various factors, namely biological factors, physical factors, and human factors. Human factors that can cause damage to coral reefs include mining, bombing, and the use of non-environmentally friendly fishing gear. Biological factors that can cause damage to coral reefs are the presence of predation and disease, while physical factors that can cause coral damage are an increase in water temperature.

Growth height and width of transplanted Acropora *sp.*

From the observation, the growth width of *Acropora* sp. in each treatment continued to increase from months 1-3 (Figure 6). The average growth of the *Acropora* sp. fragment width at the end of the study ranged from 0.84 to 0.90 cm. The highest growth in the width of the fragments of *Acropora* sp. was found in treatments D and E, which was 0.90 cm. The lowest growth of *Acropora* sp. fragment width was found in treatments A and C, namely 0.84 and 0.84 cm. The growth in height and width of *Acropora* sp. in the first month was lower than in the second month. It was thought to be due to an unsuitable aquatic environment parameter for coral growth, namely temperature. It was also possible because coral reefs were still in the process of adapting to the used substrate.

The low growth height of *Acropora* sp. presumably was due to many influencing organisms such as algae attached to coral reef fragments and transplantation substrates. According to Gomez and Yap (1984), algae are known to be competitors of corals in both space and light. Algae can cause damage to coral tissue and eventually the death of coral colonies

The results showed that the growth in height and width had the same pattern. However, in the first month, they were lower than in the second month. Although the low growth in the first month was thought to be due to low temperatures (Table 2), another possible cause was the adaptation process between coral reefs and the used substrate. Herdiana (2001) explains that coral reef growth takes 2-3 weeks to adapt.

In the second month, the growth of coral reefs, *Acropora* sp., increased significantly. In the second month, the coral reefs might have begun to adapt to the environment. In the third month, the growth rate continued to increase but was lower than in the second month, presumably due to a lack of energy. The energy of adapted coral reef growth was to strengthen the attachment of fragments to the transplanted substrate. According to Soedharma's (2008) statement, the energy of coral reef growth will affect the attachment of fragments to the substrate.

Growth in height and width of coral reefs in the first month with a mixture of cement substrate: dead coral and cement: sand got a small value, possibly due to environmental factors that did not match the quality standards. The brightness, temperature, salinity, and TSS had values below the quality standard in the first month. It could have an impact on the growth of coral reefs. Brightness and TSS were related to the penetration of light into water. The turbidity of the waters would reduce the incoming light. Zooxanthellae used the light entering these waters to carry out the photosynthesis process. Without sufficient light, the photosynthesis process would be inhibited, which could be a serious threat to growth (Insafitri and Nugraha 2006).

Growth rate of height and width of Acropora *sp.*

The decrease in the growth rate in height and width in the first month was thought to be due to a decrease in temperature, which was far from the optimum range for coral reefs to grow, namely 28-32°C (Syaifullah 2015). The maximum growth rate of height and width of *Acropora* sp. occurred in the third month, possibly due to the decrease of factors affecting the growth rate, such as the adaptation stage to the environment and the substrate in which coral reefs live. Overall, the growth rate of height and width of *Acropora* sp. continued to increase from months 1-3.

At the end of the observation, the highest growth rate for height was found in treatment B (cement: dead coral reefs) and C (cement: dead coral reefs), i.e., 0.82 cm and 0.76 cm, respectively. The lowest growth rate was found in treatments A, D, and E, namely 0.72 cm and 0.73 cm. At the end of the observation, the highest increase in width growth rate was seen in treatments A, C, D, and E with 0.76 cm, 0.74 cm, 0.73 cm, and 0.72 cm, respectively. At the same time, the lowest width growth rate in the final observation was in treatment B with 0.69 cm. The results of this study were lower when compared to Aditiyana's (2012) study, which got an average height growth rate of 1.04-2.69 cm/2 months.

The result of the calculation using the ANOVA test showed Fcount was smaller than Ftable, namely 4.20 < 5.31, then H0 was accepted. It showed no difference in the growth rate in either height or width for each type of used substrates. The average measurement of the growth rate of height and width for each type of substrate showed no different results.

Water parameters

The results of the current velocity measurement obtained an average value of 0.05 m/s (Table 2). This result was higher when compared to Insafitri and Nugraha (2006) finding that the current velocity in small island waters was 0.04 m/s. The currents from the observations could be suitable for the growth of coral reef transplants. These results indicated that the current strength at the study site supported the rate of coral reef growth. The results of the brightness measurement at the research location with a depth of 2m obtained an average value of 100% (Table 2). This result was higher when compared to research by Rasyid (2005) in Karimunjawa waters that obtained a brightness value of 71%. The observed value in the waters of Baai Island is much better for coral reef transplantation than in Karimunjawa waters. Brightness was one of the supports for the growth of coral reefs. The results of these observations indicated that the brightness at the study site supported the rate of coral reef growth.

The average temperature obtained during the observation was 30.08ºC (Table 2). This result is almost the same as the result in the study of Syaifullah (2015) conducted in the waters of Meranci Island with a temperature value of 31ºC. The result indicated that the temperature at the study site supported the growth of coral reefs. According to Supriharyono (2007a,b), the temperature range (30-31ºC) is the ideal temperature to help coral reefs grow optimally. Therefore, the temperature is one factor in determining the feasibility of coral reef cultivation sites. The results of the observations showed that the temperature value was categorized as supportive of the growth rate of coral reef transplants. Based on the measurement of salinity at the study site, the average value was 33.99‰ (Table 2). The result was higher when compared to the study of Wildanun et al. (2016) in the waters of Mandingin Island, with a salinity value of 32‰. According to Dhahiyat et al. (2003), the stable salinity value as a place for transplanting coral reefs is 33-34‰. The results of this observation indicated that the salinity at the study site supported the growth of coral reefs.

The result of the degree of acidity (pH) obtained during the observation was an average of 7.93 (Table 2). This result was higher than Cahyadi's (2001) research in Pari Island waters, with a pH value of 7. Although the pH value in this research location was higher than the study result by

Haris et al. (2017), the pH value from observations could be suitable for the growth of transplanted coral reefs. These results indicated that the pH of the water at the study site could support the growth of coral reefs. The results of the average TSS measurement obtained during the study were 0.01 mg/L (Table 2). This result was lower than the study result by Andaris et al. (2015) in Pari Island waters with a value of 0.16 mg/L. These results indicated that the value of the water parameters at the research site could support the rate of coral reef growth.

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