JURNAL PERIKANAN
UNIVERSITAS GADJAH MADA
Terakreditasi Ristekdikti No: 158/E/KPT/2021

ISSN: 2502-5066 (Online)
ISSN: 0853-6384 (Print)
Vol. 23 (2), 105-116
DOI 10.22146/jfs.68510

Stylophora pistillata: Effect of Fragment Size and Water Depth on Growth Rate of Transplanted Coral

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Submitted: 22 August 2022; **Revised:** 17 October 2022; **Accepted :** 10 February 2023

ABSTRACT Coral transplantation activities are carried out as conservation efforts to save coral reef ecosystems and the species that live and depend on these ecosystems. In its implementation, knowledge regarding effective and efficient transplantation methods is required. The aim of this research was to determine the effect of fragment size and water depth on the growth rate of transplanted *Stylophora pistillata* at Serangan Beach. By knowing this, coral transplantation activities can be carried out effectively. Field research was carried out from November to April 2022 using the Randomized Block Design method with two factors, namely depth variation (1 m, 3 m, and 5 m) and initial fragment sizes (3 cm, 5 cm and 7 cm). This study used 135 fragments of *Stylophora pistillata*. The analysis showed that the fragment sizes of 3 cm, 5 cm and 7 cm had significant differences in the rate of coral growth. However, based on the depth variation, only the depth of 1 m differed significantly from the other two depths. The best coral growth rate was observed in corals using an initial fragment size of 7 cm which was transplanted at a depth of 1 m with the highest average growth rates of 0.93 cm/month (height) and 0.79 cm/month (width). Based on the results, it was also known that the number of corals remaining at the end of the study was 265 fragments so the value of survival rate from transplantation activities was 97.78%. Maintaining environmental water conditions and carrying out maintenance and cleaning corals from algae and sedimentation needs to be carried out intensively to maintain the survival rate on Serangan Beach.

Keywords: Serangan Beach; survival rate; transplantation; water environmental conditions

INTRODUCTION

Indonesia has high potential aquatic biodiversity to be utilized, including coral that have very high economic and ecological value (Zurba, 2019). However the high value of coral reefs is accompanied by high threats, especially due to pressure from human activities (Ferrigno *et al.*, 2016). This condition is feared to threaten the existence of coral reefs and species that depend on these ecosystems. Therefore, in order to prevent further damage to coral reefs, conservation efforts need to be carried out, one of which is through controlled breeding activities or known as coral transplantation activities (Subhan *et al.*, 2014; Hadi *et al.*, 2018).

Besides being able to repair damaged coral reef ecosystems and repair coral reefs, coral transplantation activities is believed can fulfill economic aspects (Kasmi *et al.*, 2017). Transplanted corals have been used as aquarium decorations for export abroad. *Stylophora pistillata* is one type of coral that is in demand by foreign consumers. Bali Natural Resources Conservation Agency noted that in 2020 the foreign market demand for coral species a reached 28.748 pcs /year. The corals were sent to America, Hong Kong, Paris, Singapore, China and others. This coral is a coral with a high market demand beside the *Acropora* sp, because these corals have beautiful colors and shape (Bali Natural Resources Conservation Agency, 2020). Suharsono *et al*. (2013) stated that there are several factors that must be considered in coral transplantation activities. Site selection by considering aquatic environmental factors is one of an important factor that must be considered in transplantation activities. In addition, knowledge related to effective and efficient transplantation methods both in terms of initial fragment size and water depth at the transplant site is important to know. By knowing the correct transplantation method and environmental factors required, it is hoped that transplant activities carried out by business actors can be successful as well as effective and efficient. The purpose of this study was to determine the most effective initial fragment size for transplantation and the appropriate depth for the growth of *Stylophora pistillata* ornamental coral at Serangan Beach.

MATERIALS AND METHODS

Materials

The material used in this study was 135 pcs of *Stylophora pistillata* coral. The samples were cut into three different sizes, namely 3 cm, 5 cm and 7 cm. The source of this materials was taken from the parent coral belongs to PT. Aksara Bahana Abadi.

Methods

Data Collection

This research was carried out from November 2021 to April 2022 at Serangan Beach, Denpasar (Figure 1). Research activities were carried out starting from fragment preparation, coral planting, coral care, to measuring the growth rate and survival rate of corals. This study applied a randomized block design with two factors, namely initial fragment sizes variation and depth variation. Each treatment combination was repeated 15 times (Hidayat, 2021). The variables observed in this study were the environmental conditions at each water depth and the coral growth rate. The environmental condition observed were namely water clarity, temperature, salinity, pH, current velocity, and sedimentation, whereas the coral growth rate observed the length, the width and the survival rate of transplanted coral.

made of a mixture of cement and sand using coral glue (Polyster putty - Alfaglos). The fragments must be attached strongly to anticipate strong current conditions. The samples were placed on a 2 x 1 m transplant table made from iron (Figure 2[B]). The transplant tables wer placed at three different depths, namely 1 m, 3 m, and 5 m. Each coral fragment was tied by cable ties to minimize the risk of being lost due to strong currents, storm and theft. Laying the tables at theree different depths were done at the same time.

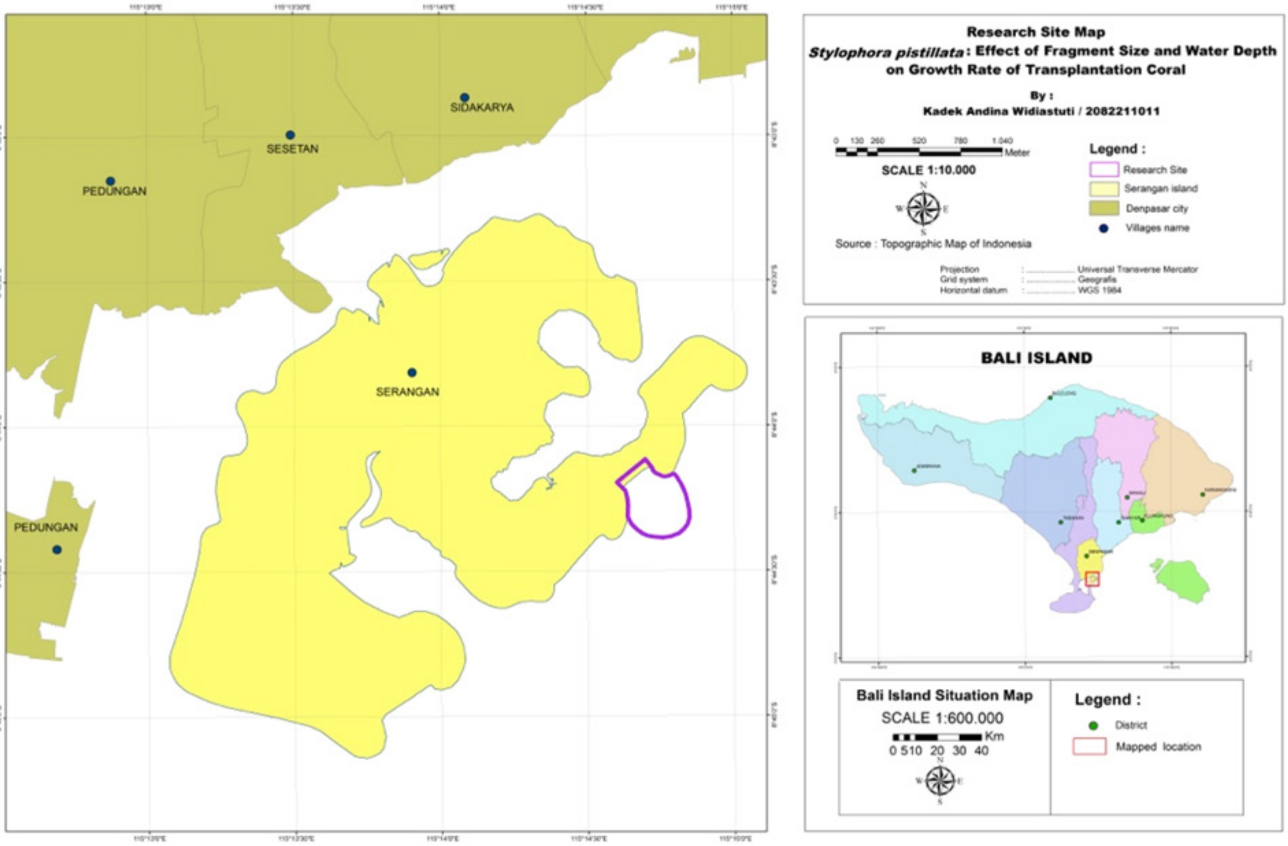

Figure 1. Research site map.

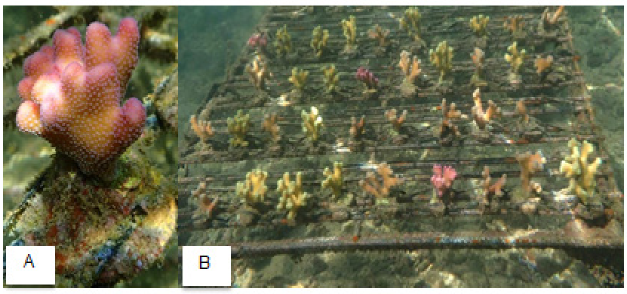

Figure 2. Coral fragment (A); the samples were placed on a 2 x 1 m transplant table (B).

The transplantation activities was carried out starting from preparation of the research sample, namely *Stylophora pistillata* (Figure 2[A]). The research samples were taken by chosing the donor colonies of *Stylophora pistillata* which has diameter more than 20 cm. These corals donor obtained from culture on 1, 3 and 5 m depth. The donor colonies were cut into three different sizes (3, 5, and 7 cm) of length, then they were attached to a substrate

Monitoring of corals was carried out every two weeks, each transplanted coral was also treated from brown algae/seaweed that can interfere with coral growth. Measurement of coral growth was carried out by measuring the length and height of the coral at the beginning of the study (T0) and at the end of the study (T_5). The growth of the length and width of the transplanted corals at three different depths were measured using a ruler and a caliper (Putra *et al*., 2020). Each measurement was repeated twice. Measurements at shallow depths (1 m) were carried out using a snorkel, while at deeper depths (3 and 5 m) were carried out using diving equipment. Measurement of aquatic environmental conditions, namely water clarity, temperature, salinity, pH and sedimentation were also carried out when measurement of coral growth data. Corals lost/carried away by currents were recorded as dead corals.

Growth rate measurement

The growth rate of transplanted corals was obtained by the following formula (Effendi,1997) :

$$GR = \frac{Lt - Lo}{t}$$

Description :
GR = Growth rate (cm/month)
Lt = Coral length at time t (cm)
Lo = Coral length at the beginning (cm)
t = Research time (month)

In addition to the growth rate, coral's survival rate also needs to be known in this study. Coral transplantation can be said to be successful if the survival value is above 50% (Suharsono *et al*., 2013). The method used to calculate the level of coral survival is as follows (Sadarun, 1999):

$$S = \frac{Nt}{No} \times 100\%$$

Description :
S = Survival rate (%)
Nt = Number of living fragment corals at the end of the study (pcs)
No = Number of living fragment corals at the beginning of the study (pcs)

Statistical analysis
After the data was collected for 5 months, then it was analyzed using One Way Analysis of Variance (ANOVA) Test. The dependent list observed were the growth rate and the factor were treatments (differences in fragment size and water depth). The test was then continued with the Tukey test to determine the best effect of several factors (differences in fragment size and water depth) on coral growth (Sadarun, 1999).

RESULT AND DISCUSSION

Water environmental conditions
Environmental conditions are an important factor for the growth of transplanted corals (Barus *et al*., 2013). Corals are known to be able to grow optimally under certain conditions, depending on the type of coral. Coral growth will be good if the water conditions are good (Suharsono *et al*., 2013). The water qualities at three different depths during the study are shown at Table 1.

Table 1. Average measurement of aquatic environmental conditions at three different depths (± Standard error).

No.	Parameters	1m	3m	5m
1	Water clarity (%)	100.00±0.000	100.00±0.000	95.00±0.000
2	Temperature (°C)	29.50±0.428	28.83±0.307	28.17±0.307
3	Salinity (ppt)	35.00±0.258	34.83±0.167	35.17±0.211
4	pH	7.95±0.022	7.98±0.017	7.98±0.017
5	Sedimentation**	659.33±5.506	732.33±5.469	743.33±4.455
6	Current velocity (m/s)**	0.14±0.005	0.11±0.003	0.11±0.003

Coral growth is not only influenced by tides, water depths, currents and waves, but is also influenced by several other physical and chemical limiting factors such as water clarity, temperature, salinity, pH, and sedimentation (Suharsono *et al*., 2013). Water clarity is a measure of the clarity of the waters. Fachrurrozie *et al*. (2012) in his research stated that light intensity, water clarity, and zooxanthellae has a positive correlation, which means that the relationship with zooxanthellae will be directly proportional to water clarity and light intensity. It was further explained that the clearer the waters, the greater the light intensity so that the abundance of zooxanthellae on a coral will increase. Thus, the efficiency of coral growth will be better (Fachrurrozie *et al*., 2012; Subhan *et al*., 2012). The brightness of the waters is also influenced by weather conditions, time of day, suspended solids, and water depth. Waters that have high clarity values will usually be seen when the weather is sunny and at shallower depths. When the weather is clear, the water looks clearer. This means that there are less of suspended materials in the water (As-Syakur, 2016; Mainassy, 2017). Water clarity is also related to the presence of particles in the air column. The higher the number of dissolved particles in a water, the more turbid the water will be. This can cause the growth and life level of corals to be stunted (Koniyo, 2020). In this study, it was found that water clarity at a depth of 1 m and 3 m was 100%, which means that light penetration reaches the bottom of the water and this is good for coral growth.

Temperature is known to be a limiting factor for coral growth (Juhi *et al*., 2018). Rohata *et al*. (2020) stated that in tropical areas such as Indonesia, seawater temperatures tend to be more stable. Corals can grow well in tropical areas that have stable temperatures (Balumpapung *et al*., 2022). It is known that corals can grow optimally in waters with temperatures in the range of 23°C - 30°C. Corals can still tolerate a maximum temperature of up to 36°C - 40°C, and a minimum temperature of 16°C – 17°C (Nybakken, 2018). Based on the results of the study, it is known that the temperature range is still in a good category for *Stylophora pistillata* transplanted at from November – April 2022. Sidabutar (2019) states that depth is one of the factors that can affect water temperature. Based on research conducted in the waters of Prigi Trenggalek Bay, the coefficient of determination of the temperature variable to depth is 0.63. This means that the temperature is affected by the depth of the water, where the temperature value decreases with increasing depth. This is in line with research conducted at Serangan beach, the lowest average temperature value at three different depths is seen at a depth of 5 m which is the highest depth in the study. However, the temperature difference is not too significant, this is related to its location which is still in one zone, namely the photic zone. Sartimbul *et al*. (2017)

mention that the average temperature in the photic zone has almost no significant difference.

Salinity is another important factor in coral growth and a limiting factor for the existence of life in a waters (Kalangi *et al.*, 2013). The range of good salinity values for coral growth is 25 - 40 ppt (Supriharyono *et al.*, 2000; Kuanui *et al.*, 2015). This means that the average salinity value obtained at Serangan Beach is still in the good category for coral growth, which is in the range of 34.33 – 35.00 ppt. Salinity is usually influenced by rainfall, evaporation, river flow and water circulation (Nontji, 1993; Patty, 2013). The value of the salinity range at Serangan Beach decreased in December 2021 in line with the increase in rainfall in that month, on the contrary in April 2022 the salinity value increased along with the decrease in rainfall. This is in line with research conducted by Ompi *et al*. (2019) which states that rainfall and temperature affect the salinity value. If the rainfall is high, then the salinity value will decrease. Rizal *et al*. (2016) in his research found that the decrease in salinity values was influenced by high rainy weather at the time of data collection on the coast of Terkulai Island. Supriyadi *et al*. (2020) also stated that salinity increased in May and June which had low rainfall intensity in the waters of Paiton, Probolinggo. The increase in salinity value is related to the increase in water temperature which causes evaporation and an increase in salt content in the waters.

pH in marine waters is usually more than 7 (Patty *et al*., 2018), which means it is alkaline. Variations in pH are usually used as an indicator of the quality of waters. pH has a major influence on plant and animal life in a waters. Usually alkaline water can encourage the process of disassembling organic matter into minerals in the water which is then assimilated by plants and phytoplankton (Patty *et al*., 2018; Ompi *et al*., 2019). The pH range in Indonesian waters is generally 7 - 8.5. This is beneficial for Indonesian waters because the ideal pH limit for the growth of marine biota such as coral reefs ranges from 6.5 - 8.5. (Corvianawatie & Abrar, 2018; Barus *et al*., 2018). Based on this, the measured pH variation at Serangan Beach which is in the range of 7.95 - 7.98 can still be categorized as good for coral growth and tends to be alkaline. Acidic waters are known to inhibit calcification on coral reefs. (Yanti, 2016). Based on the results of research at Serangan Beach, it is known that the pH values at three depths do not have significant differences. The high pH value at Serangan Beach supports coral growth because coral calcification occurs well.

Current velocity has an important role in coral growth (Mardani *et al*, 2021). The speed of the currents forms a layer that attracts nutrients and food supplies, supplying corals with oxygen from the high seas (Orejas *et al*., 2019). In addition, the layer produced by water currents can also be useful for removing sediment and metabolic waste. Corals will grow well in areas with strong currents (Nontji, 1993; Schutter *et al*., 2011). Current velocity also serves to deal with changes in aquatic environmental conditions, especially acidification of sea water. Comeau *et al*. (2014) stated that coral reef communities with stronger currents had better calcification rates than communities with small currents. Currents are influenced by several things, namely wind, weather, speed and tides. The higher the depth, the lower the value of the current velocity. This has been proven by Dinda *et al*. (2012), where the energy that move the current will decrease as the water depth increases. Research at Serangan Beach also shows that the current velocity becomes low at the highest depth of 5 m. The current velocity at Serangan Beach is still good for coral growth, especially the species of *Styphophora pistillata*. These corals are corals that have massive and submassive shapes (short thickness) and require strong currents (Giyanto *et al*., 2014).

Corals grow well in clear waters (Zamani, 2015). Turbid waters can affect the penetration of incoming light. This can interfere with the rate of coral growth. Water is said to be cloudy if it contains a lot of suspended particles so that it gives a dirty/muddy color. These particles can come from mud, organic matter or other suspended particles. (Guntur, 2011; Prasetyo *et al*., 2018). Sedimentation has a negative impact on the presence of coral in the waters. Risk (2014) revealed that sediment stress can interfere coral growth, and affect morphology. Sedimentation is directly proportional to the water depth. The deeper water, the higher sedimentation value. Prayoga *et al*. (2019) stated that corals placed at the lowest level (close to the substrat) had lower coral growth rates, compared to those at higher levels. This is presumably because the position of the coral at the lowest level has the closest position to the sediment. This makes the polyps become closed and difficult to get food and nutrition. There is a relationship between current velocity, sedimentation and coral reef conditions. The stronger the current, the less sedimentation that keeps the coral reef in good condition. This is in line with the observations of Ekayogiharso *et al*. (2014) where the stations with locations that have stronger current velocity have good coral reef conditions because of their small sedimentation. Research at Serangan Beach also shows that at locations with stronger currents, the sedimentation is low.

Based on Table 1 above, it is known that the parameters at each depth have different values. However, to determine whether there is a significant difference in parameter values at each depth, a one-way ANOVA test is carried out with the hypothesis H0 = There is no difference in parameter values at the three depths, and H1 = there are differences in parameter values at each depth. Based on these results, it is known that sedimentation and water flow have a p value <0.05 so that H0 is rejected. This means that the sedimentation value and current velocity have significant differences at each depth. While the values of water clarity, temperature, salinity, and pH have $p > 0$ so that H0 is accepted, meaning that the parameter values are not significantly different at each depth. This is presumably because the distance between the depths is not too far, so the parameters are still in a small range.

Coral growth rate

Growth rate is seen by knowing coral growth (height, width) per unit time. Coral growth is known to affect the coral growth rate. The coral growth rate is usually positively correlated with coral growth, where the higher the coral growth, the higher the value of the coral growth rate. Coral growth and coral growth rate are influenced by several things including abiotic factors (water quality conditions), biotic factors (predation, competition, coral aggression), the species used, and the method applied (planting method, selection of fragment size, type of substrate used, etc.) (Tioho *et al*., 2014). Coral growth in the research conducted at Serangan Beach showed that the growth of coral width was greater than its height. This is related to the location of transplant activities carried out in relatively shallow waters with high intensity of sunlight and water clarity. This means that corals don't have to expend a lot of energy looking for upward sunlight for photosynthesis, resulting in greater growth in width. (Chow *et al*., 2019 ; Putra *et al*., 2020).

largely determined by the fragments size. This is related to the rate of regeneration and the ability of corals to escape from the sediment cover (Johan, 2001; Arisagy *et al*., 2021). Hermanto (2015) said that survival rate and coral growth is influenced by several factors, including coral physiology and its ability to respond / adapt the changes in environmental conditions. Several studies related to the effect of the initial fragment size on the growth and rate of coral growth have been carried out on several types of corals. In this study conducted at Serangan Beach, three different initial fragment sizes were used (3 cm, 5 cm and 7 cm). It was carried out to determine the most effective fragment size used in transplanted *Stylophora pistillata*. The effect of different initial fragment size on the average coral growth rate, both height and width of corals was seen in Figure 3 and Figure 4.

Table 2. Average growth rate of coral height for five months.

Depth 1 M				Depth 3 M				Depth 5 M			
Month	Fragment size			Month	Fragment size			Month	Fragment size		
	3 cm	5 cm	7 cm		3 cm	5 cm	7 cm		3 cm	5 cm	7 cm
1	0.63	0.65	0.82	1	0.48	0.68	0.66	1	0.31	0.61	0.71
2	0.59	0.66	0.79	2	0.48	0.59	0.67	2	0.33	0.50	0.63
3	0.56	0.62	0.78	3	0.46	0.59	0.69	3	0.37	0.49	0.63
4	0.56	0.64	0.82	4	0.46	0.58	0.71	4	0.40	0.52	0.64
5	0.51	0.62	0.79	5	0.42	0.54	0.66	5	0.38	0.51	0.61

Table 3. Average growth rate of coral width for five months.

Depth 1 M				Depth 3 M				Depth 5 M			
Month	Fragment size			Month	Fragment size			Month	Fragment size		
	3 cm	5 cm	7 cm		3 cm	5 cm	7 cm		3 cm	5 cm	7 cm
1	0.61	0.69	1.01	1	0.45	0.67	0.78	1	0.46	0.35	0.59
2	0.55	0.73	0.96	2	0.45	0.71	0.74	2	0.41	0.42	0.55
3	0.56	0.66	0.94	3	0.45	0.63	0.75	3	0.40	0.48	0.62
4	0.52	0.69	0.98	4	0.46	0.60	0.79	4	0.41	0.54	0.66
5	0.52	0.67	0.93	5	0.43	0.57	0.74	5	0.38	0.54	0.68

The results of measuring the growth rate of the height and width of the *Stylophora pistilla* coral which were studied for 5 months are shown in Table 2 and Table 3. From the results, it is known that the transplanted Styl*ophora pistillata* every month have positive growth. *Stylophora pistillata* coral has increased in size both in height and width from its previous size. It means that the transplanted *Stylophora pistillata* grow well in Serangan Beach.

Variations Coral growth rate is seen every month. This is caused by differences in environmental conditions and different weather. In this study, the growth rate was used to determine the effect of the transplantation method applied, namely the initial fragment size and the water depth. Initial fragment size and water depth are known to be several factors that need to be considered in coral transplantation activities.

Effect of the initial fragment size

As previously mentioned, there are several factors that can affect coral growth and coral growth rate (Suharsono *et al*., 2013). The growth and survival rate of corals is largely determined by the fragments size.

Based on Figure 3 and Figure 4, it can be seen that the size that has an average value of coral growth rate both height and width each month is seen at the highest size, which is 7 cm. The average growth rate of coral height at the size of 7 cm at the end of the study was the highest at each depth. This can be seen in the 5th month, at a depth of 1 m, the 7 cm fragment size has the highest average height growth rate (0.79 cm/month), then followed by 5 cm and 3 cm fragment sizes (0.62 cm/month and 0.51 cm/month). At a depth of 3 m, the 7 cm fragment size had the highest average height growth rate (0.66 cm/month), then followed by the 5 cm and 3 cm fragment sizes (0.54 cm/month and 0.42 cm/month). This is also seen at a depth of 5 m, the 7 cm fragment size has the highest average height growth rate (0.61 cm/month) then followed by 5 cm and 3 cm fragment sizes (0.51 cm/month and 0.38 cm/month).

This is also seen in the average growth rate of coral width. In line with the growth rate of coral height, the average growth rate of coral width at the end of the study was highest at 7 cm fragment size. This can be seen at a depth of 1 m, the 7 cm fragment size has the largest average width growth rate (0.93 cm/month), then followed by 5 cm and 3 cm fragment sizes (0.67 cm/month and 0.52 cm/month). At a depth of 3 m, the 7 cm fragment size had the highest average width growth rate (0.74 cm/month), followed by 5 cm and 3 cm fragment sizes (0.57 cm/month and 0.43 cm/month). This is also seen at a depth of 5 m, the 7 cm fragment size has the highest average width growth rate (0.68 cm/month), followed by 5 cm and 3 cm fragment sizes (0.54 cm/month and 0.38 cm/month).

Premeliasari *et al*. (2012) and Bauman *et al*. (2013) stated that better coral growth with a larger initial fragment size was possible because smaller corals allocated their energy for maintenance and wound repair to avoid stress/ death, so that the energy allocation for growth was reduced. This study is in line with this research at Serangan Beach, where the highest initial fragment size (7 cm) had the best effect on growth rate compared to the other two fragment sizes at each depth. From the results of the analysis carried out by ANOVA, the effect of fragment sizes of 3 cm, 5 cm, and 7 cm on the growth rate of coral height at each depth was significantly

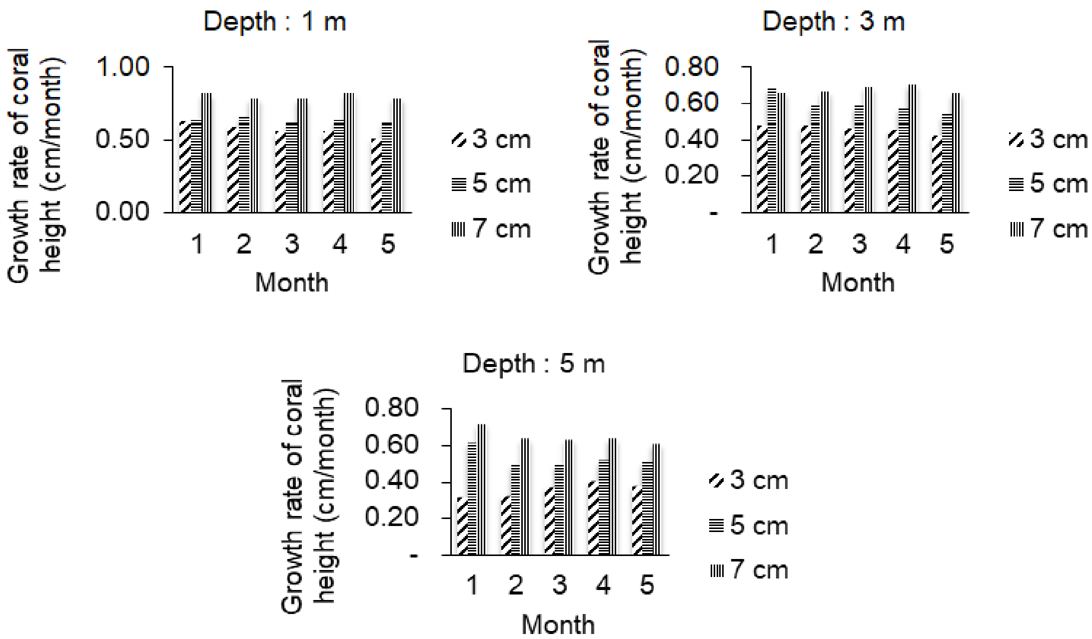

Figure 3. The effect of different initial fragment sizes on the average growth rate of coral height *Stylophora pistillata* at different depths.

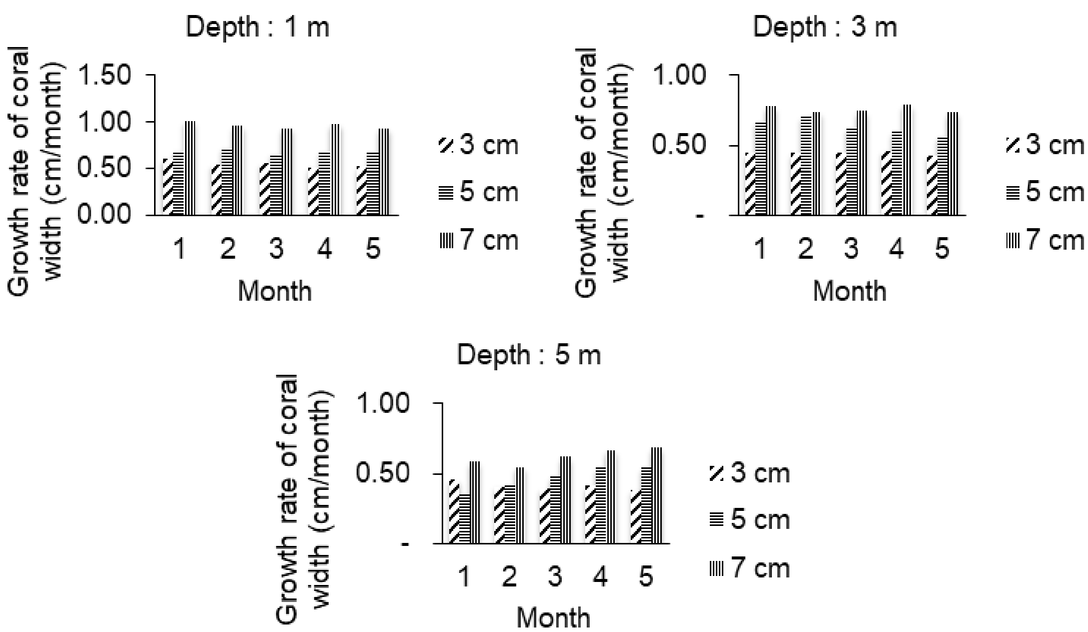

Figure 4. The effect of different initial fragment sizes on the average growth rate of coral width *Stylophora pistillata* at different depths.

different. Based on further analysis through Tukey's test (Figure 5 and Figure 6), it is known that the size of 7 cm has a better effect on the rate of growth in height and compared to the other two fragment sizes.

Effect of water depth

In this study, Stylophora pistillata was transplanted at three different depths, namely 1 m, 3 m and 5 m. This was done to determine the effect of depth on the coral growth rate. The effect of water depth on the average coral growth rate of coral height and coral width can be seen in Figure 3 and Figure 4. Based on these figures, corals that had the best average coral growth rate, both in height and width, were seen in corals planted at a depth of 1 m.

Corals with a fragment size of 3 cm planted at a depth of 1 m had the highest average height growth rate (0.51 cm/month), followed by corals at a depth of 3 m and 5 m (0.42 cm/month and 0.38 cm/month). In coral fragments measuring 5 cm, coral planted at a depth of 1 m had the highest average height growth rate (0.62 cm/month), followed by a depth of 3 m and 5 m (0.54 cm/month and 0.51 cm/month). This was also seen in corals measuring 7 cm, where corals at a depth of 1 m had the highest average height growth rate (0.79 cm/month), followed by a depth of 3 m and 5 m (0.66 cm/month and 0.61 cm/month).

Depth is also known to have a different effect on the average growth rate of coral width. The average growth rate of coral width at the end of the study was highest at a depth of 1 m. Corals with a fragment size of 3 cm planted at a depth of 1 m had the largest average width growth (0.52 cm/month), followed by corals of the same size at a depth of 3 m and 5 m (0.43 cm/month and 0.38 cm/month). Corals with a fragment size of 5 cm planted at a depth of 1 m had the highest average width growth rate (0.67 cm/month), then followed by a depth of 3 m

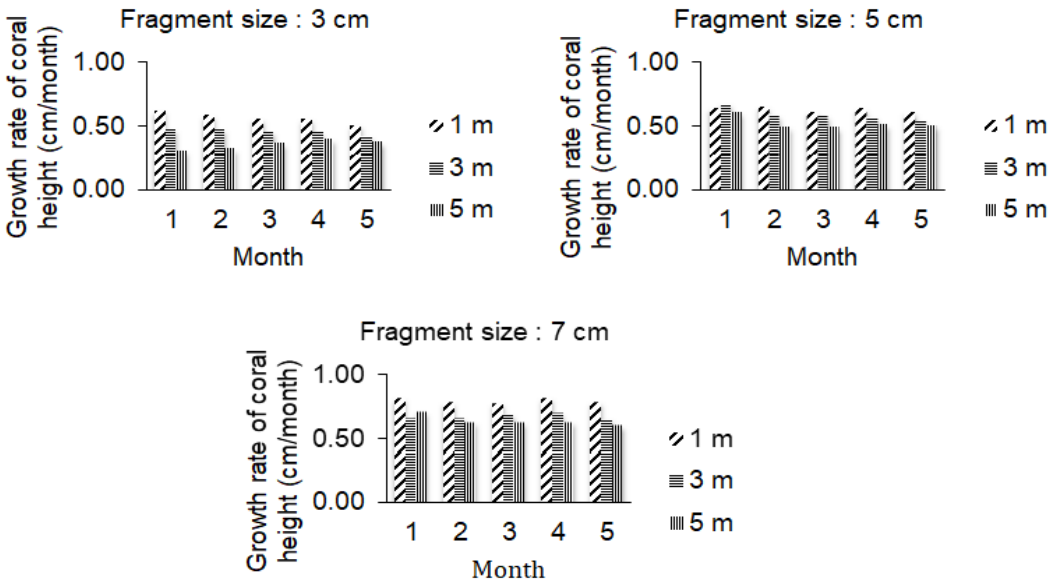

Figure 5. The The effect of depth differences on the average growth rate (height) of coral *Stylophora pistillata*.

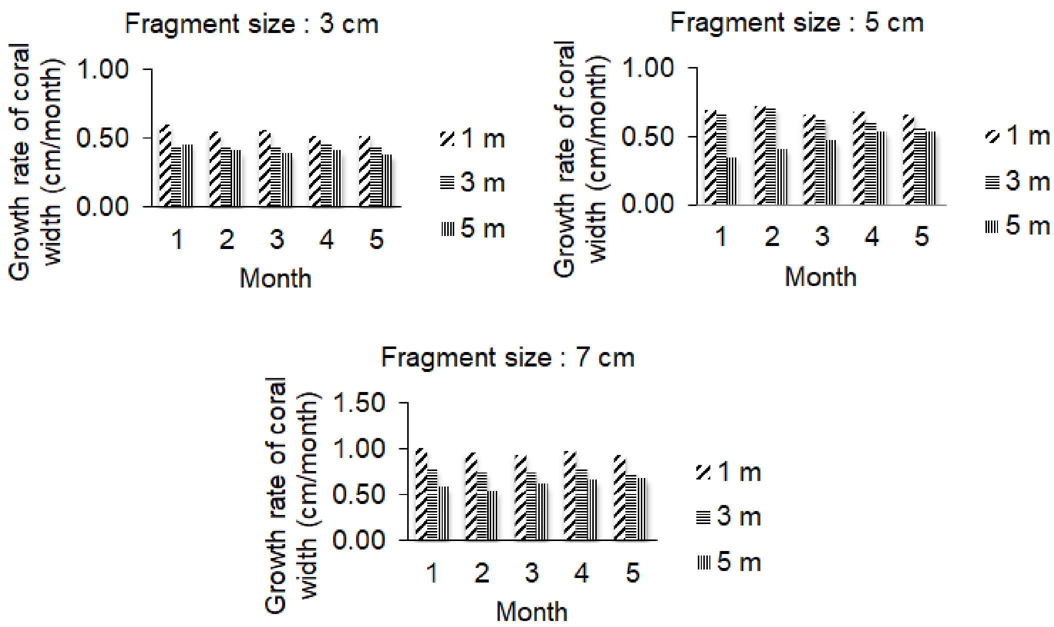

Figure 6. The effect of depth differences on the average growth rate (width) of coral *Stylophora pistillata*.

and 5 m (0.57 cm/month and 0.54 cm/month). This was also seen in corals measuring 7 cm, where corals at a depth of 1 m had the highest average width growth rate (0,93 cm/month), then followed by a depth of 3 m and 5 m which was 0,74 cm/month and 0,68 cm/month.

Water depth is related to aquatic environmental conditions such as light intensity and clarity water, current velocity, sedimentation, pH, salinity, etc. (Cohen *et al.*, 2015). The relationship between depth and environmental conditions allows coral growth at different depths. Water depth is also known to affect the morphology and shape of corals as a form of coral adaptation. Corals at shallow depths with stronger currents will usually have thicker branches, while corals at deeper depths will have thinner branches. This is in line with the type of coral *Stylophora pistillata* studied, where this type of coral has a thicker branching form, where this coral usually survives at shallow depths (Suharsono, 2008; Mass *et al.*, 2010).

In addition to affecting the morphology and shape of corals, depth also affects the growth and rate of coral growth (Ali *et al.*, 2017). In this research, it is known that the growth (both height and width of the coral) and its growth rate are influenced by water depth. Corals transplanted at a shallow depth of 1 m had better growth and growth rates than the other two depths, 3 m and 5 m. This is thought to be related to the different water conditions where the water conditions at the three depths differ significantly in terms of water currents and sedimentation. The value of the current velocity at a depth of 1 m has a greater value than the other two depths. It is known that water currents can prevent excess sedimentation which can inhibit coral growth. Sedimentation that occurs at a depth of 5 m also has a high sedimentation value. Sedimentation is known to be a fairly influential barrier to coral reef life. Besides being able to cause turbidity in the waters and causing reduced light penetration, sedimentation can also cover polyps so that corals are difficult to get food and nutrients (Dahuri *et al.*, 2001). This is in line with research conducted by Nikita *et al*. (2021), where sedimentation affects coral growth. The difference in sedimentation at that depth is influenced by the influence of current conditions. In addition, the type of substrate at each depth also affects the sedimentation. In the current research, it is known that at a depth of 1 m, the substrate at the bottom of the water is coral fragments, the 3 m substrate consists of a substrate of coral fragments and sand, while at a depth of 5 m the basic substrate is sand so that sedimentation is at a depth of 5 m higher than the other two depths.

After further analysis using ANOVA, it is known that the comparison of the effect of depth on the average growth rate of coral height at the end of the study. Based on the picture, it is known that the depth of 1 m is significantly different from the other two depths, but between the depths of 3 m and 5 m does not show a significant difference. Based on further analysis through the Tukey Test, it was found that a depth of 1 m had a better effect on the growth rate of coral *Stylophora pistillata* than the other two depths.

This can also be seen in the data analysis carried out to determine the effect of depth on the rate of growth of width on the transplanted *Stylophora pistillata* at Serangan Beach. It can be seen that there is a comparison of the effect of depth differences on the average growth rate of coral width at the end of the study. Based on this analysis, it is known that the depth of 1 m is significantly different from the other two depths, but between the depths of 3 m and 5 m does not show a significant difference. The depths of 3 m and 5 m were not significantly different, presumably due to the influence of water conditions, where the water conditions at a depth of 3 m and 5 m were also not significantly different. After further analysis through the Tukey test, it was found that depth of 1 m had the best effect on growth rate compared to the other two depths. Kambey (2013) stated that corals planted at shallow depths had the best length growth related to the ability of corals on each coral to get light to grow and photo-synthesis which caused good calcification. Succhia *et al*. (2020) stated that the number of coral larvae of *Stylo-phora pistillata* found at shallow depths was more than those found at deeper depths. This has the potential to lead to better coral growth in shallow locations. Based on the description above, it is known that the transplantation of *Stylophora pistillata* at Serangan Beach will be more effective if it is carried out at a shallow depth of 1 m.

Survival rate

The success of the transplant can be measured by knowing the survival rate of corals at the end of the study. Survival itself can be defined as coral survival to the end expressed in % units. In a study conducted at Serangan Beach, it was found that the value of survival rate at the end of the study was 97,78% (Table 4). This can be interpreted as a successful transplant activity. Suharsono *et al*. (2013) stated that the transplant activity can be said to be successful if survival rate of the transplanted coral is more than 50% at the end of the activity. At the beginning of the study the number of corals were 135 pcs, but at the end of the study there were 132 living fragments. Two coral fragments at 3 m depth competed against algae attack, while one fragment at 5 m depth was missing (presumably dead). Brown algae were found at a depth of 3 m and attached to the substrate. The algae that grew and covered coral polyps at a depth of 3 m was thought to be the cause of competition between algae and corals which resulted in coral death (Figure 7). This is in line with Dianastuty *et al*. (2016) where grass algae that attach and grow can have a big influence on growth, so the growth rate becomes negative. This shows that competition between algae and corals is a threat to coral growth. Coral cleaning is one method to prevent coral death. Coral cleaning is also carried out to clean corals from coral deposits attached to corals so that corals can grow properly (Prasetyo *et al.*, 2018).

Optimum time for coral cleaning needs to be considered so that corals can adapt and not experience stress (Bukhari *et al.*, 2021). In this study, coral cleaning was carried out every 2 weeks. This time is considered a good time for corals to adapt and not experience stress.

Table 4. Number of *Stylophora pistillata* corals at the beginning and end of the study.

Fragment size	Number of living fragments at the beginning of the study (pcs) in different depth			Number of living fragments at the end of the study (pcs) in different depth			Number of living fragments at the beginning of the study (pcs)	Number of living fragments at the end of the study (pcs)
	1 m	3 m	5 m	1 m	3 m	5 m		
3 cm	15	15	15	15	14	15		
5 cm	15	15	15	15	15	15	135	132
7 cm	15	15	15	15	14	14		
Survival Rate	$\frac{132}{135}$ x 100% = 97,78%							

Corals can be stressed and produce mucus. Nurman *et al*. (2017) mentioned that corals can experience stress when in unfavorable conditions by secreting mucus.

One fragment is missing at a depth of 5 m. This was caused by an error attachment fragments to the substrate used, so that the coral was separated from the substrate and then lost. This also happened in a study conducted by Rani *et al*. (2017) where some corals were considered dead because they were lost from the substrate due to imperfect binding techniques so the fragments became detached and lost. Based on the description above, it can be seen that it is necessary to pay attention to environmental factors, coral hygiene, transplantation methods and techniques in order to obtain a successful transplant.

Figure 7. Competition with algae causes coral death.

CONCLUSION AND RECOMMENDATION

Conclusion

The best coral growth rate was observed in corals using an initial fragment size of 7 cm which was transplanted at a depth of 1 m. The value of survival rate from transplantation activities was 97,78%.

Recommendation

Further research is needed which includes the effect of depth on the shape/morphology, color and thickness/diameter of coral branches so that the economic value and beauty transplanted corals can also increase In addition, it is necessary to know the type of algae that competes with *Stylophora pistillata* in order to find out other species that can associate with *Stylophora pistillata* in preventing competition with algae.

AUTHOR'S CONTRIBUTIONS

KAW, LPEKY, and IAA designed the research and wrote the manuscript. KAW collected and analyzed the data. LPEKY and IAA supervised all the process.

ACKNOWLEDGEMENT

This research was funded by the Ministry of Environment and Forestry.

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How to cite this article Widiastuti, K.A., L.P.E.K. Yuni & I.A. Astarini. 2023. *Stylophora pistillata*: Effect of fragment size and water depth on growth rate of transplanted coral. Jurnal Perikanan Universitas Gadjah Mada. 25 (1): 105-116. DOI https://doi.org/10.22146/jfs.77207