Jurnal Ilmu Kelautan
SPERMONDE (2021) 7(1): 7-15

P-ISSN: 2460-0156
E-ISSN: 2614-5049

ACCELERATION OF CORAL REEF RECOVERY FROM BLEACHING PHENOMENON WITH TRANSPLANTATION METHOD IN LIUKANGLOE ISLAND IN 2019

Chair Rani[1*], Abdul Haris[1], Indra Dwiantara[2],

Submitted: June 8, 2021 Accepted: July 15, 2021

[1]Lecturer of Marine Science Study Program, Faculty of Marine Science and Fisheries, Hasanuddin University.
[2]Undergraduate Students of Marine Science Study Program, Faculty of Marine Science and Fisheries, Hasanuddin University.
Corresponding Author;
*Chair Rani
E-mail: erickch_rani@yahoo.com

ABSTRACT

The aim of this study were to analyze the success of coral reef restoration techniques due to the coral bleaching phenomenon by using several forms of dead coral substrates as a transplantation technique based on the growth and survival of several types of transplanted fragments and to analyze the linkages between coral transplanted growth and environemtal factors. Growth and survival of the transplanted corals on a natural substrate with measured environmental parameters. There are three observation stations for each form of dead coral substrate (natural substrate) which will be used as an attachment medium. The area selection is based on the extent of the bleaching event at a depth of 3-5m. The technique for restoring coral reefs that will be carried out was the transplantation technique which was carried out by three methods, namely by 1) utilizing a natural substrate (dead coral as a coral attachment medium) with a massive form, 2) utilizing a natural substrate with a branching form, and 3) utilizing a natural substrate with a tabulate form. Corals used as transplant fragments were *Acropora nobilis*, *Acropora formosa*, and *Porites cylindrica*. In this study, several environmental parameters were measured, i.e., temperature, salinity, pH, and current velocity. Based on the growth and survival rate values of the *Acropora nobilis, A. formosa*, and *Porites cylindrica* species, the use of dead coral substrates (massive, tabulate, and branching) as natural substrates is equally effective in rehabilitating coral reefs due to the bleaching phenomenon. The mean value of coral growth on massive media ranged from 0.04 - 0.35 cm, Tabulate media ranged from 0.04 - 0.32 cm, branching media ranged from 0.04 - 0.20 cm, and on natural media as control media ranged from 0.08 - 0.35 cm. The survival rate of transplanted corals for 4 months of observation showed a relatively high value with general survival rates ranging from 86.67% - 93.33%. Based on the type of media used, it has the same survival value in massive media, i.e., 93.33%, while in tabulate media the survival value is around 86.67% -93.33% and *Acropora* media is around 90% -93.33%.

Keyword: Coral *Reef, coral bleaching, Acropora nobilis, Acropora formosa, Porites cylindrica,* and Liukangloe

INTRODUCTION

As an archipelagic state, the impact of El Nino in Indonesia is not just a trigger for weather anomalies. El Nino, or the South Pacific climate anomaly that last occurred in late 2015 to mid-2016, turned out to stimulate coral bleaching event. In contrast to the normal cycle, coral reef ecosystems, especially in reef flat areas, can adapt when exposed to tides. However, during the El Nino period, tidal exposure lasts for a long time which results in coral bleaching, and even coral death (Ampou, et al., 2017). Based on data from the UK's Met Office Hadley Centre, the Climatic Research Unit of the University of East Anglia, the National Oceanic and Atmospheric Administration (NOAA) and NASA's Goddard Institute for Space Studies, the World Meteorological Organization (WMO) stated that 2016 was the hottest year in history (Jogja Tribun News, 2017). The global mean temperature last year was 0.07 degrees Celsius higher than 2015. This increase in temperature also has an impact on Indonesian waters, especially in the waters of the Makassar Strait and Flores Sea, which increased from 27°C to 30°C.

Based on the results of coral reef monitoring conducted by the Marine Science Diving Club, Hasanuddin University, there has been more than 50% coral bleaching in the waters of Bira Cape and Liukangloe Island in 2016 which is thought to be caused by an increase in seawater temperature (The Jakarta Post, 2016). From the monitoring results, it was found that at a depth of 3-5 m, the bleaching impact was high and occurred at all observation points with dead coral covered with algae ranging from 35-60%. The coral genera *Acropora* and *Montipora* were the genera that experienced a lot of bleaching. *Acropora palifera* is classified as a coral that is susceptible to bleaching both at a depth of 3-5 m and at a depth of 8-10 m with the intensity of bleaching colonies ranging from 12-93%.

Liukangloe Island is located in Bontobahari District, Bulukumba Regency, precisely in the Flores Sea. This island is one of the tourist destinations in Bulukumba Regency. The occurrence of bleaching in this area causes the decrease of the underwater natural beauty because the colour of the coral reefs is dominated by white colour and algae that have grown, so this can have an impact on the interest of visitors for snorkelling and diving in these waters. Besides that, this area is also a fishing ground for traditional fishermen. As a result of the bleaching, the fish population associated with coral reefs is reduced so that it has an impact on fishermen's catches (Rani et al., 2017).

The purpose of this study was to analyse the success of coral reef restoration techniques due to coral bleaching phenomenon by utilizing several forms of dead coral substrate as a transplant technique based on the growth and survival rate of several species of transplanted fragments and to analyse the relationship between transplanted coral growth and environmental factors.

MATERIALS AND METHODS

This research was conducted in the northern waters of Liukangloe Island (Figure 1) from May to September 2019.

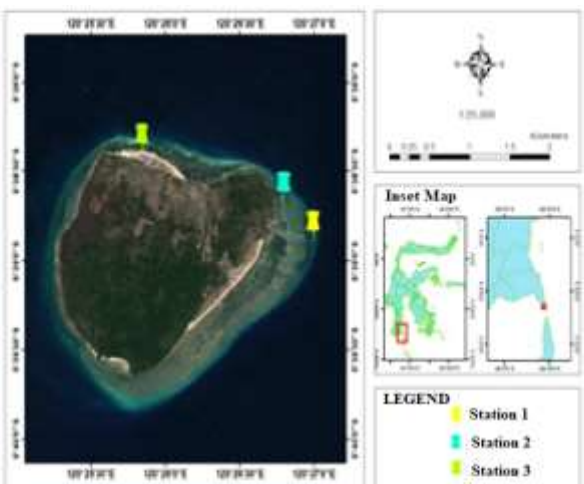

Figure 1. The location of the study in Liukangloe Island, located on the southern coast of Bulukumba Regency

Research on coral reef rehabilitation using transplantation techniques was carried out in three methods, i.e., 1) utilizing natural substrates (dead coral as a medium for coral attachment) with massive forms, 2) utilizing natural substrates with branched shapes, and 3) utilizing natural substrates with natural tabulated forms.

Transplantation Media

Natural substrate in the form of massive dead coral

This technique was appliede by first finding a natural substrate of dead coral that was suitable as a medium for attaching transplanted corals. The search for natural substrates was carried out at the points of coral reefs that experienced many deaths due to bleaching. A good substrate in the form of dead massive coral was used as an attachment medium.

After obtaining suitable substrate, the nails were used as a medium for attaching the fragments and then looking for coral species as transplants by selecting healthy corals (not exposed to bleaching) and large in size and at a depth that was relatively the same as the area to be transplanted (3- 5 meters). Corals used as transplant fragments consisted of three species namely *Acropora nobilis*, *A. formosa*, and *Porites cylindrica*. Some of the coral colonies were taken in the form of small coral fragments to be transplanted on the selected natural substrate in the area to be rehabilitated. The diameter of the fragments used was 10 cm.

The coral fragments that have been collected were then attached or tied to a natural substrate (dead massive coral) made of concrete nails that have been plugged into the substrate using plastic ropes (cable ties) with the bottom of the coral fragments attached to the natural substrate. The number of transplanted fragments was 10 fragments for each species with a spacing of 20 cm (Figure 2).

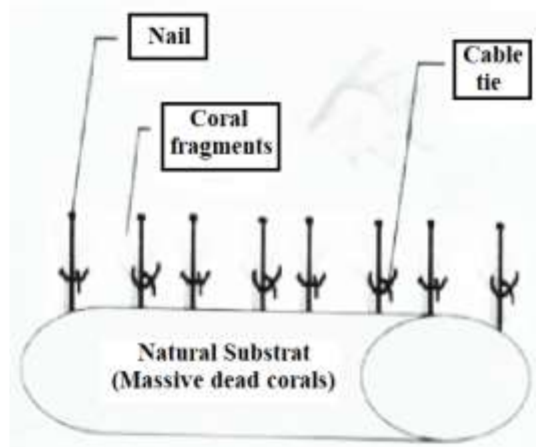

Figure 2. Transplantation technique using natural substrate (dead coral) in massive form (Haris et al, 2017)

Natural substrate in the form of branching dead coral

The species of coral used and will be attached to the natural substrate of branch coral was only branched coral. The natural substrate was chosen dead branching coral with a large branching structure.

Furthermore, live coral fragments were tied to the natural substrate on the main branch using cable ties. Selected three species of branched corals with 10 fragments each to be attached to the natural substrate with the number of areas determined as three areas (Figure 3).

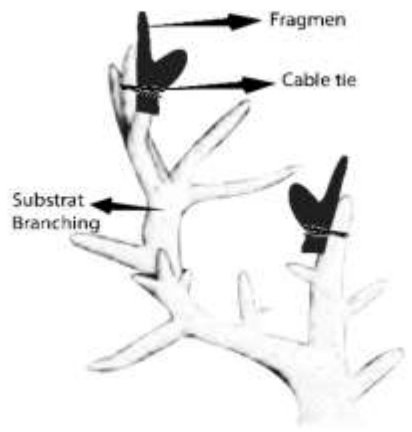

Figure 3. Transplantation technique using natural branched substrate (dead coral)

Natural substrate in the form of dead coral in tabulate shape

The substrate used was tabulated coral that had died from bleaching with a size of 2x2 m. Then the substrate is perforated at the parts to be bonded fragments, or by binding the fragments at the ends of the tabulate substrate. The number of fragments used consisted of three species of coral, each species consisting of 10 fragments with the number of areas determined was three areas (Figure 3).

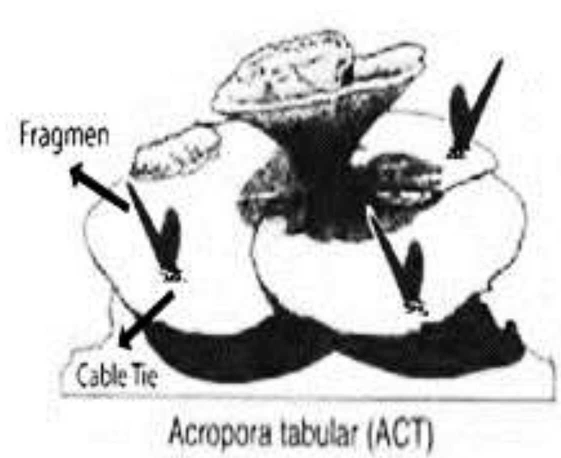

Figure 4. Transplantation technique using natural tabulate (dead coral) substrate

Measurement of coral growth and survival

Before observing the growth and survival of all transplanted coral fragments, the moss around the transplant was cleaned first. Observation to monitor coral growth and survival in each area was carried out per month for five times of observations. At the beginning of maintenance, the transplanted corals were first measured in length as the initial length using a caliper ruler. Then every month for 5 months, the length of branches, new shoots, and the number of dead coral fragments were measured. Measurements using the manual method, using a caliper ruler with the smallest scale of 0.05 cm which was carried out in the waters.

Oceanographic parameter data collection

Temperature measurement (^{0}C) was carried by dipping the thermometer directly into the water and then recording the value listed on the scale. The speed of the water currents was measured using a drift float equipped with a 10-meter-long rope. The drift float was released into the waters at the same time as the stopwatch was activated. When the string on the float had been tightened, the stopwatch was deactivated and the distance of the stretched string was calculated, and the time stated on the stopwatch was recorded.

Whereas, for salinity (‰), samples were taken from the water and then dropped on the handrefractometer and then recorded the value that was read on the scale of the tool. Measurements of the degree of acidity (pH) and turbidity of the waters were carried out at each observation station. Measurements were carried out ex situ, by taking seawater samples which were then measured using a pH meter for pH and a Turbiditymeter for turbidity in the laboratory.

Data Analysis

Absolute growth

Coral growth in a certain time can be calculated using the following formula;

$$\beta = Lt - Lo$$

β= Growth (mm), Lt = Mean height after the t-observation, Lo = Mean height at initial observation

Coral survival rate

Coral survival measurement data was calculated using the coral survival rate formula:

$$S = Nt / No\, x100\%$$

S = Survival rate (%), Nt = number of coral fragments at the end of the study, No = number of coral fragments at the initial of the study

Growth success and survival of transplanted corals

Growth and survival rate were grouped according to the type of natural substrate (massive, tabulate, and branching) used as transplant media and tested for differences in average using One-way Anova analysis of variance for each month of observation. Data processing applied SPSS software then the results of the analysis will be displayed in graphical form.

Analysis of the relationship between coral growth and survival with environmental parameters

The correlation analysis of coral growth and survival rate on oceanographic condition was analysed using Principal Component Analysis (PCA) in the XLSTAT Program. This analysis examined the magnitude of the correlation between coral growth and survival rate with the oceanographic condition of Liukangloe Island, which was presented in the form of two-dimensional graphs (Axis 1 and Axis 2).

RESULTS AND DISCUSSION

Oceanographic Conditions

The results of measurements of several oceanographic parameters are presented in Table 1. The temperature obtained in each month of observation is in the range of 26-28 ^oC. According to Hasyim et al (2010), the distribution of sea surface temperature in the waters of the Flores Sea and Makassar Strait is relatively homogeneous in the range of 28-31 ^oC. This temperature difference is due to sampling carried out at a depth of 3-5 meters so that the temperature obtained is lower than the surface temperature. This is corroborated by Nontji (2005) that the presence of high solar radiation during the day causes the surface layer of the waters to have a temperature with a mass of warm water, while based on the depth the temperature will decrease.

Table 1. Data from observations of oceanographic parameters in Liukangloe Island

Time	Temperature (oC)	Salinity (o/oo)	pH	Turbidity (NTU)	Current Velocity (m/second)
Month 1	28.33	28.25	7.62	1.22	0.08
Month 2	28.33	33.75	7.46	1.81	0.14
Month 3	26.67	34.33	7.67	0.56	0.17
Month 4	26.67	34.00	7.34	0.44	0.13

The salinity obtained is in the range of 28-34 where in the first month the salinity value is lower than the following month. This is caused by the sampling was carried out in June-September where the Makassar Strait waters experienced the east monsoon. According to Labiana et al (2017) the distribution of salinity in the east season in the waters of Makassar Strait is slightly lower (33.14 – 34.76) when compared to the distribution of salinity in the West Season (33.48 – 34.82). This is also supported by Nontji (1993) which states that the distribution of salinity in the sea is influenced by several factors such as water circulation patterns, evaporation, rainfall, and river flow.

The value of the acidity (pH) obtained from each station for 4 months of observation showed a relatively stable value in the range of 7.3-7.6 ppm. Coral reefs are

sedimentary rock structures formed from the process of calcification of calcium carbonate ($CaCO_3$) so that the value of the acidity of waters plays an important role in the process of calcification of coral reefs.

The measurement of the turbidity level of the waters at each station for each month obtained an average value of 0.44 NTU - 1.22 NTU. Based on this value, it may be classified that the turbidity value at each observation station is not an inhibiting factor for coral growth. This is supported by the provisions in Minister Decree No. 1 of 2010, which stated that marine organisms can still continuously grow and develop properly at a turbidity level of 5 – 30 NTU.

The surface current velocity measurements carried out at each station ranged from 0.08 m/s – 0.17 m/s. Based on this value, the current velocity in Liukangloe Island is classified as very fast current speed. This is based on the grouping of waters based on current speed as stated by Mason (1991) where the waters have very fast currents (>0.1 m/s), fast currents (0.05 – 0.1 m/s), medium currents (0.025 – 0.05 m/s), slow current (0.01 – 0.025 m/s) and very slow current (<0.01 m/s).

Absolute Growth

The growth of coral fragments in each transplant medium presented in Figure 5 showed a significant difference ($P<0.05$) in the 1st month of observation for *Acropora nobilis* and *A. formosa* corals, while in the next 3 months the growth did not show a significantly different value ($P>0.05$). This shows that these two species of corals have different growth values in the three transplant media plus control in the 1st month, where both species of coral and Station 2 on the 1st month so that the difference is not too distinct.

The difference in the mean growth obtained in the 1st month is different from the following month due to differences in the accuracy of the measuring instrument used, where in the initial measurement (t0) the tool used is a ruler with an accuracy of 0.5 mm while in the next month measurement using a caliper with an accuracy of 0.05 mm.

Based on the type of substrate, the average growth of the three coral species transplanted in massive media ranged from 0.04 – 0.35 cm, tabulate media ranged from 0.04 to 0.32 cm, branching media ranged from 0.04 to 0.20 cm, and in natural media as control medium ranged from 0.08 – 0.47 cm. The growth of the three species of coral in massive, tabulate, and branching media was not much different from the growth of the three species of coral in nature. Thus the use of the three transplant media does not affect coral growth because it only functions as an adhesive medium. It also shows that the transplanted corals can adapt quickly to their new environment. Taking coral fragments close to the transplant site is thought to be a factor in which the transplanted corals can adapt easily. According to Rani (1999), the environmental conditions of the transplant area, which are relatively the same as where the parent was taken, are the determining factor so that the transplanted corals do not need to spend a lot of energy to adapt to their new environment.

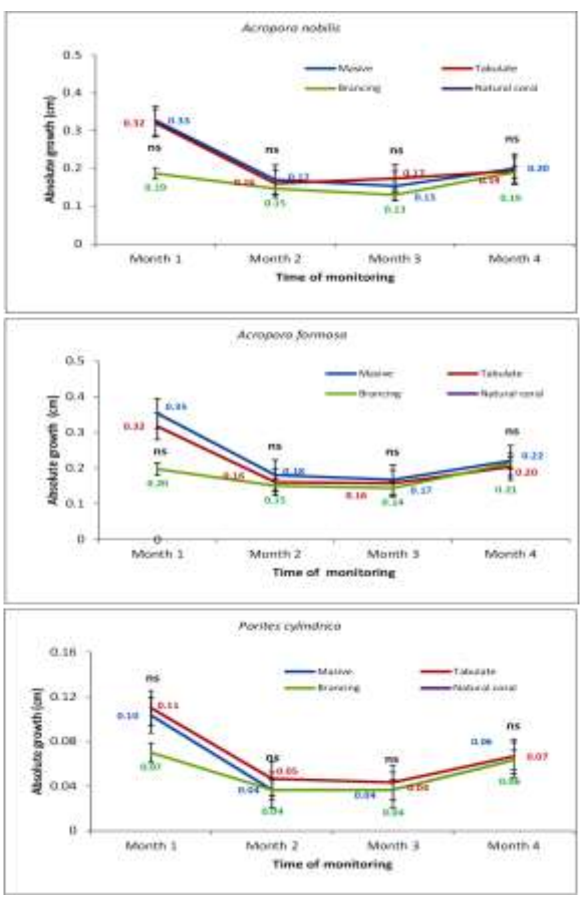

Figure 5. The absolute growth value of each species of coral in each transplantation method according to the time of observation

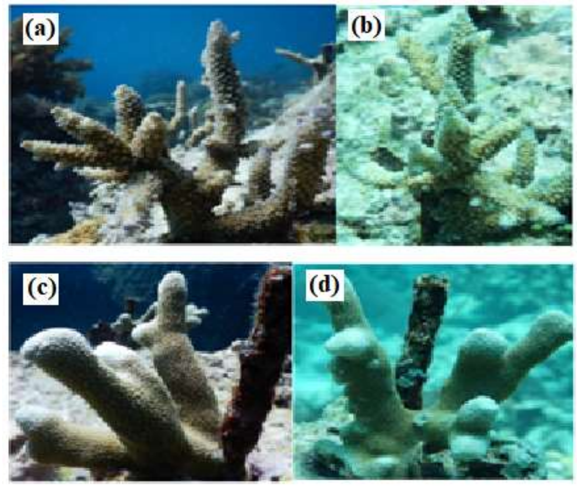

Figure 6. Coral growth of *Acropora nobilis* in 2nd month (a) and 3rd month(b) with *Porites cylindrica* coral growth in 2nd month (c) and 3rd month (d)

Based on statistical tests on the growth of the three species of coral on massive, tabulate, and branching media, there was not much difference, so it may be assumed that the use of these three media was equally effective in transplantation activities. A faster increase in length was observed for *Acroposa formosa* of 0.14 - 0.35 cm/month compared to *Acropora nobilis* of 0.13 - 0.33 cm/month and *Porites cylindrica* of 0.04 - 0.11 cm/month. When viewed from the growth point of view (Figure 6), Acropora is a species of family that has a fast growth because its calcareous skeleton structure is more porous than *Porites* which has a more massive or dense skeleton structure. Boarden and Seed (1985) suggested that the growth rate of coral skeletons varies according to species, age, habitat and growth form. Meanwhile Goreau et al, (1982) found that although temperature, light intensity and water circulation were quite uniform, different species showed different growth. Kaleka (2004) found that the colony shape of *Acropora formosa* tended to be smaller so that the increase in length experienced was relatively longer than that of *Acropora velensiennesi* and *Acropora brueggenanni* which tended to be larger.

The growth results obtained in this study were relatively the same as the results of Kembey's (2013) study on coral *Acropora* sp in Malalayang Waters, North Sulawesi, at a depth of 3 meters obtaining 0.55 cm/month. Hermanto (2015) conducted research in the waters of the Lembeh Strait for *Acropora formosa* with an observation period of four months ranging from 0.54 cm/month. Muhlis (2019) showed that the skeletal length growth of *Acropora nobilis* in Sengingi Waters, Lombok was 0.148 mm/day or 0.44 cm/month. The differences in the growth of the transplanted corals were related to the different transplantation locations which had different water conditions and the different methods used. Likewise for the three species of coral in this study which experienced differences in growth each month due to different stations and dynamic oceanographic conditions each month. According to Nybakken (1992), the growth of coral colonies can be different from each other, branching colonies tend to grow faster than sub massive and leaf shape corals.

Survival Rate

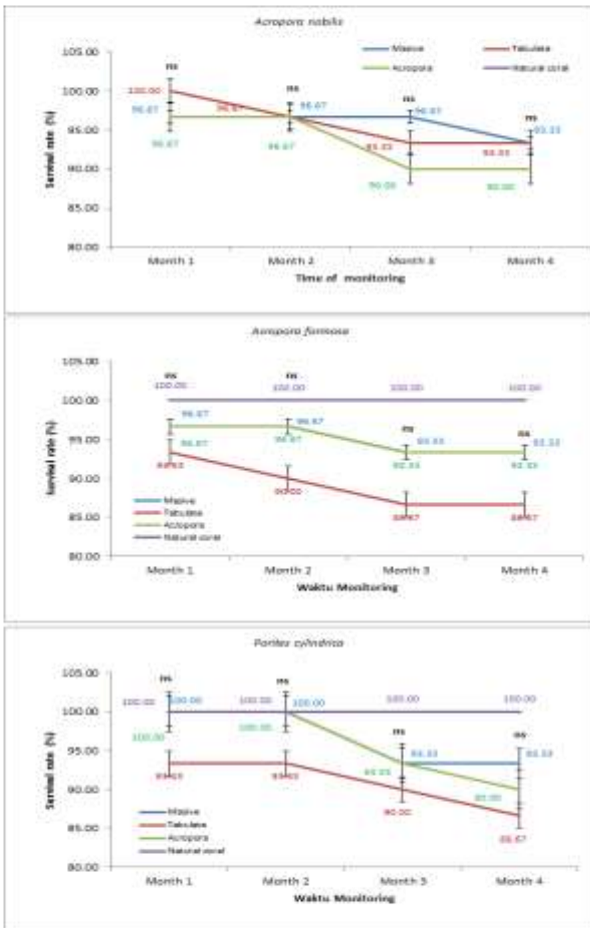

Figure 7. The value of survival rate of each species of coral in each transplantation method according to the time of observation

The results of the observations presented in Figure 7 show that the survival values in general ranged from 86.67%-93.33% during the month of observation. The three species of coral have a significance value greater than 0.05 (P>0.05), which means that each month there is no significant difference in survival rate values between massive, tabulate, and *Acropora* media. Thus, based on these statistical values, it may be concluded that the use of these three natural substrates as transplant media is equally effective.

Based on transplantation media, these three coral species had the same survival rate value in massive media, i.e., 93.33%, while in tabulate media the survival values ranged from 86.67%-93.33% and *Acropora* media ranged from 90%-93.33%. Meanwhile, based on the species of fragments transplanted, coral *Acropora nobilis* had the highest survival rate of 90%-93.33%, then *Acropora formosa* and *Porites cylindrica* 86.67%-93.33%.

This difference in survival rates was caused by the mortality experienced by the transplanted coral fragments. In addition to death in a biological sense, the release of zooxanthella from polyps due to stress was also caused by the release of coral fragments from the attachment medium (Figure 8).

This is caused by faults in the binding of fragments that are not too strong, and also because the strong current factor occurs continuously. The results of monitoring the survival rate are quite high, i.e., >85%. According to Mompala et al (2017) coral transplantation activities are claimed successful if they have a survival rate between 50%-100%.

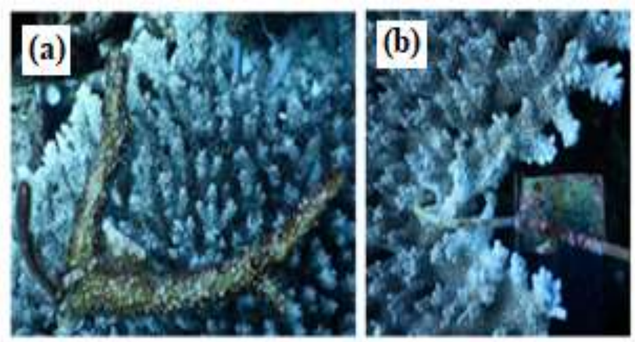

Figure 8. Coral fragments that die due to stress (a) and are released from the attachment medium (b)

However, this value is lower when compared to previous studies using the same transplant medium. The results of research by Awaluddinnoer (2009) using coral species of *Acropora nana* and *Acropora loripes* as transplant fragments at a depth of 3 and 7 meters obtained a survival rate value of >96%. Similarly, the results of research that has been carried out by Rani (2017) using coral species of *Acropora robusta*, *Porites cylindrica*, and *Pocillopora verrucosa* at a depth of 3-4 meters for 28 days of observation obtained a survival rate value of >95%. The use of massive media obtained a higher survival rate than tabulate and *Acropora* media, although statistically it was shown that there was no significant difference in the use of these three media. This is presumably because the structure of the massive media is larger and denser than other media, so that even though the water conditions are very dynamic with strong currents, the fragments in the massive media are less likely to be released. Coral species *Acroporoa nobilis* is the species that has the highest survival value during the observation period, which ranged from 90%-93.33%, while *Acropora formosa* and *Porites cylindrica* ranged from 86.67%-93.33%. Harriott and Fisk (1998) stated that *Acropora* corals are very suitable to be used as coral fragments for transplantation activities because they have a high survival rate and relatively fast growth.

Observations made for 4 months showed that the death of coral fragments was not only caused by biological death but also due to the release of fragments from the adhesive media so that it was suspected that errors in binding and dynamic water conditions were the cause of the difference in survival values obtained. *Acropora* has a long branching shape and larger corallites than *Porites*, so this is also a factor that *Porites* are easier to be separated from the adhesive medium. The high survival value obtained for the three species of coral was due to efforts to minimize coral stress levels at the time of transplantation. Corals that experience stress will secrete mucus (Mocus) as a form of adaptation to the environment. According to Johan in Nurman et al (2017), corals will take a long time to secrete mucus if they are in unfavourable environmental conditions for their growth. The secretion of mucus is useful for corals to protect themselves from unstable external conditions and will return to normal after these effects have worn off. Efforts were made to reduce stress on corals, namely in the process of transporting coral fragments to the transplant area by watering the transported seedlings so that corals always get water for preventing dryness of the polyps. Efforts to acclimatize were also carried out by Haris et al (2017) on transplantation of ornamental corals of *Acropora* sp. in the waters of Tonyaman Village, Polewali Mandar, by continuous watering with seawater during transportation. This effort is supported by the location of seed collection which is close to the transplant location so that the process of transporting seeds is easier and does not require a long time. This is in accordance with the statement of Nurman et al. (2017) that the success rate of coral transplantation survival is due to the location of planting (transplantation) not far from the location of taking seeds (fragment) which is adjusted to its depth. So that the adverse effects due to environmental changes, especially depth and water quality parameters do not have much effect on the transplanted specimens. Kaleka (2004) also emphasized that the seed sample taken not far from the research location would make it easier for corals to adapt so that coral seedlings did not experience much stress.

Correlation of coral growth and survival to environmental parameters

The results of the Principal Component Analysis (PCA) test show that there were 2 moon groupings based on the growth of the transplanted corals. Group 1 was in quadrants I and II which came from observations of months 2, 3, and 4 which were characterized by low growth of the three species of transplanted corals associated with current velocity and high salinity. Meanwhile, group 2 was in quadrant III which came from the observation of the 1st month which was characterized by high growth of the three transplanted coral species with low current velocity and salinity. Differences in current velocity and salinity are very striking characteristics of these two groups, while other parameters such as temperature, pH, and turbidity show relatively similar values during the observation period.

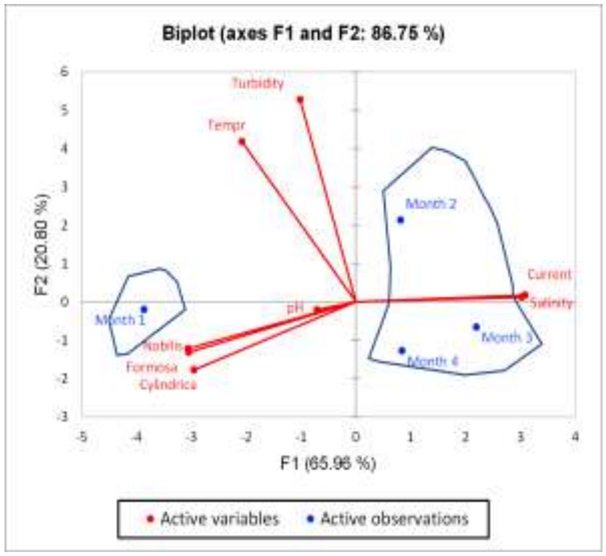

Figure 9. Correlation of coral growth and survival to environmental parameters

Dynamic water conditions cause transplanted corals to require a lot of energy to build a skeleton, known as the calcification process. The current velocity obtained in the 2nd to 4th month is very fast ranging from 0.13 - 0.17 m/s, this is considered to cause the corals tied to the transplant medium to experience friction so that the corals have to adapt by building a larger framework. According to Daniel (2015) that hydrodynamic factors such as waves and currents will cause horizontal changes, the stronger the currents and waves, the coral will grow shorter, stronger and creeping, while in protected areas tend to be slimmer and elongated.

The high salinity value obtained in the 2nd month causes corals to need to adapt to prevent excessive discharge of fluids in their bodies. The difference in salinity causes corals to experience pressure in receiving incoming fluids so that if the salinity is lower than their tolerance range, the corals will lack fluids so that not many nutrients enter and vice versa if the salinity is higher, it will cause the fluids in their bodies to come out.

According to Marsuki (2012), salinity is one of the important factors in aquatic ecological conditions, salinity will affect the osmotic pressure in the organism's body so that the organism will expend energy to be able to adapt to its environment through osmoregulation mechanisms. According to Eliza (1992), the ideal salinity for coral growth and development was between 25-40.

CONCLUSION

In terms of the growth and survival rate values of coral species *Acropora nobilis*, *A. formosa*, and *Porites cylindrica*, the use of dead coral substrates (massive, tabulate, and branching) as natural substrates is equally effective in rehabilitating coral reefs due to the bleaching phenomenon. The average value of coral growth on massive media ranged from 0.04 – 0.35 cm, tabulate media ranged from 0.04 – 0.32 cm, branching media ranged from 0.04 – 0.20 cm, and on natural media as control medium ranged from 0.08 – 0.35 cm. The survival rate value of transplanted corals for 4 months of observation showed a relatively high value with general survival values ranging from 86.67% - 93.33%. Based on the type of media used, the survival value for massive media was 93.33%, whereas for tabulated media the survival values ranged from 86.67%-93.33% and *Acropora* media ranged from 90%-93.33%. The correlation of coral growth and survival with environmental parameters showed that current velocity and salinity were very striking characteristics for the growth of transplanted corals in Liukangloe waters, while the parameters of temperature, pH, and turbidity showed relatively similar values.

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