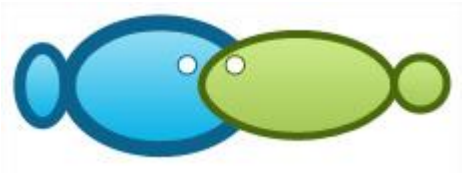

Analysis of transplanted coral growth using the rock pile method in Karimunjawa National Park, Central Java, Indonesia

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Abstract. The condition of coral reefs in Indonesia is experiencing high degradation. Human factors have contributed more to the coral reefs damage than natural causes. Coral transplantation is an effort made to rehabilitate coral reefs by cutting live coral to accelerate the regeneration process of damaged coral reefs, to support population availability. The purpose of this study was to transplant corals *Acropora formosa* and *Acropora aspera* using the rock pile method, namely the use of dead coral as a natural substrate. The research was conducted in Legon Lele waters, Karimunjawa, Central Java, Indonesia. We were able to observe and collect data on the growth rate of corals and the survival rate of transplanted corals. Based on the results of the study, it can be concluded that corals *A. formosa* and *A. aspera* experienced positive growth in 3 months. The absolute growth height of *A. formosa* was 13.04 cm, while that of *A. aspera* was 7.74 cm. The average growth rate of *A. formosa* and *A. aspera* were 4.3 and 2.5 cm month^{-1}, respectively. The survival rate until the end of the observation of *A. formosa* was 93.3%, while for *A. aspera* it was 90%. Based on these results, the transplant was considered successful.
Key Words: coral reef, coral rehabilitation, degradation, transplantation.

Introduction. Coral reefs are one of the main components of the marine coastal ecosystems, in addition to mangrove forests and seagrass beds. Coral reefs and all marine life are also represent natural resources. The condition of coral reefs in Indonesia is experiencing degradation. Human factors contributed more to the coral reef damage than natural causes (Praveena et al 2012). Fishing with bombs is an example of the destructive activities. The natural repair process of damaged coral reefs is slow. According to Yunus et al (2013), the typical restoration of coral reefs takes a very long time. However, there are many known methods for coral reef rehabilitation, one of which is the coral transplantation method.

Coral transplantation is one of the efforts to rehabilitate coral reefs through grafting or cutting live coral, which is planted in other places that are damaged or can create new habitats on vacant land. According to Clark (2002), the benefit of coral transplantation is expediting the regeneration process of damaged coral reefs to enable them to support the availability of the population.

The natural repair process on coral reefs requires not only a long time but also adequate environmental conditions. The transplantation method carried out generally uses an artificial substrate. The use of artificial substrates in the current conventional coral transplantation methods is uneconomical, requiring a relatively large cost due to the materials to produce it and transportation from the manufacturing area to the transplant site (Mustafa et al 2020). To reduce the cost of coral transplantation, the rock pile method was introduced, namely the use of dead coral as a natural substrate.

This study aims to determine the growth rate and survival rate of coral reefs from transplants with the rock pile method in Legon Lele waters, Karimunjawa, Central Java, Indonesia.

Material and Method. The study was conducted in Legon Lele Beach, Karimunjawa National Park (KNP), Karimunjawa Island, Province of Central Java, Indonesia, from March to June 2019 (Figure 1).

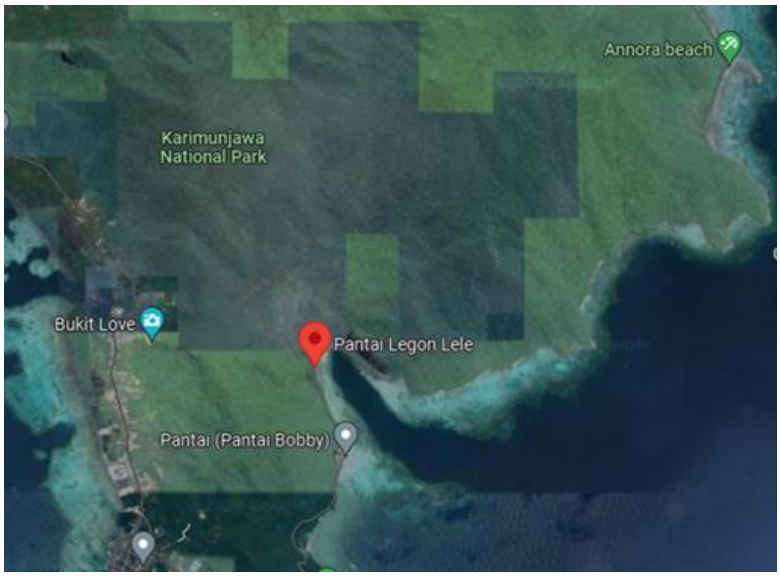

Figure 1. The study site at Legon Lele beach, Karimunjawa Island (google.maps).

Coral reef data collection. Collection of dead coral for transplant media took place on Legon Lele Beach, Karimunjawa Island. Retrieval was done by snorkeling. 26 pieces of dead coral were collected for transplant media (Figure 2). Cleaning was conducted so that algae, shells and invertebrates attached were removed.

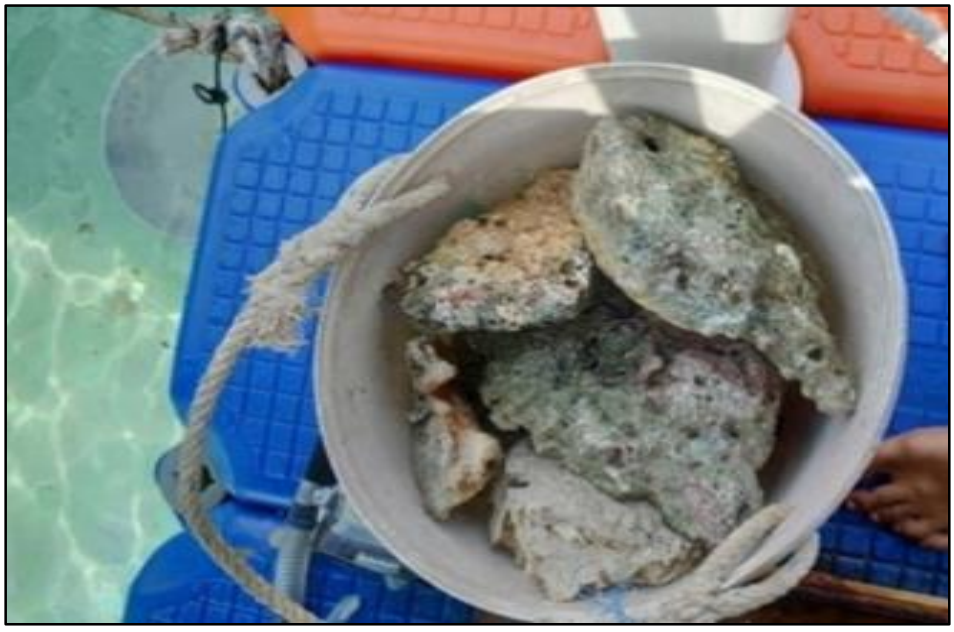

Figure 2. Dead corals used as transplant media.

The coral fragments for transplantation come from coral reefs in Legon Lele Beach. This was done to avoid damage to corals in other locations due to indiscriminate collection of fragments. The coral fragments used were 7-10 cm in size. The fragments were cut using a cutting tool, one parent being cut only once to avoid damage the coral. The coral fragments for transplantation were placed in containers with seawater (Figure 3).

Figure 3. The coral fragments for transplantation.

Methods and sampling design. The 'Rock Pile' method is a transplant method using large dead corals as a transplant medium, as well as a natural substrate (Subhan et al 2022). The substrate was created with the help of a cement mixture. Dead coral used as a substrate was first cleaned. The cement was placed into gaps in the transplant medium, then the coral fragments to be transplanted were fixed in the cement.

Attachment of the coral fragments to the cement medium was carried out quickly, in a shady place, so that the fragments would not be under a lot of stress. During the attachment itself, the fragments may release water when removed. They were left to stand for a day, dried out and remained at rest. Once the coral fragments and cement have dried, they were carried into the water, to a predetermined location, where further maintenance was possible. In this study, 26 rock piles were used, each media consisting of 1 to 3 coral fragments (Figure 4).

Figure 4. Coral transplantation with the rock pile method.

Observations of growth, growth rate and survival of transplanted coral reefs were carried out every week for 3 months at Legon Lele Beach, Karimunjawa Island. Transplants were carried out on 30 *Acropora formosa* corals with an initial size of 7.6-10 cm and 30 *Acropora aspera* corals with an initial size of 8-9.8 cm.

Data analysis. Field data was analyzed and presented as coral growth, coral growth rate and survival rate of coral. In addition to coral reef transplant data, water quality measurements were also carried out. The water parameters included temperature, brightness, acidity (pH), and current velocity around the research location. Temperature was measured using a digital thermometer, brightness was measured with a Secchi disk, acidity (pH) with a pH paper and current velocity with a current meter. Measurements were needed, since these water parameters are the determining factors in the growth of transplanted corals (Prayoga et al 2019).

Absolute height growth is the difference between the height at the end of the study and the initial height. The difference in transplanted coral fragments was calculated using the formula provided by the Directorate of Conservation and National Parks (2002):

$$\beta L = Lt - Lo$$

Where: βL - absolute height growth (cm); Lt - average height after the t month (cm); Lo - average initial height (cm).

On the other hand, measurement of coral growth includes vertical (upward) height gain. According to the Directorate of Conservation and National Parks (2002), the extent of coral fragment length or transplant growth rate can be measured as:

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

Where: P - extent of coral growth (cm per month); Lt - average height after the t month (cm); Lo - average initial height (cm); t - observation time.

The survival rate of transplanted coral species was evaluated using the formula proposed by based on the Directorate of Conservation and National Parks (2002):

$$SR = \frac{Nt}{No}\ x100$$

Where: SR - life success rate (%); Nt - number of living coral fragments at the end of the study; No - number of coral fragments at the beginning of the study.

Results and Discussion

Water parameters. Water quality parameters in Legon Lele Beach, Karimunjawa Island, meet the Water Quality Standards for Marine Biota stipulated in the Decree of the Minister of Environment of the Republic of Indonesia No. 51 of 2004 (Ministry of Environment 2004) (Table 1).

Table 1

Water quality at the study location and water quality standards for marine biota

Parameters	*Value*	*Standards (No.51/2004)*
Temperature	28-31°C	28-32°C
Visibility	3-5 m	>3 m
Acidity (pH)	6-7	6.5-8.5

Growth of transplanted corals. The results of observations of 60 coral transplants for 3 months (13 weeks) showed that the average size of *A. formosa* in the first month was 9.21 cm, in the second month it was 10.47 cm, and in the third month it was 13.11 cm (Figure 5). The average growth of *A. formosa* was 4.5 cm. The average size of *A. aspera* in the first month was 9.13 cm, in the second month it was 9.87 cm and in the third month it was 12.10 cm (Figure 5). The average growth of *A. aspera* was 3.4 cm.

It conveys that there is a difference in absolute height growth in the two types of coral. Prabhuwinata et al (2020) explained that the increase of coral length transplanted

with artificial substrates is suspected to occur due to differences in the shape and size of the diameter of coral colonies.

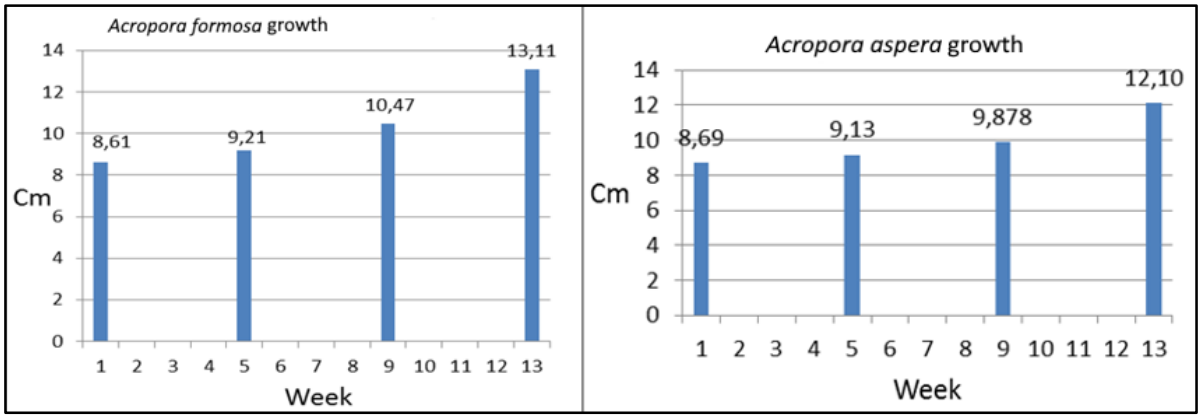

Figure 5. *Acropora formosa* coral growth (left) and *Acropora aspera* coral growth (right).

The growth of coral reefs is generally determined by coral colonies formed by thousands of polyps. In their basic form, corals consist of a single polyp that has a tubular body shape with a mouth located at the top. In most species, an individual coral polyp will develop into many individuals called colonies. Therefore, the greater the number of polyps, the greater the opportunity to obtain food for corals is. The rate of growth process will be faster for corals that have many polyps than for those with fewer polyps (Prayoga et al 2019).

For the first month, the growth of *A. formosa* was 0.6 cm, while *A. aspera* had a growth of 0.44 cm (Figure 6). The average growth rate of A. formosa was 1.5 cm month^{-1} and of *A. aspera* 1.14 cm month^{-1}. *A. formosa* has a faster growth rate than *A. aspera*. The growth of different corals is influenced by several factors such as age, shape, and size. In addition, according to Wijaya et al (2017), factors that affect the growth of coral reefs are water temperature, sunlight, salinity, sedimentation, water quality, currents, and circulation of seawater.

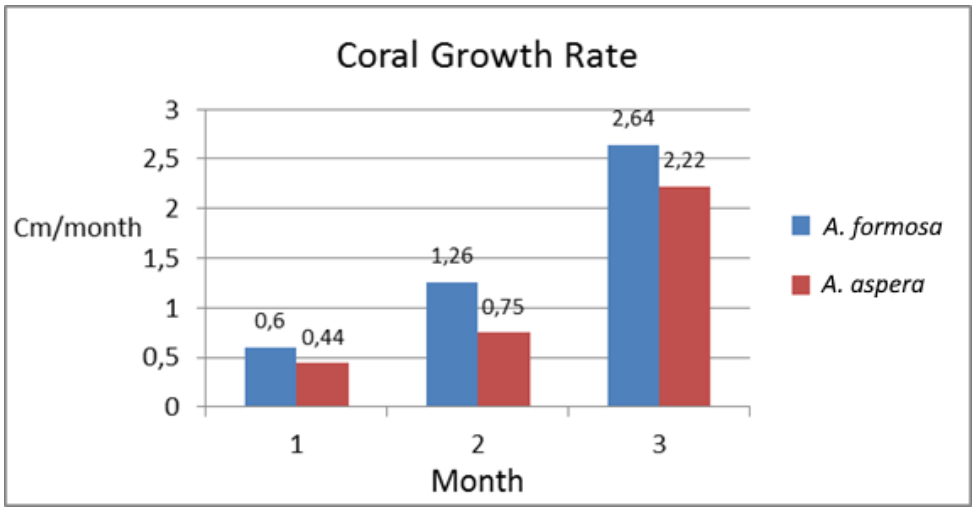

Figure 6. Coral growth rate.

Survival of coral transplants. The success of coral transplantation can be determined by the survival rate of transplanted corals. The survival rate depends on coral biology, environmental conditions and the size of the transplanted coral fragments. According to Nugraha et al (2019), the ability to adapt to the environment greatly affects the survival

rate of corals. There were some corals that failed in the experiment, 2 *A. formosa* and 3 *A. aspera*. The survival of corals from the transplantation process can be seen in Table 2.

Based on Table 2, it can be seen that the survival of *A. formosa* was higher than that of *A. aspera*. *A. formosa* had an average survival of 93.3%, while *A. aspera* had an average survival of 90%. The survival rate below 100% was due natural factors at the research location, such as the east monsoon, which resulted in coral fracture and changes in the position of the transplanted corals.

Table 2

The survival of transplanted corals

Species	*Initial number*	*Final number*	*Percentage (%)*
Acropora formosa	30	28	93.3
Acropora aspera	30	27	90.0

Water quality is an important factor for the growth of marine biota, especially for transplanting coral reefs, which require a certain level of water quality in order to grow healthily (Yuliana et al 2020).

Water temperature is an important factor in the growth of coral reefs. Water temperature affects the metabolic activity of biota and is closely related to dissolved oxygen (Pasaribu et al 2022). At low temperatures, coral metabolism will be hampered. Increasing temperature will increase metabolism, which will increase coral growth. However, excessive growth rates can cause coral death (Patty & Akbar 2018). The results of water temperature at the study site showed values between 28-31°C. These values are categorized as supporting the growth of coral reefs according to the Water Quality Standards for Marine Biota stipulated in a Government Regulation (Ministry of Environment 2004).

The visibility of the waters is a measure to determine the penetration of sunlight into the water column. The water visibility is largely determined by the suspended solids and the intensity of light entering the waters. A higher visibility level means better incoming light intensity (Fabricius 2005). This means that sunlight is able to reach the bottom of the ocean, enabling zooxanthella algae to carry out photosynthesis. The waters in Legon Lele have 3-5 m visibility. Therefore, it can be concluded that the waters of Legon Lele are within the good level of visibility for transplant activities (Barus et al 2018).

The acidity (PH) of ocean waters affects the rate of coral growth as well. The slightest change in pH will cause modifications and imbalances of CO_2 levels, endangering marine life. The pH value for good coral growth ranges from 7 to 7.5 (Patty & Akbar 2018). Legon Lele waters have acidity values between 6-7. These values arel categorized as supporting the growth of coral reefs according to the Water Quality Standards.

Currents are needed by corals to bring food in the form of plankton. In addition, currents help clean the coral from sediment and supply oxygen from the open sea. The current velocity at the observation site ranges from 0.5 to 0.15 m s^{-1}. The current speed is in the slow and medium category. Coral growth is better in areas with moderate currents, because they do not damage corals and help remove unwanted materials attached to corals (Wijaya et al 2017).

During our study, the transplants were carried out using corals that were commonly found in Legon Lele waters, namely the *Acropora* species. The species of coral that were transplanted were *A. formosa* and *A. aspera*. Corals of the genus *Acropora* are reef-building animals that live in colonies and are able to produce high calcium carbonate. This is in accordance with the research conducted by Hermanto (2015) in the waters of the Lembeh Strait. If we compare the growth of the two transplanted corals, the growth of *A. formosa* is greater than that of *A. aspera*. This is possibly due to differences in the substrate content of the transplant media and environmental factors. According to Tumion & Sasongko (2017), the growth of coral reefs depends on environmental factors such as up welling, sunlight, clarity, depth, water temperature, salinity, deposition, currents and substrate. Tides and currents play a very important role

in carrying nutrients, supplying food for microorganisms and oxygen and preventing corals from accumulating sediment (Rizqika et al 2018).

Coral growth can also be seen from the growth rate. Based on Figure 6, it can be seen that there is an increase in the growth rate of coral transplants every month. The average growth rate of *A. formosa* is higher than that of *A. aspera*. Different coral growth rates are affected by several factors such as age, shape, and size. In addition, according to Wulandari et al (2022), factors that affect the growth rate of coral reefs are water temperature, sunlight, salinity, sedimentation, water quality, currents, and seawater circulation.

The survival rate of coral reefs determines the success of coral reef transplants. Survival rates depend on coral biology, environmental conditions and the size of the coral fragments transplanted. According to Nugraha et al (2019), the ability to adapt to the environment greatly affects the survival rate of corals. Based on Table 2, it can be seen that the survival of *A. formosa* is higher than that of *A. aspera*. The difference in survival rates is usually due to failed transplants. Some of the causes include corals that do not grow or are damaged due to environmental factors (Prayoga et al 2019). In addition, there are natural factors at the study site such as the east monsoon, which cause coral fractures and changes in the position of the propagated corals.

Coral maintenance needs to be done to determine its adaptation and ability to survive, so that coral growth can be investigated. Coral reef maintenance activities include shifting the location of corals exposed to currents, and brushing substrates that are overgrown with algae and other organisms such as sponges and spiny starfish. Maintenance of coral reefs aims to keep corals growing optimally without being disturbed by other organisms that grow as parasites (Kurniawan et al 2021). Coral health surveys and monitoring are important to provide data for management and identifying impacts when the diseases occur. There is an important need in understanding the diseases of corals for management implications (Fahlevy et al 2019). During the coral transplant activities, there were problems that could interfere. These problems can be classified into two types, namely internal factors and external factors. Internal factors are problems that come from the coral transplantation process itself, while external factors come from outside the transplantation activities. Internal problems include parasites that live on corals and can affect coral growth and even cause death if not cleaned. Meanwhile, external factors involve the occurrence of storms accompanied by strong winds that increase the movement of currents in the waters. The increase in current speed that occurs excessively can damage the structure of coral reefs (Santoso & Kardono 2008).

Conclusions. From the observations on coral transplantation in Legon Lele waters, Karimunjawa, the absolute height growth of *A. formosa* was 4.5 cm and of *A. aspera* 3.41 cm. The average growth rate of *A. formosa* was 1.5 cm month^{-1} and 1.14 cm month^{-1} for *A. aspera*. The survival rate at the end of the observation of *A. formosa* was 93.3%, while for *A. aspera* it was 90%. Based on these results, the experiment was considered successful.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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