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# Evaluation of three species coral (*Acropora branching*) transplantation, case study; pantai tirtawangi Banyuwangi East Java

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**Abstract.** The coral reef plays an important role in the marine ecosystem. These ecosystems are currently in decline due to a variety of factors such as irresponsible fishing, live coral capture for commercial purposes, seawater acidification, and others. Several attempts have been made to improve the situation, one of which was the transplantation method. Three *Acropora* species, *Acropora Brueggemanni*, *Acropora Nobilis*, and *Acropora yongei*, were planted at the best depth using the PVC rack method (5 meters) Tirtawangi Beach is located in Banyuwangi, East Java, Indonesia. We tracked the survival and growth of three transplanted corals on a monthly basis. A descriptive analysis was performed to determine the relationship between both and environmental parameters. The survival and growth rates of three *Acropora* corals transplanted at the optimal depth were discovered to be different for each species. Meanwhile, the three species' survival rates ranged from 96 to 100 percent, and their growth rates (mean SD) were  $0.35 \pm 0.11$ ,  $0.81 \pm 0.39$ ,  $0.47 \pm 0.15$  cm.month<sup>-1</sup>, respectively. Furthermore, fragment adaptability to environmental changes is a major factor determining fragment growth, survival, and regeneration.

## 1. Introduction

Coral reefs are typically found in shallow water in tropical areas. Coral reefs are formed by the activities of a variety of calcifying organisms, the majority of which are hermatypic corals related to symbiotic algae. Many organisms, including coralline algae, mollusks, bryozoans, and the green alga *Halimeda*, secrete limestone-like forms of carbonate [1, 2]. Coral reefs protect the coast from abrasion, serve as feeding, spawning, and nursery ground for various aquatic organisms, provide marine tourism activities, and balance the accumulation of nutrient content such as carbon, nitrogen, and phosphate from terrestrial ecosystems during the rainy season [3, 4]. Unfortunately, widespread coral reef ecosystem decline has been reported in a number of locations [5, 6]. Human activities such as irresponsible fishing, live coral capture for commercial reasons, as well as coral mining for construction materials cause damage to coral reefs [3] or as a consequence of natural factors such as rising sea temperatures [7].

The coral reef ecosystem can recover on its own, but it will take a long time. As a result, several techniques are being used to speed up the restoration of coral reef damage. Coral transplantation is one of them, and it is the most widely used method for coral reef recovery [8]. Coral transplantation is a technique that uses fragmentation techniques to extract coral fragments from coral colonies [9]. This method was chosen primarily because it is less expensive and effectively shortens the recovery time of



damaged coral reef ecosystems [8]. Coral transplantation is considered successful if the survival rate of the transplanted corals ranges between 50 and 100 percent [10] and transplanted corals exhibit growth, which is primarily attributed to increased skeletal mass (calcification rate). Coral transplantation programs can be successful if the right coral species are used and the right transplantation site is chosen [11,12, 8]. If the coral species used for transplantation is naturally present at the site, the conditions for coral survival are likely to be favorable, and transplanted corals may survive well [8]. *Acropora* sp. is a popular coral species for coral transplantation because it dominates the Indo-Pacific tropical ocean and has a high survival rate and rapid growth, especially branching *Acropora* [13, 10,8]. Meanwhile, ecological parameters in transplantation sites such as salinity, light intensity, temperature, ocean acidification, terrestrial runoff, depth, and wave exposure affect coral survival and growth directly or indirectly [14,15,16]. As a result, when selecting a site for transplantation, the similarity of condition between rehabilitation sites and sites where coral fragments come from must be considered [8]. The highest growth rates on *A. Nobilis* and *A. divaricata* coral transplants were found at lower depths and decreased with increasing depth [17]. We worked with three *Acropora* coral species in this study: *A. Brueggemann*, *A. Nobilis*, and *A. Yongei*. The purpose of this study was to determine the survival and growth of transplanted corals.

## 2. Materials and methods

### 2.1. Study area

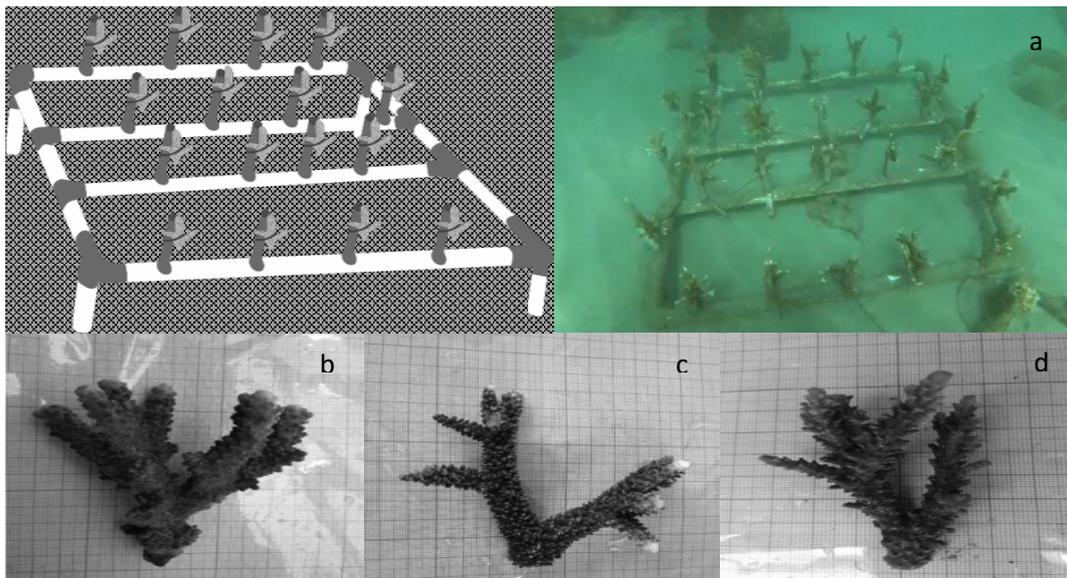
This study was carried in Tirtawangi Beach, Wongsorejo, Banyuwangi, East Java, Indonesia, for three months starting from March to May 2018 (8°01'59,4"S and 114°26'15.2"E). It is a conservation area collaboration with the local communities and the Fisheries and Maritime department in East Java province and has slope topography and slow-wave [18].

### 2.2. Procedures and Preparations

Around 400 meters from the beach was planted at a depth of 5 meters, this depth is ideal for transplanting corals [17]. The square-shaped racks used for the transplantation of corals were 100 x 100 cm<sup>2</sup>, with legs with a height of 25 cm. Racks were made of PVC pipes filled with concrete cement and each rack had 25 places to tie coral fragments. Three species of branching *Acropora* coral were used i.e *Acropora brueggemanni*, *Acropora nobilis*, and *Acropora yongei* (**Figure 1**). Coral fragments originated in the area around the transplant from colony donors and came from the same depth with a length of fragments 8-12 cm. The removal of coral fragments was no more than 10% of colony donors to ensure that the ecosystem was still good [19].

### 2.3. Collect Data and Measurement

Survival rates were observed every month by counting the number of corals that were still alive and those that had died. The definition of "survival" for a coral fragment is fragment coral still having polyp in the coral structure, although fragment corals experience bleaching [20]. Coral fragment was considered alive if there remained some living coral tissues. The growth rate of coral fragments was also measured in monthly linear extension (final length - initial length / total month) and expressed in cm month<sup>-1</sup> using calipers with an accuracy of 0.05 mm [21].



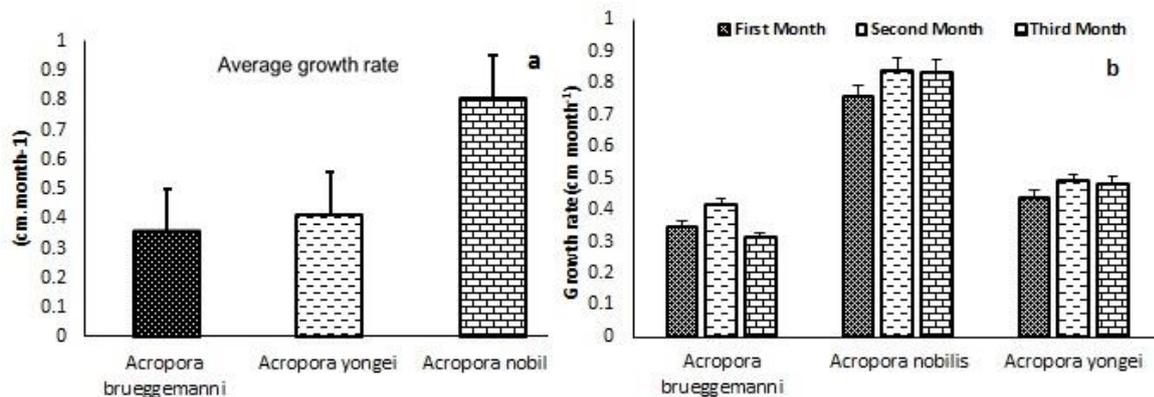
**Figure 1.** (a): Modul and rak design of transplantations, (b): Origin fragment of *A. brueggemanni*, (c): *A. nobilis*, and (d): *A. yongei*.

In addition, the water quality parameters were measured each month. Parameters such as temperature, current speed, and brightness were measured in situ. The temperature was measured by a thermometer, current speed by current ball and stopwatch, brightness by Secchi disk. Meanwhile, turbidity, sedimentation rate, nitrate, and phosphate were measured ex-situ. Water samples for measuring turbidity, nitrate, and phosphate were obtained from the same depth as the transplantation site and preserved in a cool box. Turbidity was measured in Laboratory of Airlangga University, Banyuwangi Campus using portable turbidity meter kit (LaMotte™ model smart3), while nitrate and phosphate were measured in Environmental Laboratory of Bogor Agriculture Insitute. Nitrate analysis was performed using the Brucine Sulfate method (APHA ed. 21, 2005, 4500-NO<sub>3</sub>) and phosphate analysis used the Ascorbic Acid method (APHA, ed. 21, 2005, 4500-P-E PO<sub>4</sub>). Sediment was collected using sediment trap and examined in the Laboratory of Airlangga University, Banyuwangi Campus. Sediment trap were designed and testing procedure referred to those of [22]. Furthermore, description analysis was carried to determine the survival rates and growth of transplanted corals and their correlation with water qualities.

### 3. Result and discussion

#### 3.1. Result

The three transplanted *Acropora* coral species had a relatively high survival rate. The survival rate of *Acropora brueggemanni* and *Acropora nobilis* was approximately 100%, while *Acropora yongei* was approximately 96%. *Acropora yongei* died as a result of sediment deposits covering the entire surface of dead coral fragments. The growth of three transplanted *Acropora* coral species differed from one another. *Acropora nobilis* had the highest average growth of  $0.809 \pm 0.394$  (meanSD) cm.month<sup>-1</sup> (Figure 2a), followed by *Acropora yongei* at  $0.468 \pm 0.148$  (meanSD) cm.month<sup>-1</sup>. meanwhile, *Acropora brueggemanni* had the lowest average growth of  $0.354 \pm 0.113$  (meanSD) cm.month<sup>-1</sup>. The growth of three three transplanted coral species of each month also fluctuated (Figure 2b). The growth of *Acropora brueggemanni* in the first month, second month and third month was  $0.346 \pm 0.122$ ,  $0.414 \pm 0.166$ , and  $0.311 \pm 0.132$  (mean±SD) cm month<sup>-1</sup> respectively. Furthermore, the growth of *Acropora nobilis* each month was  $0.755 \pm 0.366$ ,  $0.840 \pm 0.536$ , and  $0.833 \pm 0.410$  (mean±SD) cm month<sup>-1</sup> respectively. Meanwhile, the growth of *Acropora yongei* each month was  $0.439 \pm 0.104$ ,  $0.490 \pm 0.209$ ,  $0.480 \pm 0.243$  (mean ±SD) cm month<sup>-1</sup> respectively.



**Figure 2.** (a);The average growth rate, (b): monthly growth rate of three coral transplanted on the site study

### 3.2. Discussion

Three transplanted *Acropora* coral species had a high survival rate, according to this study. This study's survival rate was higher than the survival rates of *Acropora nobilis* transplanted on Kuta Beach, Bali Island, and Alona Beach, Bohol, Philippines, which were 57% and 87%, respectively [23,24] and 50% and 80% for *Acropora yongei* and *Acropora brueggemanni* transplanted in Gangga Island and Bunaken, North Sulawesi, respectively [25]. According [9] that coral transplantation was said to be successful if the survival rate was between 50-100%. The high survival rate of transplanted corals in this study was due to the fact that the species used originated in the same location as the transplantation site. According to [8,] the best coral fragments for transplantation must come from places with environmental conditions that are as close to those of the rehabilitation site as possible so that the coral fragments can easily adapt.

Three months after planting, there was still a death case of *Acropora yongei* coral fragments in this study. This was due to sediment deposits covering the entire surface of *Acropora yongei* coral fragments (**Figure 3**). In fact, coral reefs can naturally clean sediment deposits through passive rejection (changes in growth form) or active rejection [26]. Furthermore, the movement of currents has accelerated the process of cleaning up sediment deposits, allowing for faster physiological recovery of the reef [27]. In this study, we discovered that cleaning sediment deposits on the *A. yongei* coral surface is difficult. This was due to the death of coral fragment polyps as a result of coral predator predation. Coral predators consume the majority of the polyps, leaving a wide lesion on the surface of coral fragments. The lesion was then covered by sediment and could not be removed by polyps. Finally, sediment deposits covering the lesion increased in number, killing the entire polyps of coral fragments (**Figure 2**). [13] stated that *Acanthaster planci*, starfish, and predatory fish such as Tetraodontidae, Monacanthidae, Balistidae, Chaetodontidae, Acanthuridae, and Scaridae eat live coral tissues and are one of the causes of coral death.

The growth rates of all transplanted corals varied. *Acropora nobilis* had the highest average growth of  $0.809 \pm 0.394$  cm month<sup>-1</sup>, while *Acropora brueggemanni* had the lowest average growth of  $0.354 \pm 0.113$  cm month<sup>-1</sup>. According to [23], the average growth rate of *Acropora nobilis* transplanted at a shallow lagoon in Kuta Beach, Bali Island was 1.09 cm month<sup>-1</sup>. This value was greater than the value of the *Acropora nobilis* that we transplanted. Furthermore, the average growth rate of *Acropora brueggemanni* we transplanted was lower than that of *Acropora brueggemanni* transplanted in Kelapa Island, Kepulauan Seribu, Indonesia [28], which was  $0.48 \pm 0.32$  cm month<sup>-1</sup>. Meanwhile, the average growth of *Acropora yongei* of  $0.468 \pm 0.148$  cm month<sup>-1</sup> in this study was slightly higher than that of *Acropora yongei* of 0.415 cm month<sup>-1</sup>, measured during the summer using direct tagging method in Lord Howe Island, New South Wales, Australia (not transplanted coral) [29]. The difference of growth among those locations was likely because of the different characteristics of each transplantation site and water quality parameters.

The transplantation site in this study was near the river mouth, and the activity began during the rainy season, so there was more runoff water bringing suspended sediments from the mainland. These will increase turbidity and sedimentation in the seawater. Increased suspended sediment, particularly fine-grained sediment, reduces the quality and quantity of light level, resulting in a decrease in photosynthetic productivity by zooxanthellae, allowing the calcification process to be inhibited [30]. Calcification on the coral host is enhanced by photosynthesis of zooxanthellae. However, mechanism underlying the interaction between calcification and photosynthesis are unknown for certain and still a matter of debate [31,32, 33]. Some hypotheses have been proposed to explain these interactions: 1). CO<sub>2</sub> uptake for photosynthesis changes the equilibrium of dissolved inorganic carbon 2). Synthesis of organic matrix precursor by photosynthetic alga, 3).

We also found that the average growth rate of the three transplanted *Acropora* corals each month turned out differently. The average growth of all transplanted corals in the first month tend to be lower than that of in the second and third month (Figure 2b). It was assumed due to the adaptation of coral in the new site and healing process of lesion caused by cutting fragments that take energy. As explained by [34] that energy produced by all living beings is allocated to the maintenance, growth and reproduction functions. If the energy used for maintenance function is greater, the energy used for growth will be reduced. In addition, the turbidity, sedimentation rate and nitrate and phosphate concentration in the first month, which were higher than those of in the second and third month, might also inhibit the growth of all coral fragments. An increase in nutrient concentrations is related to eutrophication. The previous studies reported that eutrophication can have negative impacts such as the reduction of calcification level and the success of reproduction [14]. Nitrate and phosphate concentrations are generally well below 0.05 mg/L<sup>-1</sup>.

Furthermore, the growth rate of all transplanted corals increased in the second month and in the third month except *Acropora brueggemani*. The increased growth was thought because the energy allocated to growth was greater than that to adaptation and healing processes. Besides that, the decrease of turbidity, sedimentation rate, nitrate and phosphate value seemed to have an impact on increasing coral growth. Meanwhile, the decreased growth of *Acropora brueggemani* coral fragments in the third month was expected due to the rise of seawater temperature. The rising seawater temperature began in the early April when there was a transition from the rainy season to the dry season [35].

The sea surface temperature in the transition season is comparatively higher so that the seawater heating process is stronger. Moreover, *Acropora brueggemani* coral fragments also experienced partial bleaching (not documented). Based on [36] that the fluctuations of 1-2 °C above normal temperature for a short time can trigger coral bleaching and cause death if it lasts a long time, while optimal seawater temperature for coral life is 28 - 30 °C [37]. According [28] that coral bleaching can appear at a temperature of 31 °C. A severe rise in temperature can lead to a decrease in growth even before coral bleaching occurs [6]. These facts we found suggested that *Acropora brueggemani* coral fragments seemed to be more susceptible against rising water temperature than two other *Acropora* corals that we had transplanted.

#### 4. Conclusion

The adaptability of fragments to stress, coral bleaching, and the rate of deposit removal on coral surfaces all had an effect on the survival and growth rate of coral reef transplants. Temperature changes, sedimentation, and water eutrophication may also impede metabolic development and coral reef regeneration. More research was required to determine the factor that most influences the rate of growth during the various seasons.

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