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Growth and Survival of *Acropora Formosa* (Scleractinia: Acroporidae) Coral Fragments and Their Impact on Reef Fish Assemblage in Geluk Island, Terengganu

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Abstract: Coral transplantation is a widely used technique for restoring damaged reefs in order to restore coral abundance, recruitment, and species diversity. However, its limited evidence to prove the impacts on coral reef fish. In this study, the fish abundance was determined before and after a coral transplant project at Geluk island, Terengganu. Prior to the study, branching coral from acropora formosa species were propagated and evaluated for 2 years. The experimental design included a mortality percent and the growth rate of coral fragment used. Correspondingly, quantify the differences in reef fish diversity indices before and after the propagation. Overall, the coral fragment survived at rate of 96%, and the growth rates of fragment ranged between 6.4 ± 0.6 cm/year to 9.5 ± 1.1 cm/year. Pomacentridae was determined to be dominant family for coral reef fish, and the fish species increased in term of their species diversity (H1) from 0.000 (2016) to 1.053 (2017) and 2.076 (2018) respectively. High growth and survival rates of acropora formosa coral fragments and the increases pattern of fish diversity found in this study suggested that the coral propagation is successful and feasible in increasing the fish assemblages.

Keywords: Coral transplant, propagation, reef fish, coral fish, fish abundance

1. Introduction

Coral reefs around the world are degraded at frightening rates due to anthropogenic and natural disturbances (Lizcano-Sandoval et al., 2018). This massive deterioration has given a clear alarm which led to the need for efficient restoration techniques to save the coral reefs. Coral restoration can be attained through both sexual and asexual mode of reproduction (van Dongen-Vogels & Mallefet, 2006). Most of the restoration methods are based on asexual reproduction since sexual reproduction requires complex natural recruitment and depending on various factors (Endo et al., 2015). Transplantation is a feasible methodology for expediting the recovery of damaged or degraded coral reefs. The restoration through transplantation involves various vital factors such as site selection including identification of donor reef site, species selection, substrate selection and deployment, transplantation of fragments and regular monitoring (Forrester et al., 2013). Importantly, the techniques must be cost effective and eco-friendly.

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Management and Science University (MSU) has advocated a coral transplantation program at Geluk Island, Terengganu in 2016. 10 of coral frames together with 200 of coral fragments was deployed with the depth ranged between 10 - 12 meters. Another 10 frames were deployed in 2017 and followed by another 11 frames in 2018, where it becomes 31 coral frames in total. The branching corals from acropora formosa species were used as coral fragment since branching coral are one of the highest growth rates among other coral species (Okubo & Omori, 2011).

Even though coral transplant is an imperative method for coral restoration and benthic organisms, its less documented on its effect on fish diversity (Montoya et al., 2015). Hence, this study aims to determine the survival of coral fragment and its effect on fish abundance in the coral frame area. A study was conducted annually to evaluate this program include the coral growth, coral mortality, fish abundance and fish diversity.

2. Material and Method

2.1 Study Area

The study was conducted at Geluk Island, Terengganu (Figure 1). This island located at the East Coast of Peninsular Malaysia and situated between Pulau Tengkorak and Pulau Bidong. This area was chosen due to the rapid deterioration of coral reef due to the human and natural disturbance. This place frequently becomes the sheltered area for the large ship since this area is protected from monsoon winds. The scouring effect from the ship directly increases the coral's mortality. The island has patches of coral but is frequently interrupted by large patches of coral rubble. The seabed of the selected area mostly covered by coral sand, shingles and dead coral rubble.

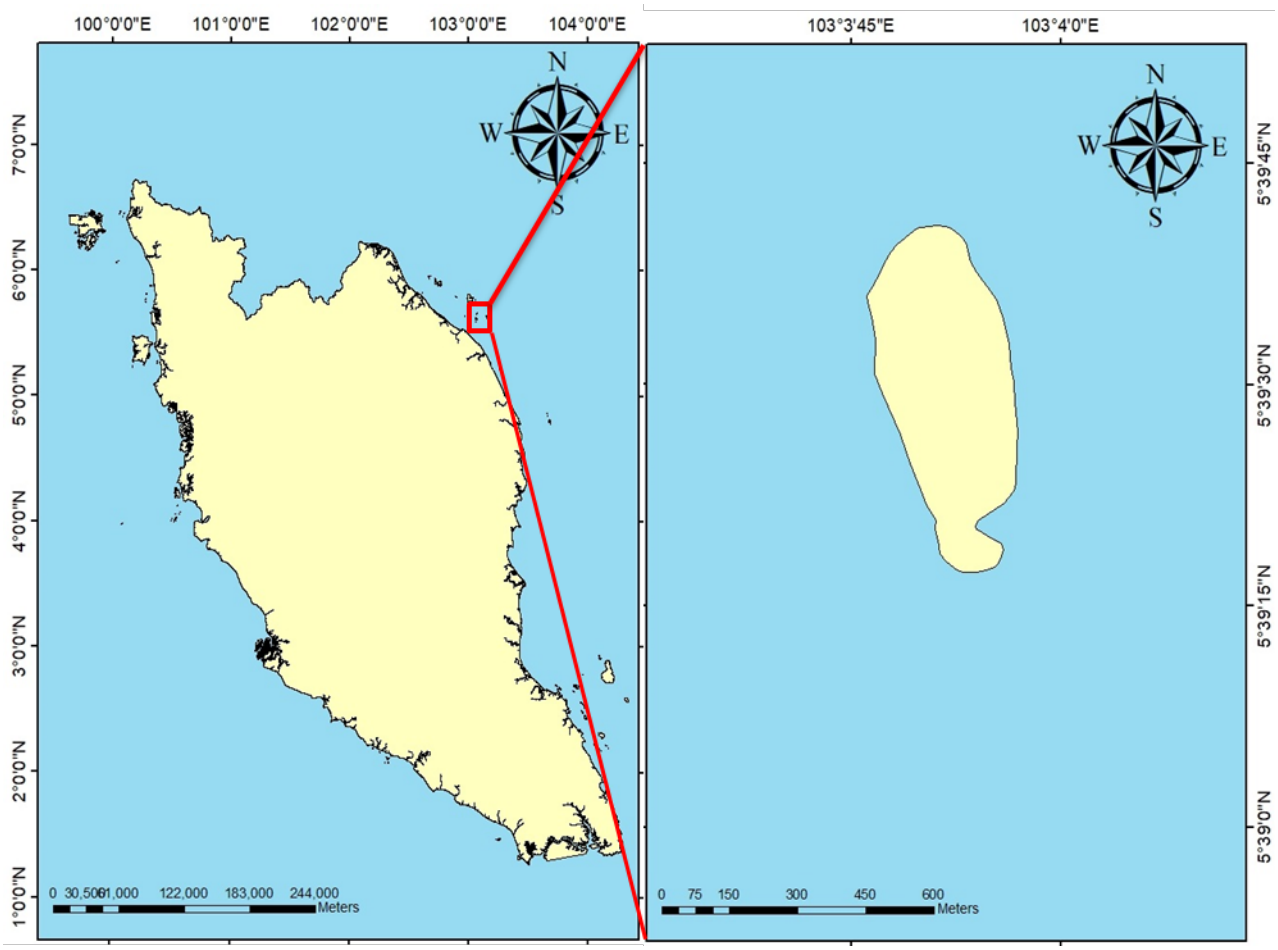

Fig. 1 - Location of coral transplant area at Geluk island, Terengganu

2.2 Coral Frame Construction

Iron rod frames were used as a frame and substrate for coral transplantation (Figure 1). Size of each frame was 59 cm (Height) x 130 cm (Diameter). Since the study sites were prone to considerable high current speed, the frames were designed pyramid-like structure to gain stability and reduce the sediment settling. These frames were coated with coral sand to protect the iron rod (Figure 2).

Fig. 2 - Coral frame's model

2.3 Transplantation of Fragment

The coral species that was used in this study is acropora formosa since the species has high availability and diversity at the donor site and has a high growth rate (Okubo & Omori, 2011). Prior to the transplant, branch fragments of coral species, acropora formosa were collected from different colonies in a reef zone about 10-12 m depth. The coral fragments were precisely cut at the donor reefs with the maximum of 5-8 cm length. Collection and transportation of fragments were done in the early morning to reduce the stress to fragments. The fragments were transported to the restoration sites in plastic buckets covered with black cloth to reduce the stress. Each frame was placed approximately 20 units of coral fragments (Figure 3). Coral fragments were tied up using cable tight (Figure 4).

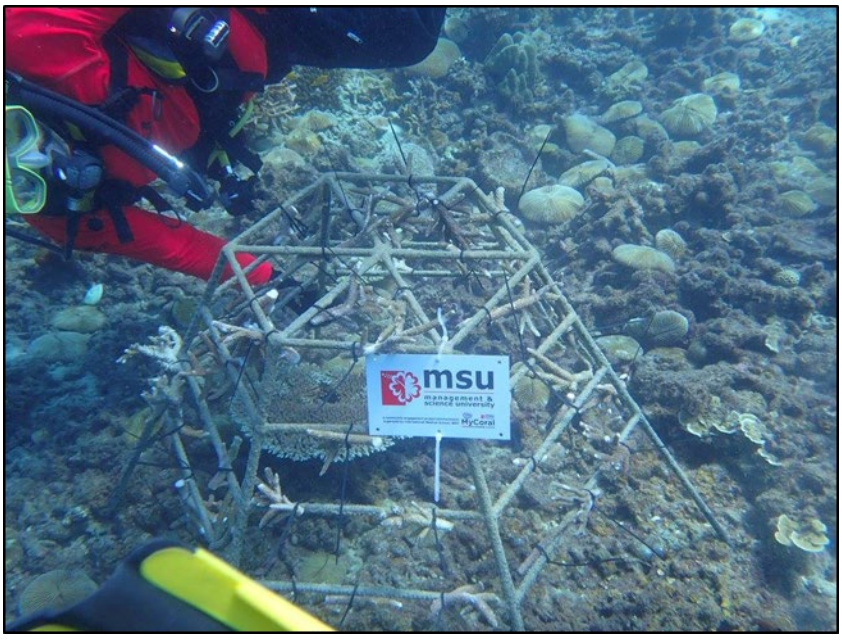

Fig. 3 - Coral fragment was tied on coral frame

Fig. 4 - Process of coral transplant

2.4 Deployment

The coral frames were taken to the targeted restoration sites using floating buoy. It was deployed at the seafloor using ropes to avoid damage, and SCUBA divers arranged the substrates in required position (Figure 5). 10 frames were deployed in 2016 (Blue colour), 10 frames were deployed in 2017 (Yellow colour) and another 11 frames deployed in 2018 (Green colour). Frames were arranged with Hibiscus flower shape with an interval of 1 to 2 meters from each other for paving the way for proper coral growth.

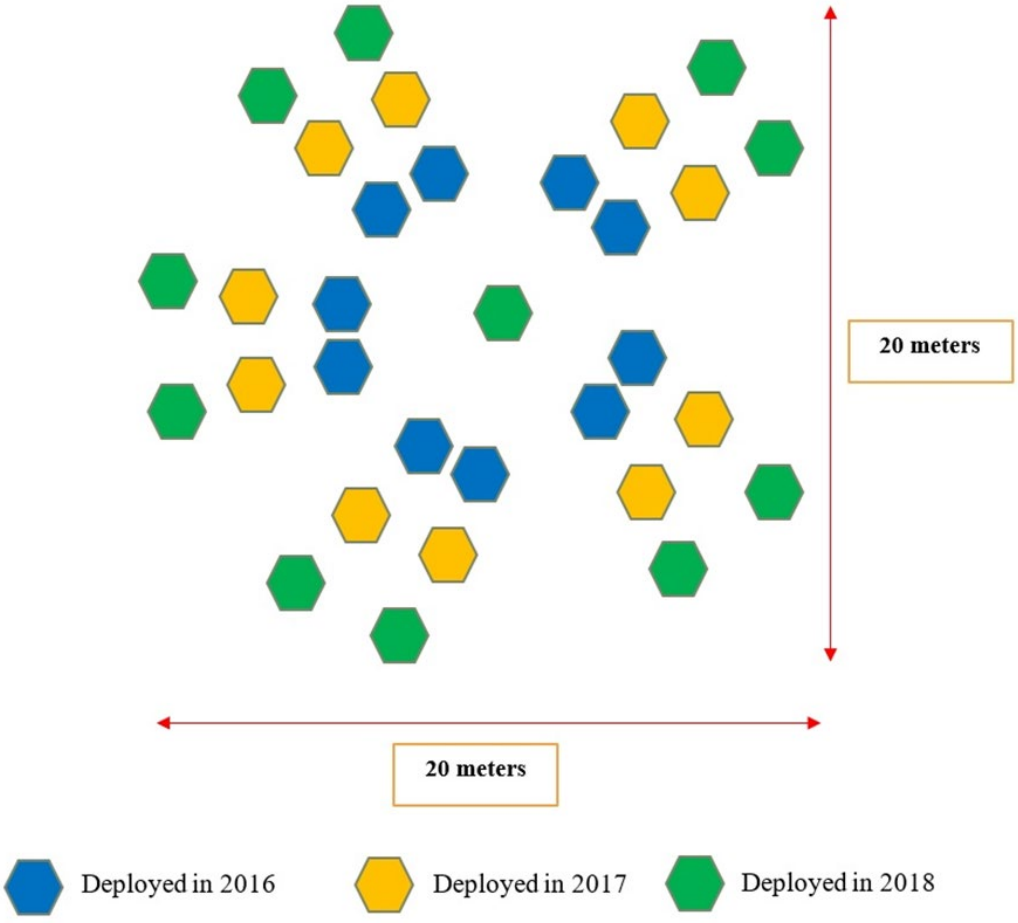

Fig. 5 - Arrangement of coral frame

2.6 Coral Growth Rates Determination

During deployment, 10 colonies of coral fragments were randomly tagged. The lengths of their fragment then were measured in every monitoring program. This tagging used to mark a specific coral to determine their growth rate in the future. Coral fragments were randomly tagged, and the length was measured to obtain the original length of the coral. The information of the original length is important because it used to determine the growth rate of the coral fragment. Coral fragments were measured using callipers and flexible ruler. The growth extension of the coral branch was monitored using direct measurement (Figure 6). Then linear measurement was taken starting from the tag until the tip of the main branch's axial end. The length of each coral depends on the type of coral. There needs to be measured only maximum width, and some just should be measured at the maximum length of the axillary fragment only. Through the measurement, the growth rate of the coral fragment can be determined using formula as below:-

$$\text{Growth rates (cm/year)} = \frac{\text{Latest length - Initial length}}{\text{Time}}$$

Fig. 6 - Process of coral length measurement

Table 1 - Table of coral growth rate in 2017 and 2018

Year of deployment	*n*	Length of coral fragment (cm)			Growth rates (cm/year)	
		2016	2017	2018	2017	2018
2016	10	5.2 ± 0.7	12.1 ± 1.1	21.2 ± 1.4	7.1 ± 0.7	9.5 ± 1.1
2017	10	-	6.8 ± 0.8	13.2 ± 1.1	-	6.4 ± 0.6
2018	10	-	-	6.4 ± 0.7	-	-

2.7 Fish Identification

The fish survey was conducted by using 'quick visual assessment technique'. Still picture of fish was taken using an underwater camera for identification. Fish identification was made up to species level based on reference book entitle Reef Fish Identification-Tropical Pacific written by (Allen, Steene, Humann, & Deloach, 2003).

Table 2 - Abundance of fish number by year

Fish species	Year		
	2016	2017	2018
Dascyllus trimaculatus	+	++	+++
Abudefduf septemfasciatus	-	+	+++
Pomacentrus sp.	-	+	+++
Chromis atripectoralis	-	-	+++

Thalassoma lunare	-	-	+++
Chrysiptera sp.	-	-	+++
Labroides dimidiatus	-	-	++
Scolopsis temporalis	-	-	++
Cheilinus chlorourus	-	-	++
Scarus sp.	-	-	+
Chaetodontoplus mesoleucus	-	-	+
Chaetodons octofasciatus	-	-	+
Siganus corallinus	-	-	+
Lutjanus sp.	-	-	+

*Abundance of fish number
+ = < 20, ++ = 21 – 100, +++ = > 100

2.8 Diversity Indices

The test of diversity indices was included Shannon-Wiener index, evenness index analysis and Simpson index analysis. Shannon-wiener index was widely used since it considers both species richness and evenness and used to determine which sample is the most heterogeneous and diverse. Evenness is the degree of equitability in the distribution of individuals among a group of species where it quantifies how equal the numbers of each species in an environment. Simpson index also known as dominance index where it takes into account both species richness and an evenness of abundance among the species present in the environment.

Table 3 - Diversity indices of fish between years

Diversity Indices	Year		
	2016	2017	2018
Simpson_1-D	0.000	0.635	0.845
Shahnnon,_H	0.000	1.053	2.076
Evenness	1.000	0.9553	0.5696

3. Results

3.1 Coral Fragment Survival

The growth of transplanted corals was monitored by 2 years of observation. By observation, 600 coral fragments of acropora formosa survived and 30 fragments died. Some of the fragments were lost for sedimentation causes while filamentous algae and macroalgae covered other dead fragments. Based on observations done during monitoring period on 2nd April 2017, the corals fragments were in a healthy condition with positive growth. The fragments were rapidly grown and some species start to expend their colony size.

Meanwhile, during monitoring on 14th April 2018, it was found that the fragments were rapidly grown and almost cover the entire frame. It was noticed that the natural coral was already grown in the centre of the arranged frame (Figure 7). This coral was from pocillopora damicornis species and might derive from nearby natural reef area. The following were the progress of coral fragment on coral frame (Figure 8).

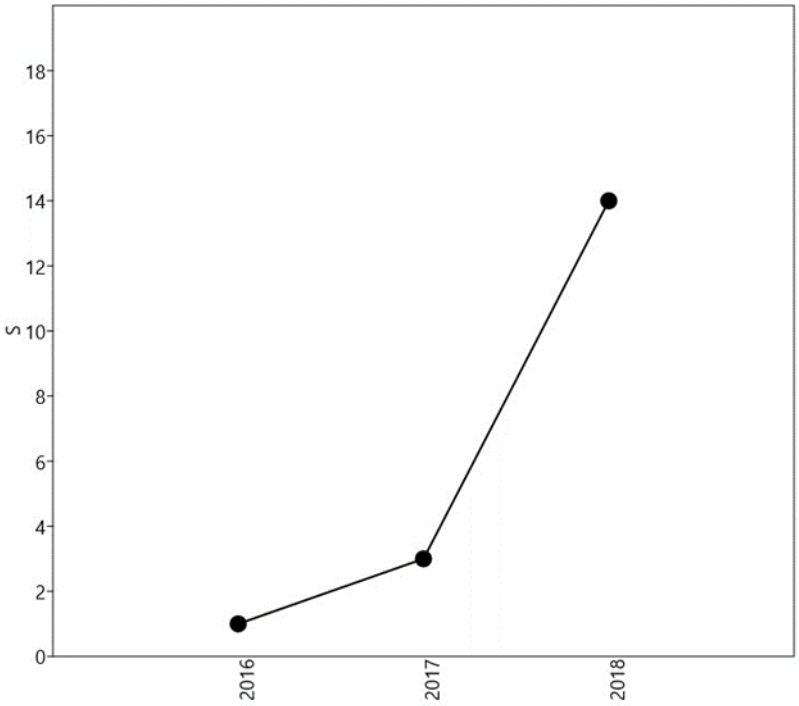

Fig. 9 - Graph of TaxaS for fish abundance

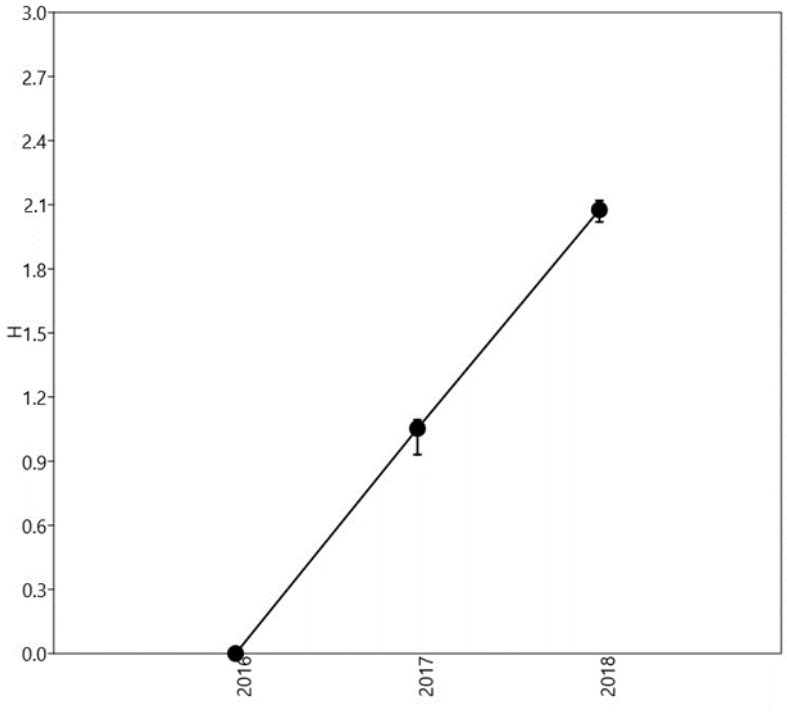

Fig. 10 - Graph of Shannon-Wiener index

4. Discussion

Based on the observation, the corals fragments were healthy with positive growth. The fragments were rapidly grown and almost cover the entire frame. During monitoring period, it was noticed that the natural coral was already grown in the centre of the arranged frame. This coral was from pocillopora damicornis species and might derive from nearby natural reef area. Prior to the frame deployment, this area was mainly covered only with coral rubble and death coral. The presence of a new coral around the coral frame area indicated that there is a chemical cue event that attracts other coral spats to start colonize on the area.

Based on the data, it is also noted, that the frame located on the seaward area has a relatively slow with coral growth. Many factors could influence coral defect. One of the elements was the scouring effect that might generate from natural wake current. Wake current also can be generated from the propeller of boating activities. This scouring effect will cause the increment level of sedimentation rate which coverings the substrate and inhibits the coral recruits (Weber et al., 2012). Hence, the sponges and turf algae will exponentially develop and engulf the coral fragment. When the coral was covered, the zooxanthellae algae that symbiotically live between calcium carbonate structures will suffocate (Yeemin et al., 2013). As a result, the calcification process stops and lead to coral death.

Another factor that causes mortality in new coral fragments is the presence of specific algae which inhibits the coral growth. Based on the observation, it was noted that the presence of the brown algae from lobophora sp. at the frame. This alga contains cyanobacteria that can inhibit coral growth (Kuffner et al., 2006; Morrow et al., 2017). There is some research has proved that lobophora sp. was responsible for rapid coral bleaching in acropora muricata (Vieira et al., 2016).

The coralline algae also noticed on coral frame surfaces. This coralline is a good indicator since the presence of coralline algae might attract the coral spat to attach on the substrate and start metamorphosis (Brown et al., 2017; Littler & Littler, 2013; Villas et al., 2005). During the observation, it was found that this area has started to become a habitat for coral reef fish. The damsel's fish are the most numerous in terms of numbers. This development was a positive sign since the coral that grows in the frame has created new habitat for fishes.

Acknowledgement

Acknowledgements and Reference heading should be left justified, bold, with the first letter capitalized but have no numbers. Text below continues as normal.

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