The performance of coral nursery with rope tree techniques in the moderate sea current environment: Morotai pilot project

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Abstract. Acknowledged as the famous destination for shark diving tourism, Morotai waters poses increasing coral reef degradation risk in recent years. Coral restoration program is needed to battle the decreasing coral cover in this waters. Instead of garnering the fragment directly from healthy coral reef habitat, which is potentially damaging the healthy coral reef, a coral nursery can be proposed as an alternative method to maintain the pristine environment of coral reef habitat in Morotai waters with future coral restoration programs. Coral rope tree nursery has proven to be effective at achieving growth speed compared to other coral nursery methods as well as high performance to withstand moderate current risk. Performance of a pilot project of coral tree rope nursery in Morotai waters has been studied for more than five months and it shows as promising method for future massive nursery.

1. Introduction
Since firstly introduced as the shark watching tourism site in 2013, Morotai growth as one of the most famous shark dive site in Indonesia with the estimate mean of shark diving value (2017 value) of 1,322,380 USD/year [1]. Provided that in average there are 771,171.07 (mean 2017 value) shark tourist visited Indonesia [1] and Indonesia is currently sit in rank-4 in the most valuable shark diving country [2], the growing of shark tourism may potentially increase the coral reef cover degradation in future.

Study in Egypt [3] showed that diving and snorkeling activities were considered as having strong relation with coral breakage. There are also different impacts of high diving intensity (HDI) and low diving intensity to coral damage in a Marine Protected Area in India which showed that HDI and LDI contribution to coral damage of 19.79% and 3.36% respectively in 2019 [4]. Apart from coral damage, activities of diving and snorkeling is also suspected to cause the increasing of coral disease prevalence up to 3-fold as it was happened in Koh Tao, Thailand [5].

However, study by Hawkins [6] showed that scuba diving activities within its carrying capacity should not be considered harmful to coral communities. If the tourism activities are kept within their carrying capacity, scuba diving and snorkelling may even increase the coral diversity [7]. In order to maintain the coral reef ecosystem undisturbed by tourism activities, the number of diving activities in Morotai should be limited by 319,045 divers/year throughout Morotai waters and 46 divers / day at Blacktip Point, the most famous shark diving location [8].

Research using LANDSAT remote-sensing imagery between 1996 to 2013 showed that there was a decline of coral coverage as big as 43.17% throughout Morotai waters [9]. One of the decline of coral coverage in Morotai waters was caused by coral bleaching event [10], albeit the impact was considered as relatively small (< 25%). Other factor such as increasing human activities (land reclamation) in Daruba, Morotai [11] has also been recorded.

In order to recover the coral reef coverage degradation, active coral restoration can be established. There are two basic approaches in coral restoration: (1) direct fragment transplantation (which has
been harvested from a healthy coral ecosystem (1) to the degraded coral reef ecosystem and (2) fragment transplantation from a nursery mari-culture [12]. In some area where hurricane poses great threat to coral reef habitat – such as northern side of Caribbean Sea – quick restoration of the colony of threatened coral species (e.g. Acropora cervicornis) is important [13]. It is a common practice that the longer is the coral fragment cultivated, the growth will be faster [14]. However, taking out the longer fragment from the healthy coral can cause the further damage which may not be easily recovered [15].

There are several nursery designs were developed: hanging the coral from wires, line or rope; suspending the coral over the sea floor, and mid-water nursery techniques [15]. One of the most innovative approach is Coral Tree Nursery [16], a method which were developed by Coral Restoration Foundation. Study from Israel [17] resulted in the survivorship of coral with the fragment transplantation using mid-water rope nursery can be as high as 97.2% for Montipora digitata.

2. Materials and Method

2.1. Field work

Basically, this research project is the first (or pilot project) coral nursery using coral rope tree technique applied in Morotai. Sampling was measured in Blaktip Point, Pulau Mitita, Morotai, Maluku Utara (Figure 1). Geographically, Blaktip Point is situated on 1°58'12" N-128°13'54" S, northward Mitita Island. Location is selected since it is in the proximity of shark diving site in Morotai, which may experience coral degradation [18]. Hence, it can be quickly deployed to the restoration area.

![Figure 1. Map of sampling site (green: land, blue: sea, red dots: dive sites)](image-url)
Figure 2 below showed the construction dimension of the coral rope tree nursery design. It is designed with the total length of 1.6 m and having five branches with the longer distance between branches of 40 cm and shorter distance of 8 cm. Each branch has a length of 40 cm and placed as to perpendicular to upper or lower branches. The structure of coral rope tree is made of Sch. 40 PVC which can be found in Morotai Island. Rope length is designed with the length of 12 to 41 cm depend on the dimension of the coral fragment with intend of avoiding collision between fragment during deployment and installation. Space between hanging rope is set at 8 cm between sample in order to avoid entanglement.

The substrates are hanged on coral rope tree nursery structure in the mid-water from depth of 8 m to 10 m. The structure shall be anchored on seabed while the top point is kept floated with a buoy [19]. The tethering line shall withstand the mild current condition on location which is approximately between 0.14 to 0.26 knots.

![Coral rope tree nursery design](image)

**Figure 2.** Coral rope tree nursery design

*Acropora formosa* is selected as the species to be cultivated since it is commonly found across Indonesia waters [20] and it is abundant in Morotai Island. Due to its widely distribution, *Acropora formosa* is among the most common transplanted branch coral in Indonesia [21]. With conventional transplantation or nursery methods, the growth rate and survivability of *Acropora formosa* varies between 0.21 – 1.41 cm/month and between 70.83% to 100% respectively [21, 22, 23, 24, 25, 26, 27, 28, 29].

Morotai waters is characterized as having mild to strong current (0 to 3 knots) and warm temperature (27 to 31°C) [30]. Other study showed that other water parameter in Morotai are as follow: pH between 8.13 – 8.44 [31], salinity between 34 – 36 PSU [31], and visibility varies between 5 to 17 meters [32].

Ideally, data gathering (on coral rope tree nursery growth and survivability) should be taken each month or within the certain periodic time. However, this not the case for Morotai waters since there are some delay or rearrangement due to bad weather or heath protocol restriction due to COVID-19 pandemic. Coral growth measurement is taken by at least two SCUBA divers using a caliper for each fragment.
2.2. Data Analysis
In order to determine the growth rate of _Acropora formosa_ in this study, following formula was used:

\[ \text{GR} = \frac{(L_t - L_{t-1})}{t} \]

where GR = Growth rate; \( L_t \) = Length of fragment of _Acropora formosa_ at month \( t \), \( L_{t-1} \) = Length of fragment of _Acropora formosa_ at previous month, and \( t \) = monthly period.

Survivorship of coral rope tree nursery was analyzed using following formula.

\[ \text{SR} = \left( \frac{N_t}{N_0} \right) \times 100\% \]

where SR = Survivorship rate; \( N_t \) = Number of _Acropora formosa_ fragment at the end of research, and \( N_0 \) = Number of _Acropora formosa_ fragment at the beginning of research. Data were analyzed using Microsoft Excel 2013.

3. Result and Discussion

3.1. Growth Rate
In total, 120 fragments of _Acropora formosa_ were cultivated in this study during May – October 2020 and it varied between sampling periods. The 120 fragments were cultivated in the two coral rope tree nursery structures, in which one structure contains 60 fragments. Figure 3 below describes the mean growth rate of coral rope tree nursery of fragments of _Acropora formosa_ in Morotai waters.

![Figure 3](image)

_Figure 3_. The mean growth rate of coral rope tree nursery of _Acropora formosa_ found in Morotai waters from May-October 2020
It can be shown that mean growth rate of *Acropora formosa* fragments on coral rope tree nursery in Morotai waters for the first four months are increase with the age. However, its mean growth rate is flattened in the month-5 for both coral rope tree structures. It is also found that highest growth rates are 3.9 and 3.2 cm/month for coral rope tree structure 1 and 2 respectively.

Comparing the results to other transplantation methods of *Acropora formosa* in Indonesia, it showed that the coral ropes technique offers relatively higher mean growth rate than most transplantation methods. It is also proven that despite the sea current in Morotai is relatively higher than other location of *Acropora formosa* transplantation, the mean growth rate in a nursery structure is maintained at approximately 1 cm/month at the end of fifth month.

### 3.2. Survivorship

Statistical analysis showed that the mean survivorship of coral rope tree nursery technique of *Acropora formosa* fragments in Morotai waters is approximately between 0.5 to 0.6. Figure 4 below describes the survivorship results for two coral rope tree nursery structures for *Acropora formosa* fragments in Morotai waters.

![Figure 4](image_url)

**Figure 4.** The mean survivorship of coral rope tree nursery of *Acropora formosa* found in Morotai waters from May-October 2020

Figure 4 showed that the survival of coral rope tree of *Acropora formosa* fragments dropped sharply within first month. However, in the following month the survivorships were flattened after two month of cultivation.

Comparison between this coral rope tree nursery technique and transplantation of *Acropora formosa* fragments in other area in Indonesia showed that the coral rope tree nursery is slightly lower than average survival rate for other transplantation technique. This may be due to mild current cultivation environment in Morotai compared to low or no current environment in other area.

### 3.3. Comparison of the result to other coral rope nursery techniques for Acropora sp. fragments

As a comparison, two researches which cultivated *Acropora sp.* fragments were selected: Eilat in Israel [19] and Teluk Awur in Indonesia [33]. Study in Israel [19] is using *Acropora eurystoma* S. while study in Teluk Awur selected *Acropora aspera* as the species understudy. Figure 5 below
described the differences on mean growth rate between this study and others. As it can be shown, this study showed that the growth rate of *Acropora formosa* in Morotai was relatively higher than the growth rate of *Acropora eurystoma S.* in Red Sea part of Israel. Despite the growth rate of *Acropora aspera* in Teluk Awur, Jepara is higher in all months except fourth month, their growth is considered as more fluctuate compared to what were happened in Morotai.

![Comparison of growth rate of Acropora sp. using coral rope nursery](image)

**Figure 5.** Comparisons of different growth rate of coral rope nursery of *Acropora sp.* in various location.

![Comparison of survival rate of Acropora sp. using coral rope nursery](image)

**Figure 6.** Comparisons of different survivorship of coral rope nursery of *Acropora sp.* in various location.

Figure 6 above showed that survival rate of coral rope tree nurseries of *Acropora formosa* in Morotai were considered as smaller than of the cultivation area in Teluk Awur and Eilat. These may be
affected by the sea current environment which showed that Morotai has higher current (up to 0.26 knots) compared to Teluk Awur (0.14 knots) [34] and Eilat (0.14 knots) [35].

4. Conclusion
With the mean growth rate of 1.1 cm/month and maximum growth rate of 3.9 cm/month, coral rope tree nursery technique proposes benefits compared to other nursery techniques. This research also proved that in the area where sea current is considered mild to strong, the nursery technique with coral rope tree offers the suitability with the survivorship rate of approximately 0.5 to 0.6. Despite its proved that in the area where sea current is considered mild to strong, the nursery technique with coral rope tree nursery technique proposes benefits compared to other nursery techniques. This research also proved that in the area where sea current is considered mild to strong, the nursery technique with coral rope tree offers the suitability with the survivorship rate of approximately 0.5 to 0.6. Despite its

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