EX-SITU GROWTH RATE OF MONTIPORA AND ECHINOPORA CORALS IN THE CORAL BREEDING FACILITY AT DAWAN DISTRICT, KLUNGKUNG REGENCY, BALI

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ABSTRACT

The phylum Coelenterata, class Anthozoa, includes a group of marine living things known as corals. Due to its geographic setting, Indonesia has an extremely high level of coral diversity and is the world's largest exporter of ornamental coral. Demand on the market for natural ornamental corals is now rising, along with trends in the rate of industrial development. Allowing this industrial activity to grow will result in huge exploitation and put the coral reef environment at danger. Therefore, to quickly increase the number of corals, this research examined transplantation methods. The montipora and echinopora genera were the focus of this study. The *Montipora capricornis* coral sample from PT. Tirta Samudra Bali had the highest growth rate of the Montipora genus corals, with an average growth rate of 1,404 cm^2/week. The highest growth rate of the Echinopora genus corals had an average growth rate of 0.362 cm^2/week. As they have a 100% survival record, cultivation activities using the transplant method performed at PT. Tirta Samudra Bali are regarded as successful.

Keywords: *Coral Culture, Montipora, Transplantation, Survival Record, Cultivation Activities*

1. INTRODUCTION

Coral is a group of marine living organisms that come from the phylum Coelenterata, class Anthozoa (Tuwo & Tresnati, 2020). Coral can form hard coral (Hard Coral) and soft (Soft Coral). Ornamental corals are part of the coral reef ecosystem which is the richest source of marine biodiversity. There are more than 70,000 different species of coral in the world and most of them inhabit warm tropical ocean waters (Fisher *et al*., 2015). This geographical location makes it possible for Indonesia to have a very high level of coral diversity. The patterns and colors of ornamental corals are very attractive for trade as ornamental corals, which makes them have a high export value. Indonesia is the largest ornamental coral exporting country in the world because of the coral potential it has (Kasmi *et al*., 2021).

Trends in the pace of industrial development and market demand for natural ornamental corals are now increasing. The export trade and high market prices for ornamental corals have their own charms (Kasmi *et al*., 2021). Ornamental coral can be a large source of foreign exchange for anyone who can manage it properly. In reality, this industrial activity cannot stand alone and is still closely dependent on nature. If this industrial activity is allowed to expand continuously, it will turn profitable activities into destructive activities and create massive exploitation. This can be catastrophic for coral reef ecosystems (Lachs & Oñate-Casado, 2020). In order to prevent this, cultivation techniques are presented as an innovative effort that can be done to overcome overexploitation and reduce dependence on nature (Subhan *et al*., 2015).

Coral cultivation techniques are suitable for application in industry. This method is carried out to obtain the number of products, types, and improve the quality of coral habitat in a planned and integrated manner (Ulfah *et al*., 2020). By utilizing this method, ornamental coral businesses can be used sustainably. Aquaculture not only has the potential to be profitable for the industrial sector, but the aquaculture process itself is also likely to provide important insights and extensive knowledge about coral ecology and biology on a large scale (Forsman *et al*., 2012).

The transplantation technique or commonly known as propagation is a technique used to reproduce coral colonies based on natural or artificial habitats (Kasmi *et al*., 2020). Coral transplantation is one of the most widely used methods for coral reef recovery. Transplantation is carried out by utilizing the ability of coral asexual reproduction, namely fragmentation (Subhan *et al*., 2015). This technique is considered suitable for industrial purposes because it can produce a large number of tillers in a relatively short time and does not require high costs (Anggara *et al*., 2022). The transplanted natural ornamental corals can then be exported as aquarium ornaments with a relatively high selling price.

This research focused on the genera Montipora and Echinopora. Montipora is a genus in the family Acroporidae. The Montipora genus has many forms, Montipora coral colonies can be submassive, sheet, or branched. Most of the species have corallites that are irregular and small in size (Purnama & Kusuma, 2020). Montipora coral grows optimally in water temperatures of 25ºC to 29ºC and can only tolerate a few degrees below this range. Montipora coral also requires high water salinity, reaching 35‰, and it is not uncommon to find it in waters with a salinity of 40‰ such as those in the Red Sea. The Montipora genus has a lower number of species compared to other corals, especially Acropora (Ko Ko *et al*., 2019). Echinopora belongs to the category of Scleractinia corals in the form of foliose (sheets) which are widely distributed in Indo-Pacific waters. The distinctive feature of this coral is that it has small calyces of around 2-4 mm (Rosdianto *et al*., 2022). This coral genus belongs to the taxonomy of the order Scleractinia, and the family Merulinidae (*Marinespecies*, 2023).

Coral growth rate is the speed of the process of increasing mass, volume, and also the area of coral over a period of time. Coral growth rates can differ from one another. This is caused by differences in species, age, and parameters or water quality where corals grow (Zamani, 2016). It is important to study coral growth rates in order to know accurately how long corals need to grow and develop. It is hoped that the results of this study can later be used as a basis for law-making and better management of coral reefs (Wicaksono *et al*., 2019). It is also expected that the resulting data from this study can be used as material for consideration as well as support the success of transplantation activities and widespread coral cultivation.

Activities carried out by the company PT. Tirta Samudra Bali focus on coral cultivation activities, both ex-situ and in-situ. One of these activities is restocking using cultivation techniques. Cultivation and restocking activities in a water area aim to increase coral cover so as to improve the function of coral reef ecosystems. This is done in order to support the value of marine resources not only on a small scale (industrial) but on a wider scale (ecosystem sustainability). Increasing the function of coral reef ecosystems can have an impact on increasing the fisheries sector and the tourism sector, so that it can be used to help improve the economy and welfare of coastal communities.

2. METHOD

This coral growth rate research was carried out from March 2023 to June 2023. The type of research used in this study is a qualitative descriptive study and took place at Coral Breeding Facility of PT. Tirta Samudra Bali, Jalan Raya Goa Lawah No. 88, Pesinggahan Village, Dawan District, Klungkung Regency, Bali.

2.1 Materials and Tools

Several tools that are used to support the measurement of coral growth rate and survival rate are:

1. Underwater camera to document coral growth rate
2. Camera mat to support and hold camera at the time of observation
3. Ruler for measuring coral growth rate
4. Refractometer to measure salinity in the aquarium
5. pH meter to measure the pH in the aquarium

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6. Thermometer to measure the temperature in the aquarium
7. LED Lights As a substitute for natural light
8. Brushes for cleaning moss and pests on research samples
9. Digital scales for measuring dosing materials
10. Profile test (salifert) to measure levels of alkalinity, calcium, and magnesium in the aquarium
11. Iodine, used as Medicine for coral recovery
12. Baking soda serves to increase Alkalinity levels
13. Kalkwasser, Ca (OH)2 to increase Calcium levels
14. Epsom Salt, Mg (SO)4 to increase Magnesium levels

2.2 Methods

Coral Selection and Placement

The first stage in the study of coral growth rate was selecting sample corals as well as choosing an aquarium as a place to care for the corals. The selection of corals to be observed includes selecting the genus and species, as well as the size and condition of the corals, to make them easier to study. The corals to be observed in this study took random species from two genera, namely Montipora and Echinopora (Figure 1). Corals were placed under sufficient LED lighting, and given the same treatment (physical and chemical parameters) for each type of coral.

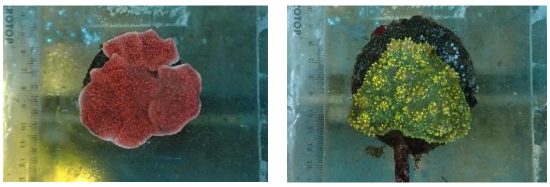

Figure 1. Coral samples: (a) *Montipora capricornis*; (b) *Echinopora* sp

Coral Treatment

Coral treatment is carried out in the coral breeding aquarium owned by PT. Tirta Samudra Bali. The treatment includes observing physical and chemical parameters on a regular basis as well as controlling the substances contained in the reef aquarium. The physical parameters observed included the intensity of current velocity and temperature, while the chemical parameters observed included salinity, pH, alkalinity, magnesium, and calcium. After measuring the parameters of the water, dosing activities can be continued to stabilize the parameters of the aquarium water. For example, adding sodium bicarbonate solution to increase the alkalinity when the amount is reduced in the aquarium. Coral substrates also need to be cleaned periodically of algae and adhering pests. The aquarium where the coral lives need to be kept clean as well. This is done so that competition for nutrients does not occur and minimizes the potential for coral death (Andika *et al*., 2020).

Photography

Taking pictures of corals is done using an underwater camera in the same position for each picture. This position can be maintained by using a camera mat that is shaped in such a way as to have a ruler, a place-to-place coral, and a hole to place camera so that the shooting position does not change with each observation. Coral images were taken from the top and side views to determine the increase in height and width of the coral.

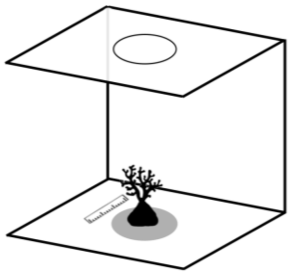

Figure 2. Custom camera mat

Processing and Data Analysis

The processing stage of coral growth rate data is carried out by utilizing the ImageJ software. This software is commonly used for processing sample data that is small to microsized. ImageJ is software used to process photo data to obtain distance values for the rate of coral growth seen from the length of coral growth over a period of time (Octavina *et al*., 2021). The digitized data was then processed using Microsoft Excel. The value of the coral growth rate is calculated by dividing the average area increase by the length of observation. The measurement of coral growth rate is calculated using the formula according to Effendi (1997) as follows:

$$P = \frac{L_t - L_0}{t} \quad (1)$$

P = Addition of length/height of coral
Lt = Average length/height after the t-th observation
L0 = Average length/height at the start of the study
t = Observation Time

The data resulting from the growth rate is also processed to obtain the survival rate value. The survival rate value can be determined by comparing the number of living corals at the end of the study (Nt) with the number of corals sown (No), using the formula according to Effendi (1997) as follows:

$$SR = \frac{N_t}{N_0} \times 100\% \quad (2)$$

SR = survival rate (survival rate)
Nt = Number of individuals at the end of the study
No = Number of individuals at the start of the study

3. RESULTS AND DISCUSSION

Almost all types of coral are very sensitive to changes in physical and chemical waters (Luthfi *et al.*, 2017), so the water parameters in the aquarium need to be considered and maintained properly. The results of the physical and chemical conditions of the waters can be seen in (Table 1).

Table 1. Measurement of Aquarium Water Conditions

Data Collection time	**Parameter**					
	Temperature (°C)	**pH**	**Salinity (ppm)**	**Alkalinity (dKH)**	**Magnesium (ppm)**	**Calcium (ppm)**
I (8-4-2023)	24	8,4	1.025	9,9	1290	410
II (23-4-2023)	24	8,5	1.025	9,9	1290	420
III (2-5-2023)	24	8,3	1.025	10,5	1200	400
IV (18-5-2023)	25	8,4	1.024	9,6	1230	370
V (1-6-2023)	24	8,3	1.026	8	1230	390

3.1. Montipora

Based on the results of data processing on the growth rate of corals from March 2023 to June 2023, data on the increase in area varied for each size (Table 2). Montipora coral sample 1 experienced an increase in area from the 1st observation to the 2nd observation, namely from 10.25 cm² to 14.8 cm², followed by an increase in area again to 15.35 cm² in the 3rd observation, then again increased to 15.74 cm² in the 4th observation, and increased again to 15.77 cm² at the last observation. The overall sample of Montipora corals showed a positive trend, and the increase in coral area increased significantly (Figure 3). In the study of this genus, there was no decrease in the total area of the coral samples.

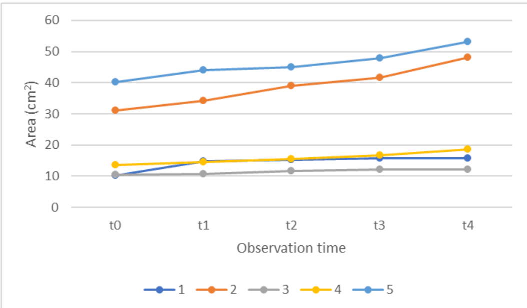

Figure 3. Graph of Growth Area of Montipora Corals

Montipora genus has a fast growth rate with a perforate structure (Kuffner *et al.*, 2012). These corals also have the ability or mechanisms to deal with any extreme conditions, and has a high tolerance of stress that comes from the extreme tidal conditions and competitors. Asexual reproduction of these corals is the optimal strategy to support this (Harpeni & David, 2011). Coral growth rates for 4 months showed different results (Figure 4). Based on the graph of the growth rate of Montipora corals, it can be concluded that sample 2 occupied the highest coral growth rate with an average growth rate of 1,404 cm²/week. The lowest coral growth rate was occupied by the 3rd sample, with a growth rate of 0.143 cm²/week.

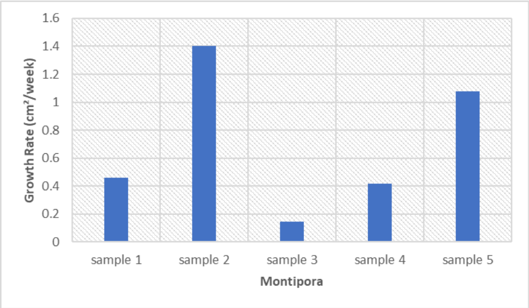

Figure 4. Montipora Corals Growth Rate

Table 2. Growth Area of Montipora Corals

Sample	Species	Area					Avg
		t0	t1	t2	t3	t4	
1	*M. danae*	10.25	14.8	15.35	15.74	15.77	14.382
2	*M. Capricornis*	31.15	34.17	39.09	41.65	48	38.812
3	*M. digitata*	10.48	10.72	11.67	12.1	12.2	11.434
4	*M. danae*	13.63	14.46	15.4	16.72	18.66	15.774
5	*M. danae*	40.25	44.14	44.97	47.98	53.19	46.106

3.2. Echinopora

Based on data processing of coral growth rates from March 2023 to June 2023, various data were obtained (Table 3). The area in sample 1 increased towards the 2nd observation to 31 cm², then decreased in the 3rd observation to 28.97 cm², and decreased in the 4th and 5th observations, respectively, to 27.99 cm² and 27.54 cm². Coral sample 2 increased from 6.18 cm² to 6.25 cm² in the 2nd study, then decreased in the 3rd study to 5.02 cm² due to bleaching and being overgrown with moss, then increased again in the 4th observation to 5.23 cm² and continued to increase until it reached 5.61 cm² at the 5th observation. Coral sample 3 experienced a decrease in area at each observation time, successively, the area of sample 3 from start to finish was 12.16 cm², 11.55 cm², 10.98 cm², 10.94 cm², and 10.78 cm² so that the average area was 11.28 cm². Sample 4 was the only Echinopora coral sample that had a significant increase in area (Figure 5), from 24.61 cm² to 25.22 cm² in the second observation, and again increased to 26.06 cm² in the third observation. The area decreased to 26.02 cm² in the 4th observation before increasing again to 28.96 in the 5th observation. Coral sample 5 decreased from 41.47 cm² to 40.23 cm² during the 2nd observation, then increased significantly from the 3rd to the 5th observation, namely 40.34 cm², 41.67 cm², and 42.15 cm².

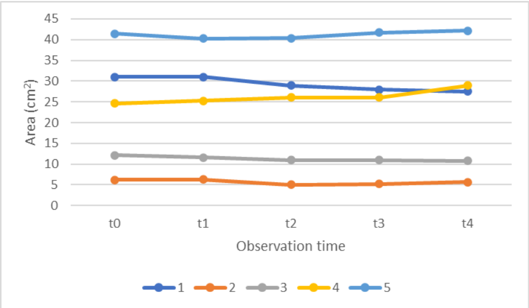

Figure 5. Growth Area of Echinopora Corals

The genus Echinopora has the characteristics of not branching and slow growth (Dela Cruz *et al.*, 2015). Growth rate of Echinopora for 4 months showed varied results (Figure 6). Based on the graph of the growth rate of Echinopora corals, it can be concluded that the highest coral growth rate was occupied by Echinopora coral sample 4, with an average growth rate of 0.362 cm²/week. The lowest coral growth rate was occupied by Echinopora sample 1, which had a decreasing growth rate of -0.287 cm²/week. Due to many different organisms that have an impact on it, such as algae that stick to the fragments of coral reef, this coral grows slowly and may even shrink. Algae are understood as coral's competitors in terms of nutrients, available area, and light. Algae can harm coral tissue and eventually result in coral mortality (Andika et al., 2020).

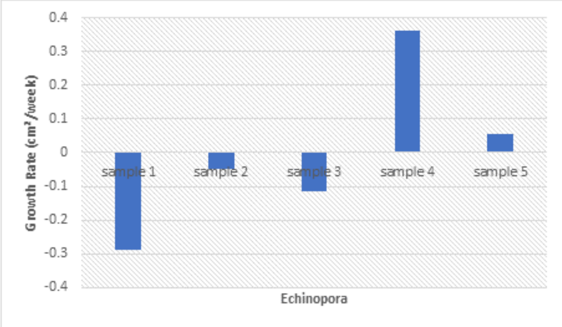

Figure 6. Echinopora Corals Growth Rate

Table 3. Growth Area of Echinopora Corals

Sample	Species	Area					Avg
		t0	t1	t2	t3	t4	
1		30.99	31	28.97	27.99	27.54	29.298
2		6.18	6.25	5.02	5.23	5.61	5.658
3	*Echinopora* sp.	12.16	11.55	10.98	10.94	10.78	11.282
4		24.61	25.22	26.06	26.02	28.96	26.174
5		41.47	40.23	40.34	41.67	42.15	41.172

3.3 Survival Rate

The survival rate is the ability of a coral to survive without dying during research. The survival rate of the corals studied can be used as supporting data to determine the success of the coral transplantation method (Muhlis, 2019). Based on the graph of the survival rate of the Montipora and Echinopora corals (Figure 7), it can be concluded that both corals had a 100% survival rate during the 4 months of the study, where the number of live coral fragments from the beginning to the end of the observation remained at 5 pieces. Referring to this survival rate data, it can be said that coral transplantation activities carried out at PT. Tirta Samudra Bali are considered successful. Transplantation activity can be said to be successful if the survival rate is between 50-100% (Erika et al., 2019). Salinity plays an important role in influencing coral survival rates (Siahainenia *et al.*, 2019). The survival percentage of coral species is influenced by several physical factors, which include temperature, physical oceanography, sedimentation, and inappropriate placement of artificial coral reef (Isdianto et al., 2020).

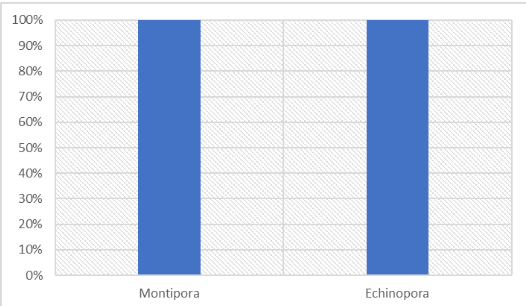

Figure 7. Graph of Survival Rate

4. CONCLUSION & RECOMMENDATION

Based on the results obtained in this study, the following conclusions can be drawn:

1. The highest growth rate of corals of the genus Montipora in the Coral Breeding Facility of PT Tirta Samudra Bali, Klungkung, occupied by sample 2 (*Montipora capricornis*) with an average growth rate of 1,404 cm²/week, and the

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lowest was occupied by sample 3 (*Montipora danae*) with a growth rate of 0.143 cm²/week. The highest growth rate of corals of the Echinopora genus was occupied by sample 4, with an average growth rate of 0.362 cm²/week, and the lowest was occupied by Echinopora coral sample 1, with a decreasing growth rate of -0.287 cm²/week.

2. Cultivation activities using the transplant method carried out at PT. Tirta Samudra Bali are considered successful. because it has a 100% survival rate.
3. The transplantation method is an activity that can be used as an alternative to enrich the value of coral abundance both for industrial needs and for needs in nature.

Suggestions for further research related to growth rates, it is better to be focused on just one or two species and use samples of similar size in order to produce more accurate data. Monitoring also needs to be done on a more scheduled basis to avoid emergence of pests and diseases that can inhibit growth and damage corals.

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