



## The Growth of *Seriatopora hystrix* (Dana, 1846) Transplant with Differences of Fragment Size and Planting Position

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### ABSTRACT

Transplantation of coral reefs requires sufficient fragments but must still ensure the sustainability of coral donors. This research aimed to know the survival rate and growth rate of transplant corals with different fragment sizes and planting positions and to determine the most effective and efficient transplantation methods of the *Seriatopora hystrix*. The research was conducted from January to April 2016 in Serangan Island waters Denpasar Bali (1-2 m depth). The method used was a field experiment with variations of planting position (vertical, horizontal) and fragment sizes (3, 5, 7 cm). The results showed a high survival rate (98.3%) of the transplanted *S. hystrix* with planting position and fragment sizes variation. The variation of planting position and fragment sizes were significantly affected the length growth rate of the *S. hystrix* ( $p < 0.05$ ). The vertical planting position showed better growth compared to the horizontal planting position. The transplantation of coral with initial fragment sizes of 5 and 7 cm showed a higher growth rate than the fragment size of 3 cm. However, statistical analysis revealed no significant difference between initial fragment sizes of 5 and 7 cm. Therefore, this study demonstrated the most effective and efficient for *S. hystrix* transplantation showed in the vertical position with the initial fragment size of 5 cm.

**Keywords:** coral bleaching, initial fragment, tropical, zooxanthellae

### ABSTRAK

Transplantasi terumbu karang membutuhkan fragmen yang cukup namun harus tetap menjamin keberlanjutan karang donor. Penelitian ini bertujuan untuk mengetahui tingkat kelulushidupan dan laju pertumbuhan karang hasil transplantasi dengan perlakuan ukuran fragmen dan posisi penanaman yang berbeda, serta menentukan metode transplantasi paling efektif dan efisien pada karang *Seriatopora hystrix*. Penelitian dilaksanakan pada bulan Januari hingga April 2016 di perairan Pulau Serangan Denpasar Bali (kedalaman 1-2 meter). Metode yang digunakan adalah eksperimen lapangan dengan variasi posisi tanam (vertikal, horizontal) dan ukuran fragmen (3, 5, 7 cm). Hasil penelitian menunjukkan tingkat kelangsungan hidup yang tinggi (98,3%) dari *S. hystrix* yang ditransplantasikan dengan variasi posisi tanam dan ukuran fragmen. Variasi posisi tanam dan ukuran fragmen berpengaruh nyata terhadap laju pertumbuhan panjang *S. hystrix* ( $p < 0,05$ ). Posisi tanam vertikal menunjukkan pertumbuhan yang lebih baik dibandingkan dengan posisi tanam horizontal. Transplantasi karang dengan ukuran fragmen awal 5 dan 7 cm menunjukkan laju pertumbuhan yang lebih tinggi dibandingkan dengan ukuran fragmen 3 cm. Namun, analisis statistik menunjukkan tidak ada perbedaan yang signifikan antara ukuran fragmen awal 5 dan 7 cm. Oleh karena itu, penelitian ini menunjukkan transplantasi *S. hystrix* yang paling efektif dan efisien adalah dengan posisi vertikal dan ukuran fragmen awal sebesar 5 cm.

**Kata kunci:** pemutihan karang, fragment awal, tropis, zooxanthela

1. Introduction

The damages of coral reefs in Indo-Pacific, Australia, and the Caribbean in the last four years reported getting increased (Bruno & Selig, 2007; De'ath et al., 2012; Jackson et al., 2014). So far, 75% of world coral reefs were currently recorded in endangered conditions (Burke et al., 2012), both because of the natural and anthropogenic factors. This condition was made worse by the slow natural regeneration ability of the coral reef. Hoegh-Guldberg (2015) even projected the loss of all world coral reefs in 2050 due to the threat of global warming, including the rise of sea temperature and acidity. The damage of the coral reef, which was expanded year by year caused the function of the marine ecosystem, cannot be fully optimized. Coral transplantation was considered as one of the effective solutions to fix the coral reef damaging ecosystems (Harriott & Fisk, 1988). The main purpose of coral reef transplantation was to accelerate the initial phase of coral growth that generally has a low survival rate and growth. At first, coral reef transplantation was developed mainly for rehabilitation purposes, however, now it is developed to support the community's economic stability, particularly for tourism and ornamental coral trade commodity sectors. Green & Hendry (1999) noted that coral reef exploitation for ornament trade commodities reached US\$ 500 million per year. Bruckner (2001) also stated that the live coral trade since the 90s continues to increase as much as 15-30% every year. Thus, the success rate and the effectiveness of these transplantation efforts are needed to prevent irresponsible exploitation of natural coral reef.

The success rate and the effectiveness of coral transplantation were influenced by various factors. According to Harriot & Fisk (1988) and Soong & Chen (2003), fragment size was one of the factors affecting the success rate of the coral reef transplantation. A suitable and appropriate size of the fragment was needed to increase the

growth rate without causing overexploitation of the main coral colony. Planting orientation both vertically and horizontally affects the growth of coral fragment. Edmunds (1999) mentioned that planting orientation has influenced a parallel relation with the surface area of a fragment in terms of receiving light. The surface area of living tissue in each fragment's length affects the coral's ability to obtain energy for photosynthesis (Soong & Chen, 2003). Photosynthesis activity carried out by coral's symbiont, namely zooxanthellae, which able to faster the calcification process and eventually builds the coral's skeleton (Castro & Huber, 2005). The influence of planting position and fragment size variation towards coral *Seriatopora hystrix* growth, which transplanted in previous research has not been studied to date. The suitable position and appropriate size of the coral fragment are necessary for effective and efficient transplantation, both ecologically and economically. Moreover, to determine the most optimum planting position as one of the efforts in maximizing the growth of transplanted coral fragment.

2. Materials and Methods

*Seriatopora hystrix* fragment used in this analysis obtained from the refined coral of a commercial company in Bali. This research conducted in Serangan Island Bali Indonesia from January to April 2016. The Randomized Block Design (RBD) used in this research with 2 factors i.e., the fragment sizes (3, 5, and 7 cm) and planting position (vertical and horizontal). Each treatment replicated in 10 trial units, which randomly placed in transplanted shelves. The detailed experimental design was shown in Figure 1.

Each experimental unit was tied and fastened to the propped substrate using cable ties. The vertical planting position was accomplished by tying coral fragments parallelly to the fork of the substrate; while for the horizontal planting position was made by tying coral fragments

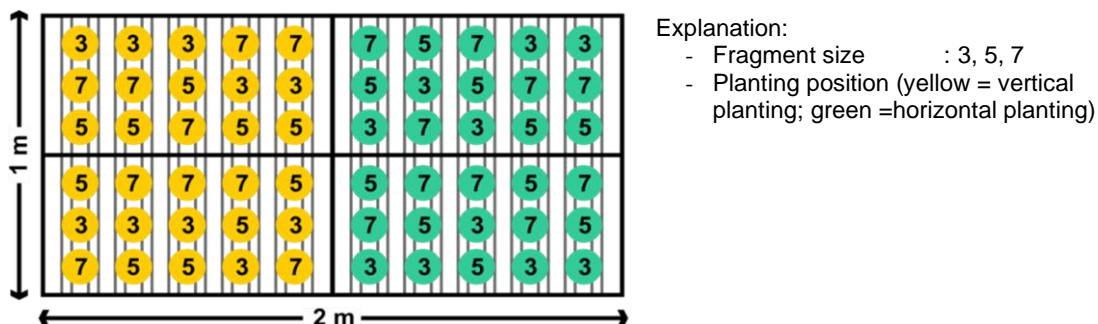
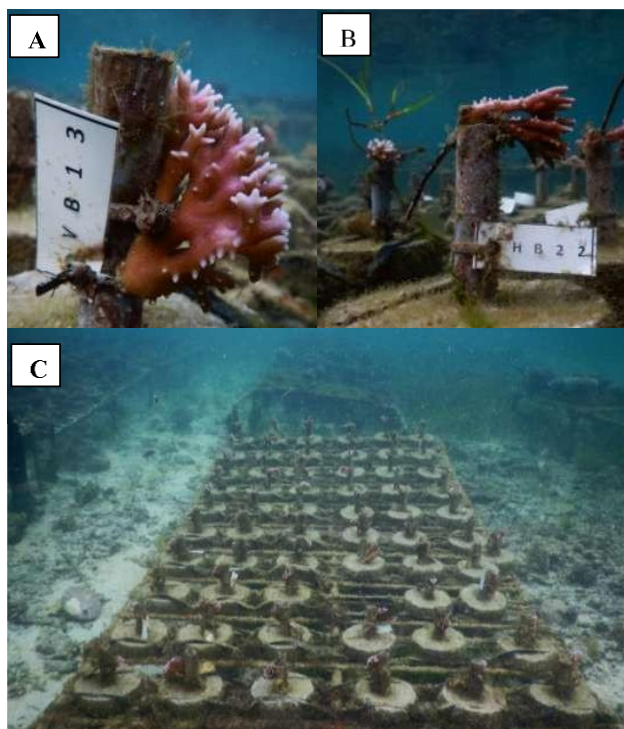


Figure 1. The experimental design of *S. hystrix* transplantation with differences of fragment size and planting position



**Figure 2.** The experiment of *S. hystrix* transplantation with differences of fragment sizes and planting position (A: vertical position of initial fragment, B: horizontal position of initial fragment, C: Placement of corals transplant on the metal racks).

perpendicularly to the fork of the substrate (Figure 2). The coral fragments that were tied to the fork of the substrate then tucked randomly on transplantation experiment shelves based on the experiment planning set. Those transplanted coral fragments then maintained for about ± 12 weeks.

The coral reef growth and rate survival were calculated using these following formulas:

**a. Coral absolute growth length/width**

$$\beta = L_i - L_0$$

Explanation:

$\beta$  = Transplanted coral absolute growth length/width (cm)

$L_i$  = Average length/width coral fragments in week number-i (cm)

$L_0$  = Average length/width coral fragments in the first observation (cm)

**b. Increased number of coral buds/branches**

$$\Delta C = C_i - C_0$$

Explanation:

$\Delta C$  = Increased number of coral buds

$C_i$  = Average length/width coral fragments in time number-i (cm)

$C_0$  = Average length/width coral fragments in the first observation (cm)

**c. Coral growth rate (Okubo *et al.*, 2005)**

$$P = \frac{L_i - L_0}{t}$$

Explanation:

P = Coral growth rate (cm/month)

$L_i$  = Average length, width, or branch in time number-i (cm)

$L_0$  = Average length, width, or branch in the first planting (cm)

t = Planting length (month)

**d. Coral survival rate (Ricker, 1975)**

$$SR = \left( \frac{N_t}{N_0} \right) \times 100\%$$

Explanation:

SR = Live survival rate (%)

$N_t$  = Coral fragments amount alive at the end of the observation

$N_0$  = Coral fragments amount at the first observation

The data obtained were then processed using Microsoft Excel 2007 and SPSS (Statistical Product and Service Solution) program for Windows version 22. Data processing started by testing the normality of growth data in length, width, and bud's formation. Two-way Analysis of Variance (Two Way ANOVA) test at a 95% confidence level was conducted to determine the difference of data average and the effect of treatment on the growth variable.

### 3. Results and Discussions

Coral fragments that were planted horizontally have a lower survival rate (96.67%) than coral fragments, which are planted vertically (100%). Coral transplantation *Seriatopora hystrix* with variation planting position and fragment size overall show the high success rate with SR value was 98.3% (Table 1).

The growth rate of length, width, and bud in coral *S. hystrix* was very diverse between planting position and fragment size treatment. The coral fragment, which was planted vertically, gives a higher growth rate than the horizontal coral fragment. The highest growth of length, width, and bud experienced in coral fragment with 7cm size both in vertical and horizontal planting position. Generally, the bigger the fragment size, the faster its growth rate.

Analysis of two-way ANOVA towards planting position and fragment size treatment of coral *S. hystrix* shows a significant difference on its length growth rate ( $p < 0.05$ ) (Table 2). The analysis growth of width and bud indicates that there is a slight difference if compared to the length growth rate. Planting position treatment did not significantly impact the coral growth;

however, the treatment for fragment size still significantly affects the growth of width and bud in coral fragment *S. hystrix* ( $p < 0.05$ ).

In detail, the growth rate of coral *S. hystrix* transplantation results with a planting position and the fragment size difference shown in Table 3.

Planting position treatment gives a significant effect on the length growth coral *S. hystrix*. The coral fragment, which is planted vertically, shows better length growth and higher value compared to a coral fragment which horizontally planted (Figure 3).

The two-way ANOVA analysis towards the width and bud growth shows a little difference. The planting position treatment both vertically and horizontally was not affect the growth rate speed of bud and width on *S. hystrix*. Nevertheless, the width and bud of coral were growth faster on the vertical planting position than the horizontal planting position (Figure 3).

The initial fragment size treatment has a significant impact on the growth of length, width, and the bud of *S. hystrix*. Generally, the bigger the initial fragment size will provide faster growth and bud formation. The Tukey HSD statistical

**Table 1.** Survival rate of *S. hystrix* transplantation with differences fragment sizes and planting positions

Planting Position	Fragment Size	N <sub>0</sub>	N <sub>t</sub>	Survival Rate (%)	Average
Vertical	3 cm	10	10	100	100 %
	5 cm	10	10	100	
	7 cm	10	10	100	
Horizontal	3 cm	10	10	100	96.7 %
	5 cm	10	9	90	
	7 cm	10	10	100	

**Table 2.** Two-way ANOVA test results on the growth rate of the *S. hystrix* corals with different planting positions and fragment sizes.

	Source	Df	Mean square	F	Sig.
Length	Planting Position	1	0.116	32.231	0.000*
	Fragment Size	2	0.027	7.410	0.001*
	Planting Position * Fragment Size	2	0.001	0.369	0.560
	Error	53	0.004		
	Total	59			
Width	Planting Position	1	0.001	0.182	0.638
	Fragment Size	2	0.047	6.166	0.004*
	Planting Position * Fragment Size	2	0.000	0.014	0.981
	Error	53	0.008		
	Total	59			
Bud	Planting Position	1	29.944	0.435	0.482
	Fragment Size	2	1226.337	17.796	0.000*
	Planting Position * Fragment Size	2	0.810	0.012	0.987
	Error	53	68.910		
	Total	59			

\* significant differences (sig. < 0,05)

**Table 3.** The growth rate *S. hystrix* transplantation with differences of fragment sizes and planting positions

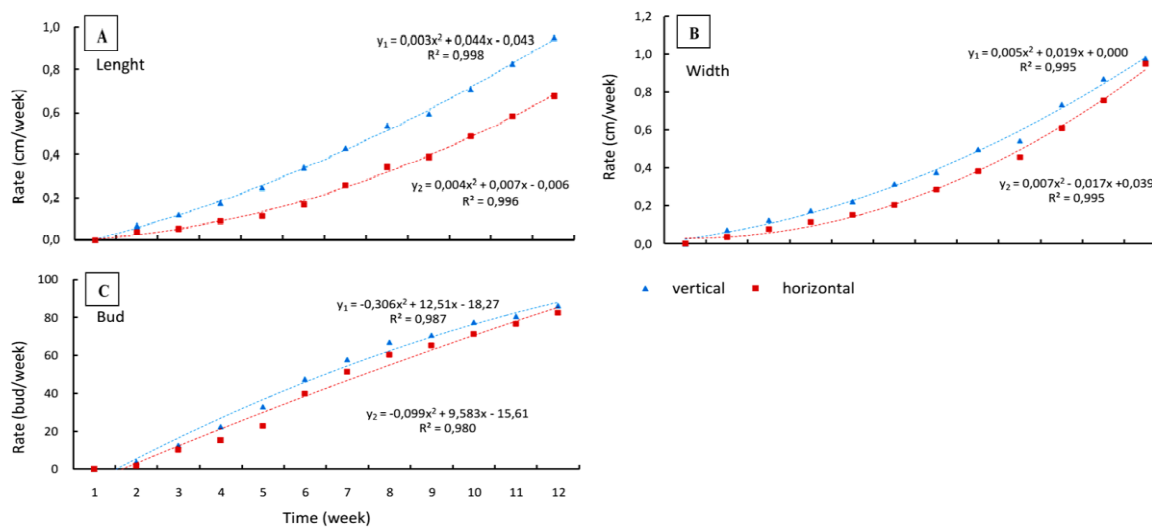
Planting Position	Fragment Size	Growth rate per month		
		Length (cm)	Width (cm)	Bud
Vertical	3 cm	0.265 <sup>a</sup>	0.267 <sup>a</sup>	19 <sup>a</sup>
	5 cm	0.339 <sup>bc</sup>	0.349 <sup>bc</sup>	33 <sup>bc</sup>
	7 cm	0.346 <sup>c</sup>	0.360 <sup>c</sup>	34 <sup>c</sup>
Horizontal	3 cm	0.195 <sup>a</sup>	0.263 <sup>a</sup>	18 <sup>a</sup>
	5 cm	0.233 <sup>bc</sup>	0.335 <sup>bc</sup>	31 <sup>bc</sup>
	7 cm	0.247 <sup>c</sup>	0.347 <sup>c</sup>	32 <sup>c</sup>

analyses on the length, width, and bud formation, the coral fragment with 5 cm and 7 cm initial size did not show a significant difference. However, those two sizes have a significant difference compared to coral fragment with the smallest initial fragment size of 3cm. The growth of length, width, and bud formation of the *S. hystrix* with variations of the initial fragment size during the experiment can be seen in Figure 4.

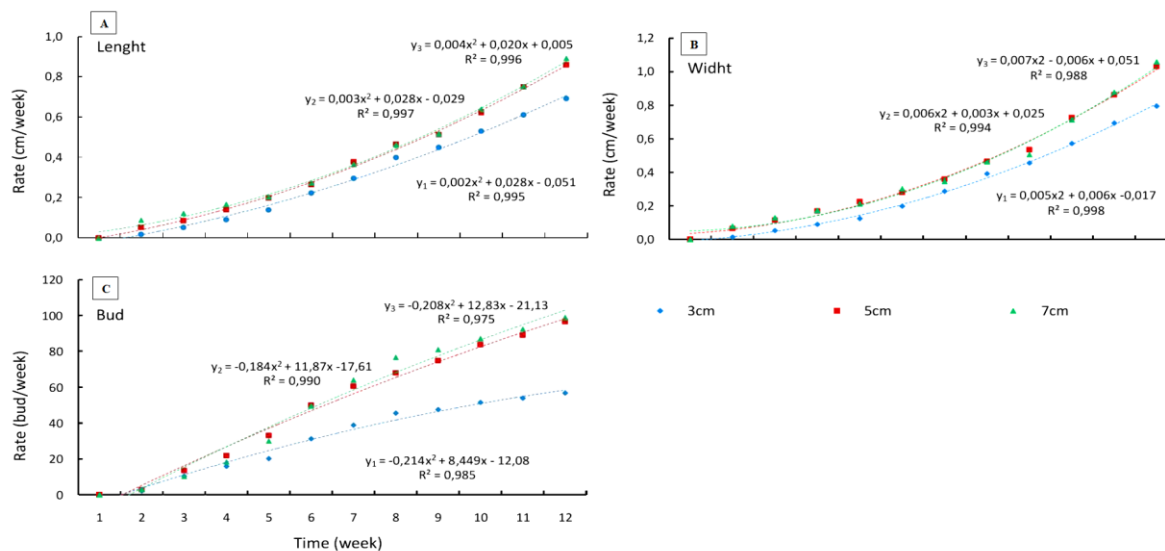
Nowadays, the world faces the risk of decreasing the area of coral reef ecosystems due to the natural impact and anthropogenic activities. Therefore, conservation is essential to reduce the high level of coral reef damage. Transplantation is an alternative to increase the effectiveness of coral reef ecosystem restoration. Transplantation of coral reefs requires sufficient initial fragments but must still ensure the sustainability of coral donors. This study shows a high survival rate (98.3%) of *Seriatopora hystrix* transplantation by treating the initial fragment size and planting position. The variation of survival rate can be influenced

by treatment factors and environmental conditions which might limit the growth of coral fragment. Based on the visual observation, coral fragments skeleton which planted horizontally looks paler compared to coral fragments which planted vertically. The vanishing color or the waning incident of this coral skeleton shows that there was bleaching in the planted plants with a horizontal planting position.

A slight long bleaching duration causes coral fragments unable to grow optimally. According to Hoegh-Guldberg (1999), coral in which experience (bleaching) can recover to its original state, however, it depends on the duration and the environmental disturbance that might affect them. Continuous environmental disturbance can increase the risk of death to the coral reef colony. The slow-paced growth due to bleaching also triggers the rise of algae to bloom; therefore, coral fragments that unable to compete eventually lead to death. According to Yap et al. (1984), algae can cause damaging of coral tissue and even the loss of the coral colony.



**Figure 3.** The growth of *S. hystrix* with differences of planting position (A: length growth; B: width growth; C: bud formation).



**Figure 4.** The growth of *S. hystrix* with differences of initial fragment sizes (A: length growth; B: width growth; C: bud formation)

Harriot & Fisk (1988) explain that coral transplantation can be noted as success when its SR value  $\geq 50\%$ . Thus, transplantation experiments both as a whole treatment group and each treatment group can be declared to be successful.

The variation of length, width, and bud growth on the coral fragment, which planted both vertically and horizontally can be influenced by external factors such as water temperature, salinity, pH, and sunlight. The coral fragment, which planted horizontally, will experience bleaching, while fragment which planted vertically will not. The bleaching mostly occurs on the coral with horizontal planting position, especially the surface sides that are exposed to the sunlight directly. However, at the bottom side, the coral was still brightly dyed. According to Brown (1997), the bleaching pattern of coral that occurs only on the upper surface of the colony indicates the influence of sunlight intensity on coral bleaching.

The coral fragment which planted horizontally has a bigger chance to get sunlight exposure compared to coral fragment with vertical position. Soong & Chen (2003) explained that the wider the fragment's surface was, the higher sunlight exposure will be received for photosynthesis. However, too high sunlight exposure will cause a decrease of zooxanthellae density (Lesser & Shick, 1989). The density reduction of zooxanthellae can cause a decrease in photosynthesis and classification rate, meaning that it was a form of coral's adaptability towards the changing of environmental conditions.

Harrison & Wallace (1990) stated that all living creatures not limited to coral have energy allocation in their living function, such as maintenance, growth, and reproduction, and if this energy allocation for maintenance is higher, then the energy for growth will decline. The coral fragment which experiences bleaching needs extra energy to lower their energy allocation for their growth. This condition will cause a lower growth rate of coral *S. hystrix* which planted through a horizontal position.

This study shows that the size of the initial fragment influenced the growth rate of coral. The initial fragment size of 7 cm showed the fastest growth rate than the initial fragment size of 5 cm and 3 cm. According to Okubo et al. (2005) and (Soong & Chen, 2003), the larger corals will grow faster than smaller corals. The size of coral fragments may affect increasing coral opportunity in obtaining the nutrition and light for the zooxanthellae. The growth rate of coral *S. hystrix* with initial fragment size of 5 cm has no significant difference compared to initial fragment size of 7 cm (Table 3). Therefore, using a smaller size (5 cm) of the initial fragment was perceived as the most suitable and the fittest for the transplantation process in the field. Using smaller initial fragment sizes means that it will be more effective and efficient economically and ecologically. The number of donors taken from the ecosystem is relatively small, greater availability, and does not cause overexploitation to the main colony. However, using the smaller initial fragment should be more discernible and careful because it might raise the transplanted coral's mortality risk (Harriot & Fisk, 1988).

#### 4. CONCLUSIONS

The survival rate of *S. hystrix* transplantation results with planting position and fragment size difference as much as 98.3%. The variation treatment towards planting position and fragment size shows a significant impact on the growth length of coral ( $p < 0.05$ ). Vertical planting position gives a better growth rate compared to the horizontal position. The most effective and efficient coral *S. hystrix* transplantation done through a vertical planting position with an initial fragment of 5 cm instead of 7 cm to avoid the high exploitation of coral donors.

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