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Survival and growth of *Acropora millepora* coral fragments transplanted in turbid water of Sepulu, Bangkalan – Madura

Farid Kamal Muzaki*, Dian Saptarini, Isabella Rahma Azizah, Inna Kartika Sari and Alif Tian Edo Pramono

Marine Ecology and Conservation Research Group, Ecology Laboratory, Biology Department, Institut Teknologi Sepuluh Nopember Jl. Arief Rahman Hakim, Surabaya 60111, East Java, Indonesia

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ABSTRACT

Turbidity and sedimentation are well known to be one of the major factors that limit the growth and development of Scleractinian corals, either in natural reef or transplanted coral for rehabilitation purpose. This study is aimed to access the survival and growth rate of *Acropora millepora* coral fragments transplanted on dome-shaped concrete artificial reef in the turbid coastal waters of Labuhan, Sepulu, Bangkalan – Madura. Ten units of dome-shaped concrete artificial reef containing 6 coral fragments deployed on the seafloor at depth ±3.5 meter in two different location (NW and NE) with relatively different turbidity. The observation of survival and growth rate were monthly basis; conducted *in situ* with Scuba diving technique. After 5 months, the results show that survival of corals was higher in NE location (92.22%) compared to NW location (88.89%). The growth rate of the corals was significantly differed (independent t-test, $p = 0.001$ at $\alpha = 0.05$) with NE location have higher growth rate compared to NW (1.948±0.276 - 1.748±0.285 cm/month, respectively).

Key words *: Survival, Growth, Acropora millepora, Turbid water, Coral transplantation, Artificial reef*

Introduction

Despite occupying only 1% of the seafloor, coral reefs are one of marine ecosystems with high biodiversity and productivity (Burke *et al*., 2011; Elliff & Kikuchi, 2017). They occur in the transition of marine and terrestrial habitat and have the potential to experience various negative impacts from any dynamics that occur from both habitats (Buddemeier *et al*., 2004); for examples are destructive fishing activities, development of coastal areas and terrestrial runoff (Weber *et al*., 2006), marine pollution, global warming (Buddemeier *et al*., 2004; Baker *et al*., 2008) and ocean acidification. Various cases of damage and quality deterioration of coral reefs have been widely reported from all over the world in the last few decades; and it can be assumed that coral reefs are one component of coastal ecosystems that experience the highest rate of degradation.

In Indonesia, only less than 7% of coral reef with very good condition and only 22.96% in state of good condition (Hadi *et al*., 2018). A relatively similar trend occurred also in the coastal area of Sepulu, Bangkalan district in Madura island. Initial survey in early 2017 resulting that life coral cover in the area was less than 15% or can be referred as in poor condition. Therefore, it is a clear need to rehabilitate and restore the coral reef in the area, either by application of artificial reef (Perkol-Finkel and Benayahu, 2005) or coral transplantation (Clark and Edwards, 1995; Soong & Chen, 2003) or combination of both (Muzaki *et al*., 2019). Artificial reef can be defined as structures introduced to areas that are degraded or less productive for the purposes of enhancing marine resources *e.g.* the generation of shelter, food, breeding grounds, and shoreline protection (Ng *et al*., 2016). Applications of artificial reef for coral reef rehabilitation are often combined with coral transplantation (Clark and Edwards, 1995; Muzaki *et al*., 2019), in which the artificial reef functioned as substratum for coral fragment fixation.

The major challenge for coral rehabilitation in northern coast of Madura Island is turbidity and sedimentation, which may directly cover the polyps and colony of the corals, reducing photosynthetic efficiency and productivity (Philipp & Fabricius, 2003; Anthony & Connolly, 2007) and inhibit settlement of coral larvae (Salinas-de-Leon *et al*., 2013; Perez III *et al*., 2014; Jones *et al*., 2015); thus, causing the death of the corals (Duckworth *et al*., 2017) . Indirectly, sediment may reduce light penetration into the water column and lower the growth rate. Although corals can reject the sediment through mucus production, tissue swelling and polyp movement, these activities could further increase energy expenditure (Anthony & Larcombe, 2000; Weber *et al*., 2006). Concerning to those reviews, in this study we test and compare the survival and growth rate of native branching stony coral transplanted on artificial reef in two different locations with relatively different level of turbidity. Results of the research are expected to be useful as baseline data for the recommendation of coral transplantation in turbid coastal water.

Materials and Methods

Study site

The research conducted in the coastal area of Labuhan village in Bangkalan district, Madura Island. Artifical reef in the form of dome-shaped concretes as a substratum for coral transplantation were deployed at the depth of 3-4 meter in the vicinity of reef flat in two different locations; namely the northwest (NW, 06°52′57.80" S & 112°58′56.80" E) and northeast (NE, 06°52′48.40" & 112°59′45.80" E) that separated with a distance about 1.6 km and have relatively different turbidity. Bottom substrate is a mixture of sand, silt and coral rubble. Visibility is low, ranging from 1.1-2.8 m in NW and 1.5-4.0 in NE.

Based on initial survey in early 2017, life coral cover in the area is less than 15% (poor condition) and dominated by massive and encrusting lifeforms from the families of Merulinidae, Faviidae, Poritidae and Euphyllidae. Some colonies of Acroporid branching coral also occurred in the area. Coral colonies grown in the reef flat are seemingly competing for life space and resources with several species of macroalgae (*Padina* spp, *Halimeda* spp and other coralline algae).

Coral transplantation

In this study, dome-shaped concrete artificial reefs were used as substratum or attachment medium for coral fragments. Concretes are considered as one of the best substrates for artificial reef or coral transplantation (Subhan *et al*., 2014) because of their durability and strength and have many pores or cracks on the surface that suitable for coral larval settlement; as well as contain calciums to accelerate the

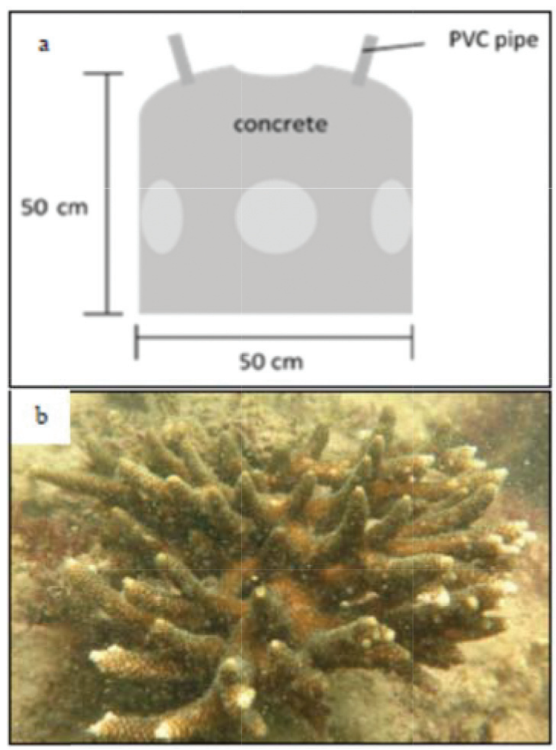

Fig. 1. A 2-dimensional model of dome-shaped concrete artificial reef used as substratum for transplantation (**a**); Colony of *Acropora millepora* used as donor colony for coral transplantation (**b**)

growth of coral (Alfeche, 2002; Soong and Chen, 2003). The dimension of the concrete used in this study is 50 cm high and 50 cm in diameter (Fig. 2a). For each location (NW and NE), there were 10 units of concretes; each concrete mounted with 6 units of coral fragments.

Fragments of *Acropora millepora* (Fig. 2b) used for transplantation were collected from adjacent area and the donor colonies must be healthy (*i.e*. not bleached nor covered by sediment and/or turf algae) and larger than 15 cm in diameter (Zhang *et al*., 2016). The length of the fragments for transplantation is ± 5 cm, based on Bowden-Kerby (2003) and Soong & Chen (2003). Fixation of coral fragments to concretes using plastic ties on PVC pipe (0.5-inch in diameter, length 10 cm) that is previously mounted on the concretes.

Transplantation was conducted at April 2019 and the observed growth parameter were the lengthening rate and survival of the fragments. The observations were recorded on monthly basis from April to September 2019; conducted *in situ* with Scuba diving technique and documented with an underwater digital camera. Measured hydro-oceanographical parameters including the temperature (°C), salinity (ppt or ‰), level of dissolved oxygen or DO (ppm), visibility (m), alkalinity or pH and turbidity (NTU).

Data analysis

Lengthening rate (vL) of coral fragments represented as ΔL (increment of fragment length from initial period or T_0 to final period or T_x) per unit time (month, t). Survival rate (Sr) counted as percentage of fragments that survived or still alive for a given period after fragment fixation on the concrete. An independent student t-test ($\alpha = 0.05$) was performed to analyze the difference of fragments lengthening rate from NW and NE locations.

Results and Discussion

During 6 months of field observation, the value of certain environmental parameters (*i.e*. temperature, salinity, DO and alkalinity) was relatively stable or showing a little fluctuation. However, other parameter such as turbidity and visibility were greatly fluctuated among observation periods. Average value of the environmental parameters is shown in Table 1.

Based on the data in Table 1, it can be assumed that the value of salinity, temperature, DO and alkalinity are still in range of suitable condition for the growth of coral. However, the values of visibility are below the standard whereas value of turbidity exceeding the quality standard. Visibility in NE station was slightly higher compared to NW station while turbidity in NW was higher. Highest turbidity (28.6 NTU in NW and 20.8 NTU in NE) recorded at August and September 2019 in both locations, presumably due to high wind-generated wave action. From April to June, and in October, the turbidity was relatively lower, suggesting that highest turbidity may be lasting only in certain periods.

Several previous studies have shown that increased turbidity could affect the physiology of coral. High sediment concentration in the water column can enhance rate of excretion and respiration, reduce light penetration to water column and lower net rates of photosynthesis (Anthony and Larcombe, 2000). Sediment can also smother and bury the coral polyps, create shading and induce tissue necrosis and population explosions of bacteria in coral mucus (Erftemeijer *et al*., 2012).

In general, average value of Sr in NW was lower than NE. In the first 3 month after transplantation (April to June 2019), survival rate (Sr) of coral fragments in both locations tend to decrease and appear

Table 1. Value of Environmental Parameters Measured in the Study Area

Parameter	Unit	Average value		QS
		NW	NE	
Salinity	‰	33.54±0.36	33.58±0.48	33-34
Temperature	°C	28.6±0.42	28.9±0.22	28-30
DO	ppm	7.38±0.13	7.26±0.26	>5
pH	-	8.15±0.16	8.13±0.18	7-8.5
Visibility	meter	2±0.75	2.84±0.79	>5
Turbidity	NTU	11.74±9.71	8.37±7.22	<5

Note: **QS**. Quality standard for coral reef based on Ministry of Environment of Republic of Indonesia, Resolution no 51, Appendix III (2004) to be stable in the next three periods (from June to September 2019) as depicted in Fig. 3; and it is expected that the *Sr* will remain stable in the future. Several first weeks after transplantation are crucial period for transplanted coral fragments to cope with new conditions and the polyps will produce more mucus as a mechanism of defense and acclimation. On the reef flat with the presence of waves, corals will be exposed to large-sized suspended sediment particles which are abrasive and potentially damaging the tissue of corals (Anthony and Larcombe, 2000). Because large particles are tended to settle rapidly, this stress will not be occurred in a long period and the corals can recover. However, if the stress continued for a long period, it could cause death to the corals due to inability to recover.

There is relatively limited information on growth rate of *A. millepora* transplanted fragments from Indonesia. However, compared to several similar researches using *Acropora* species; growth rate of *A.* *millepora* in this study is higher than transplanted fragments of *A. muricata* in clear water of Situbondo, East Java (Muzaki *et al.*, 2019). Result of independent student t-test at p = 0.05 (Fig.4) shows that coral fragments in NE station also show a significantly higher growth rate compared to those in NW stations. Average value of lengthening rate in NE was 1.948±0.276 cm/month and in NW was 1.748±0.285 cm/month, respectively; and this is probably also due to higher turbidity in NW station. As mentioned earlier, sediment can generate many negative impacts on the growth and viability of corals. However, at a certain level, corals can withstand the stress caused by short-term high turbidity or sedimentation. In this study, transplanted fragments of *A. millepora* show ability to grow in short-term stress condition during July to August. This species is well known for its ability to adapt variable conditions from clear to turbid water. Under normal condition, many coral species are able to capture and ingest a wide range of food types including large sediment particles and fine suspended particulate matter (Anthony, 2000) and may achieve up to 50% of their predicted growth from feeding on fine suspended sediment at high concentration.

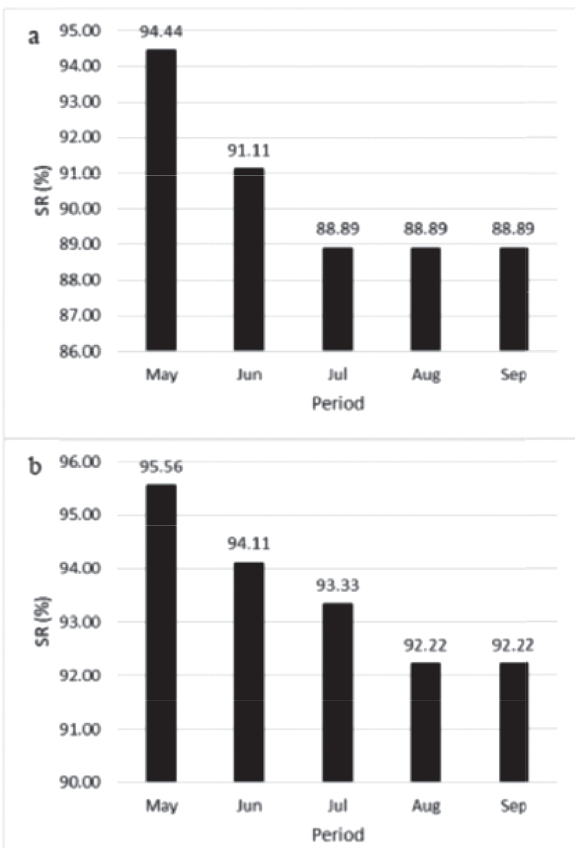

Fig. 2. Value of monthly survival rate (*Sr* in %) of transplanted *A. millepora* coral fragments from May to September 2019 in northwest (**a**) and northeast (**b**) location

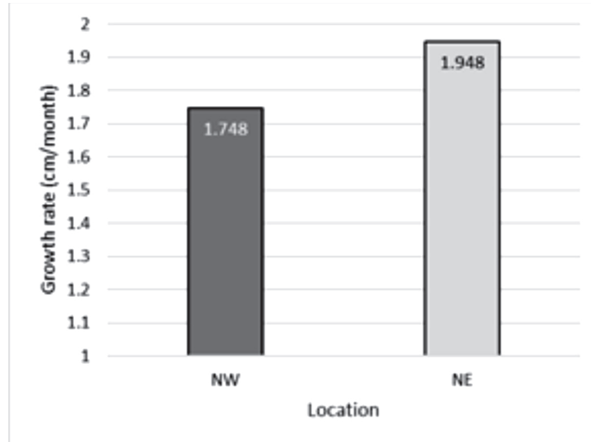

Fig. 3. Average growth rate (cm/month) of transplanted *A. millepora* coral fragments from May to September 2019. NW and NE: northwest and northeast location

A study by Anthony and Larcombe (2000) stated that photosynthetic rate of *A. millepora* in shallow water (3 meter) will severely reduce for 3 days during high turbidity event; therefore, it potentially allowing corals to recover. This species is likely adaptable for reduced light levels (and reduced rates of photosynthesis) during periods of high turbidity by

Fig. 5. Serial photographs showing the transplanted fragments of *Acropora millepora* in the study (top: April 2019; middle: July 2019; bottom: September 2019)

increasing their heterotrophy on suspended particles (Anthony and Fabricius, 2000; Anthony and Larcombe, 2000).

Conclusion

At the end of the research, we can conclude that in short-term stress caused by high turbidity, transplanted fragments of *A. millepora* are still able to survive. Therefore, coral transplantation could be an applicable solution in the effort of damaged coral reef rehabilitation in relatively turbid water.

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References

Anthony, K.R.N. 2000. Enhanced particle-feeding capacity of corals on turbid reefs (Great Barrier Reef, Australia). *Coral Reefs*. 19 : 59-67.

Anthony, K.R.N. and Larcombe, P. 2000. Coral reefs in turbid waters: sediment-induced stresses in corals and likely mechanisms of adaptation. *Proceedings of 9th International Coral Reef Symposium, Bali, Indonesia 23-27 October 2000.*

Anthony, K.R.N. and Connolly, S.R. 2007. Bleaching, energetics, and coral mortality risk: Effects of temperature, light, and sediment regime. *Limnol. Oceanog*. 52 (2): 716-726.

Bowden-Kerby, A. 2003. Coral transplantation and restocking to accelerate the recovery of coral reef habitats and fisheries resources within no-take Marine Protected Areas: hands-on approaches to support community-based coral reef management. *International Tropical Marine Ecosystem Management Symposium.* Manila, Philippine.

Buddemeier, R.W., Kleypas, J.A. and Aronson, R.B. 2004. Coral reefs and global climate change: potential contributions of climate change to stresses on coral reef ecosystems. Pew Center on Global Climate Change.

Burke, L., Reytar, K., Spalding, M. and Perry, A. 2011. Reefs at Risk Revisited. Washington: World Resources Institute.

Clark, S. and Edwards, A.J. 1995. Coral transplantation as an aid to reef rehabilitation: evaluation of a case study in the Maldive Islands. *Coral Reefs*. 14: 201-213.

Duckworth, A., Giofre, N. and Jones, R. 2017. Coral morphology and sedimentation. *Mar. Pollut. Bull.* 125: 289-300.

Elliff, C.I. and Kikuchi, R.K.P. 2017. Ecosystem services provided by coral reefs in a southwestern Atlantic Archipelago. *Ocean Coast. Manage.* 136: 49-55.

Erftemeijer, P.L.A., Riegl, B., Hoeksma, B.W. and Todd, P.A. 2012. Environmental impacts of dredging and other sediment disturbances on corals: A review. *Mar. Pollut. Bull.* 64 : 1737-1765.

Hadi, T.A., Giyanto, Prayudha, B., Hafizt, M. and Suharsono, A.B. 2018. Status Terumbu Karang Indonesia 2018. Jakarta: Puslit Oseanografi – LIPI.

Jones, R., Ricardo, G.F. and Negri, A.P. 2015. Effects of sediments on the reproductive cycle of corals. *Mar. Pollut. Bull.* 100 : 13–33.

Kleypas, J.A., McManus, J.W. and Menez, L.A.B. 1999. Environmental limits to coral reef development:

where do we draw the line? *American Zoology*. 39: 146-159.

Muzaki, F.K., Hanifa, R., Akhwady, R., Saptarini, D. and Buharianto, 2019. Short Communication: Growth rate of Acropora muricata coral fragments transplanted on dome-shaped concrete artificial reef with different composition. *Biodiversitas*. 20 (6) : 1555-1559.

Ng, C.S.L., Toh, T.C. and Chou, L.M. 2016. Coral restoration in Singapore's sediment-challenged sea. *Reg. Stud. Mar. Sci.* 8 : 422-429.

Perez III, K., Rodgers, K.S., Jokiel, P.L., Lager, C.V. and Lager, D.J. 2014. Effects of terrigenous sediment on settlement and survival of the reef coral *Pocilloporadamicornis*. *PeerJ.* 2 : e387.

Perkol-Finkel, S. and Benayahu, Y. 2005. Recruitment of benthic organisms onto a planned artificial reef: shifts in community structure one-decade post-deployment. *Mar. Environ. Res.* 59 : 79-99.

Philipp, E. and Fabricius, K. 2003. Photophysiological stress in scleractinian corals in response to short-term sedimentation. *J. Exp. Mar. Biol. Ecol.* 287 : 57–78.

Salinas-de-Leon, P., Dryden, C., Smith, D.J. and Bell, J.J. 2013. Temporal and spatial variability in coral recruitment on two Indonesian coral reefs: consistently lower recruitment to a degraded reef. *Marine Biology.* 160 : 97-105.

Soong K. and Chen, T. 2003. Coral Transplantation: regeneration and growth of *Acropora* fragment in a nursery. *Restoration Ecology*. 11 (1) : 62-71.

Subhan, B., Madduppa, H., Arafat, D. and Soedharma, D. 2014. Bisakah transplantasikarang perbaikiekosistemterumbukarang?. *Risalah Kebijakan Pertanian and Lingkungan* 1 (3): 159-164.

Weber, M., Lott, C. and Fabricius, K.E. 2006. Sedimentation stress in a scleractinian coral exposed to terrestrial and marine sediments with contrasting physical, organic and geochemical properties. *Journal of Experimental Marine Biology and Ecology*. 336 : 18-32.

Zhang, Y., Huang, H., Huang, J., You, F., Lian, J., Yang, J., and Wen, C.K.C. 2016. The effects of four transplantation methods on five coral species at the Sanya Bay. *Acta Oceanologica Sinica*. 35 (10) : 88-95.