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Survival and growth of *Acropora spp.* in mid-water nursery and after transplantation at Phi Phi Islands, Andaman Sea, Thailand

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Abstract. This study aims to determine the survival and growth rates of coral fragments in a mid-water nursery and after transplantation at Phi Phi Islands, the Andaman Sea. A total of 1,120 fragments of two dominant species, *Acropora grandis* and *A. muricata,* were used as seedlings. The average size of fragments was 4.6 cm (SD ± 1.2) and monitoring was conducted monthly. After 4 months in the nursery, survival of fragments was 95.8% and 94.8% for *A. grandis* and *A. muricata*, respectively. There was a significant difference ($p<0.05$) of growth rate in the nursery between *A. grandis* – 0.41 cm mo^{-1} (SD ± 0.21) and *A. muricata* – 0.23 cm mo^{-1} (SD ± 0.20). After 6 months in the nursery, coral fragments were transplanted to a nearby reef which had been destroyed by the Indian Ocean Tsunami in 2004. Survivorship of transplanted fragments after one year was 87.0% for *A. grandis* and 75.3% for *A. muricata*. Growth rates of transplants of *A. grandis* (0.28 cm mo^{-1}) and *A. muricata* (0.38 cm mo^{-1}) did not differ significantly. The relatively high survival suggests that these fast growing corals may be suitable for transplantation in the Andaman Sea area.

Key words: rehabilitation, coral nursery, coral transplantation.

Introduction

The mid-water coral nursery technique was developed in the Red Sea (Shafir et al. 2006) and has advantages in reducing impact to donor colonies, by removing small amounts of coral fragments only, and minimizing sediment smothering to corals in nursery (Shaish et al. 2008). We tested this technique, which has been shown to be successful in a turbid water environment (Putchim et al 2007) to rehabilitate a reef at Phi Phi Islands (Andaman Sea) that was damaged by the Indian Ocean Tsunami in 2004. Survival and growth of two *Acropora* spp. in both a mid-water nursery and after transplantation were studied.

Material and Methods

Study area

The study site was located in the northeast region of the Phi Phi Islands, Andaman Sea, Thailand (7°41.67′ N and 98°41.4597′ E, Fig. 1). A narrow reef with adjacent sandy substrate at approximately 5-18 m depth was chosen. Branching corals of genus *Acropora* especially *A. muricata* and A. *grandis* were dominant species. This reef is a popular diving site and was damaged by the Indian Ocean Tsunami in 2004. The environmental parameters of the area are as follow: annual salinity ranges from 30 to 32 ppt; transparency varies from 7-17 m Secchi depth; and sedimentation rate ranged from 31.2-58.3 $g.m^{-2}.d^{-1}$.

Nursery design

The mid-water nursery was set up at a depth of 12 m within 500 m of the transplantation site at the northeast of the island in May 2006 and corals were reared in the nursery for 4 months until September 2006 (Figure 2). The mid-water nursery was made of 16 modular structures, each consisting of 70 x 90 cm plastic mesh trays attached by cable-ties to rectangular 1.4 x 3.6 m frames made of 1.8 cm PVC pipe. The nursery was comprised of 2 PVC frames, at 1.5 m distance, creating a platform of 4.3 x 3.6 m. The platform was suspended at 6 m depth from four 46 cm mooring buoys which were connected to each other by ropes with small foam buoys sewn at 0.5-m interval. The mooring buoys were held in place by eight 20 kg cement sinkers, each secured to the substrate with 2 anchors.

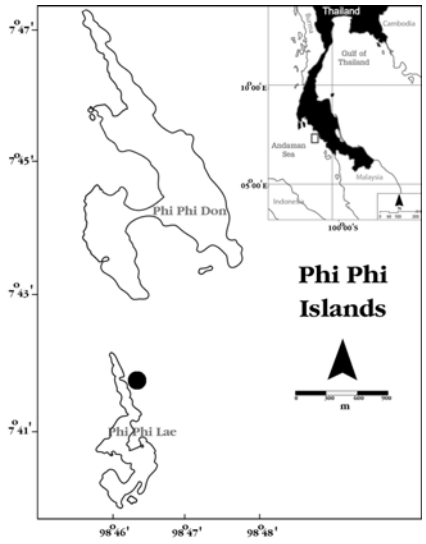

Figure 1: Study area in Thailand, showing the study site

Collecting fragments and transplanting in the nursery
Fragments of two dominant species at Phi Phi Islands, *A. grandis* and *A. muricata*, were collected from the vicinity of the nursery. The average size of the 1,120 fragments was 4.6 cm (SD ± 1.2). Each fragment was inserted into a plastic tube about 4 cm in length, which was attached to the tray mesh (70 pieces per tray). A total of 16 coral trays were fixed onto the PVC platform (Fig 3). Survival and growth were monitored every month for 4 months by recording the status of each fragment as dead, partially dead, bleaching, live, or missing. 24 fragments of *A. grandis* and 57 fragments of *A. muricata* were tagged and measured, by taking under-water photographs of fragment heights with a digital camera using a ruler for calibration.

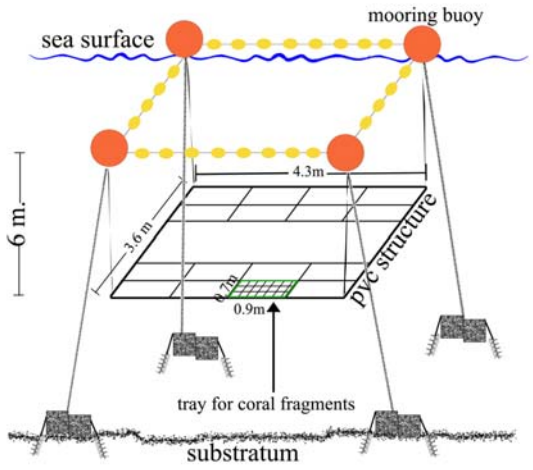

Figure 2: Diagram of floating nursery at the Phi Phi Islands

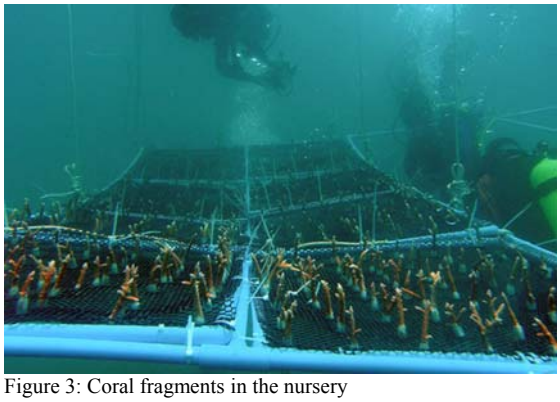

Figure 3: Coral fragments in the nursery

Transplanting to the degraded site
After 6 months in the nursery, the coral fragments were transplanted to a degraded site at 8-10 m depth in November 2006. The fragments were attached to substratum by fastening to metal bars with plastic cable-ties. Those metal bars were welded to a 1-m long metal frame with two legs at either end. Each frame comprised six 15cm long, 1.3 cm diameter metal bars and was secured directly to the substratum which was covered by dead coral rubble. A total of 116 fragments of *A. grandis* (23) and *A. muricata* (93) were transplanted and monitored for survivorship monthly. Growth was measured at beginning and the end (October 2007) of the study period. A subset of eight fragments of *A. grandis* and 18 fragments of *A. muricata* were tagged and measured.

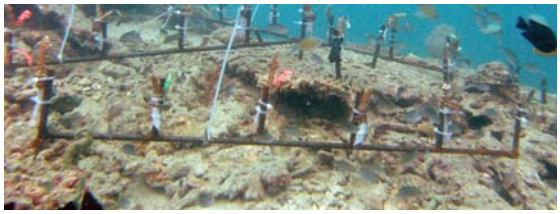

Figure 4: Transplantation method using metal bar attached to the substratum.

Data analysis
Measurement of fragments height was carried out by analyzing pictures taken from the field with Photoshop and Image-Tool software (Shaish et al. 2008). A Student's *t*-test was used to compare growth rates of the two species both in the nursery and after transplantation.

Results
Coral fragments of both species were kept in the mid-water nursery for 6 months, but growth and survivorship were monitored only for the first 4 months. Figure 5 shows the condition of *A. muricata* at the beginning and after one year of transplantation. Survivorship of *A. grandis* and *A. muricata* in the

Table 1: Survival and growth rates of *Acropora grandis* and *A. muricata* in the nursery and after transplantation. Mean and SD are shown for growth rates.

	Coral species	Survivorship			Growth		
		No.	months	%	No.	size (cm)	Growth rate (cm mo^{-1})
Nursery	*A. grandis*	210	0			4.4±0.7	
		192	4	95.8	24	6.1±1.2	0.41±0.21
	A. muricata	842	0			4.6±1.4	
		797	4	94.8	57	5.5±1.6	0.23±0.20
After transplantation	*A. grandis*	23	0			7.1±1.6	
		20	12	87.0	8	10.2±3.7	0.28±0.24
	A. muricata	93	0			5.7±1.9	
		70	12	75.3	18	9.9±3.6	0.38±0.31

nursery was 95.8% and 94.8% respectively after 4 months and growth rates were 0.41 cm.mo^{-1} and 0.23 cm.mo^{-1} respectively (Table 1). The growth rate of *A. grandis* was significantly higher than that of *A. muricata* (*t*-test, $p<0.05$).

Survivorship and growth rates of coral fragments of both species transplanted to the degraded reef area were monitored for 12 months. Survivorship of transplanted fragments was 87.0% for *A. grandis* and 75.3% for *A. muricata*. Growth rates were 0.28 cm.mo^{-1} for *A. grandis* and 0.38 cm.mo^{-1} for *A. muricata* (Table 1) and were not statistically different (*t*-test, $p>0.05$).

One year after transplanting, most of transplanted colonies still did not attach to the metal bars with only one out of 26 monitored colonies becoming partially self-attached (Fig. 6).

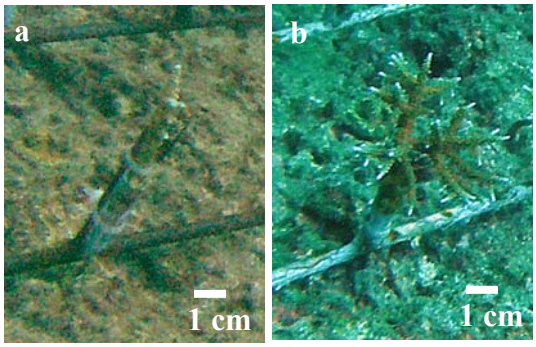

Figure 5: (a) An *Acropora muricata* transplant at the beginning of transplantation; (b) the same transplant one year after transplantation.

In August 2008, two years after transplantation, the site was also visited. About 50% of the transplanted colonies had grown to fill the 20-cm spaces in between the metal bars. However, some colonies were still at the initial transplanted size and a few colonies were missing or dead.

Figure 6: A transplanted colony partially self-attached to a metal bar after one year.

Discussion and Conclusion

Rearing of corals in mid-water nurseries is a relatively new technique (Shafir et al. 2006). The results from this study in the Andaman Sea and those of Shaish et al. (2008) from the Philippines indicate that the technique can be beneficial in areas other than the Red Sea (Shafir et al. 2006). The present study shows promise in an area with relatively high sedimentation (Putchim et al. 2007). In the Andaman Sea, we had to use larger initial fragments than those in the Red Sea because of higher turbidity and sedimentation. For example, small-sized (1 cm) *Pocillopora damicornis* fragments survived well in a mid-water nursery in the Red Sea (Shafir et al. 2006) but did not survive in turbid coastal waters of Cape Panwa, Phuket Island, Andaman Sea (Putchim 2007). Sedimentation rates at Cape Panwa varied from 200-500 g.m^{-2}.d^{-1} whereas those in the Red Sea varied from 1.8-8.4 g.m^{-2}.d^{-1} (Bongiorni 2001). In this study at Phi Phi Islands which has moderate sedimentation rates (ranging from 31.2 ± 2.7 g.m^{-2}.d^{-1} to 58.3 ± 1.6 g.m^{-2}.d^{-1}), the initial mean height for both species was 4.6 cm. This size appeared adequate to ensure survival.

This study showed high rates of survivorship in *A. grandis* and *A. muricata* in the nursery and after transplantation. The mean growth rate of *A. muricata* after transplantation (0.38 cm.mo^{-1}) was similar to that of *A. muricata* in transplantation at Cape Panwa, Phuket (0.3 ± 0.3 cm.mo^{-1}) (Yucharoen et al. 2008)

and growth rate in Okinawa (3.5 $cm.yr^{-1}$) (Okubo et al. 2005). Whereas the growth rates of *A. muricata* in the natural environment of the Andaman Sea showed seasonal variation ranging from 0.3 $cm.mo^{-1}$ during the SW monsoon to 0.9 $cm.mo^{-1}$ during the NE monsoon seasons (Charuchinda and Hylleberg 1984; Chansang et al. 1992). Growth of *A. muricata* in our study was less than that obtained using the same technique in the Philippines (0.8 $cm.mo^{-1}$) (Shaish et al. 2008). The practice of using metal bars for fixing transplanted fragments to substratum should be reviewed as growth of live tissue over the metal was very limited and adding foreign objects into the reef environment should not be encouraged. However, the metal frames helped to secure transplanted colonies until they were large enough to withstand the surrounding water movement. After 2 years, the frames were not very visible as transplanted colonies had grown to cover the frames.

In conclusion, fragments of *A. muricata* and *A. grandis* had high survivorship both in nursery and after transplantation, thus it is recommended that these coral species are suitable for nursery and transplantation in the Andaman Sea.

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