

## Transplantation of *Porites lutea* to rehabilitate degraded coral reef at Maiton Island, Phuket, Thailand

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**Abstract.** This study compared the growth and survival of different sized transplants of *Porites lutea* at Maiton Island, Thailand. Fragments in three different sizes, 5.0 x 5.0 cm (large), 3.5 x 3.5 cm (medium) and 2.5 x 2.5 cm (small), were detached from intact coral colonies. Unattached coral colonies in each size category from the site were also transplanted for comparison. The fragments and unattached colonies were cemented on concrete blocks. Medium-size fragments and colonies showed high survivorship whereas small-size fragments and unattached colonies showed low survivorship. Growth was measured as increase in colony plan area and increase in height. Area of transplants increased exponentially and the growth constant of small-size colonies was significantly higher than that of large-size colonies (S-N-K,  $p = 0.021$ ). Rates of height increase were significantly different among all sizes for fragments (with smaller fragments performing more poorly) whereas there was no difference in this parameter among colonies. Medium-size fragments appeared the appropriate size for transplantation as they showed the highest survival. It is also recommended that all sizes of loose colonies should be used for transplantation as attachment increases their chance of survival, which assists natural recovery.

**Key words:** *Porites lutea*, coral transplantation, coral rehabilitation.

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### Introduction

For decades, coral reefs in Thailand have suffered from degradation as a result of both natural and anthropogenic disturbances including coastal development, sedimentation, destructive fishing and tourism-related activities. Concerned institutions and organizations from both the government and the private sectors have initiated coral reef rehabilitation projects in an effort to restore the degraded reefs. These projects have been initiated in both the Gulf of Thailand and the Andaman Sea, and implemented with a range of objectives and using different methods (Yeemin et al. 2006). The most common method used in Thailand during the past 10 years has been coral transplantation. Like in many other areas of the world, the coral species used for this purpose were mainly branching corals, i.e. *Acropora* and *Pocillopora*. Branching species recruited well and grew fast (Yap et al. 1992; Bowden-Kerby 1997), but their high mortality rates (Clark and Edwards 1995), their susceptibility to bleaching when stressed, and their susceptibility to disease are significant risks associated with transplantation and reef restoration projects which rely on these species (Edwards and Gomez 2007). By contrast, massive species grow more slowly but they are more resistant to bleaching, and their solid, hard structure enables them to withstand storms and strong waves, thus they are

likely to survive better. Few rehabilitation studies have focused on massive coral species due to their slow growth rate and greater difficulty to transplant. However, massive corals are major reef building blocks and many of them are more resilient to natural disturbances, thus more attention should be paid to their use in transplantation.

We chose to study *Porites lutea* transplantation as it is the major reef building species of the Andaman Sea and it has shown some resilience to major natural disturbances such as *Acanthaster planci* outbreaks, increases in sea surface temperature, and storms (Phongsuwan and Chansang 1993). At Maiton Island, unattached or loose *Porites* are common on the sea floor at a depth of 3-5 m. Unless they are attached to a substrate, these corals tend to have a poor chance of survival. In this study, survival and growth of different sizes of both fragments and unattached colonies following transplantation were investigated.

### Materials and Methods

#### *Study site*

The study was carried out from November 2005 to June 2008 at Maiton Island, 8 km off the southeastern Phuket coastline (Fig. 1). The coral community on the island's northeastern side, where the study took place, lies on a flat sea floor at a depth of about 3-4 m below

mean sea level. In May 1986 the coral reef at Maiton Island and shallow water reefs nearby were severely damaged by a storm and coral recovery has been very low in comparison with reefs nearby (Phongsuwan 1991). The staghorn coral, *Acropora* spp., used to be the dominant genus as shown by debris in the area, but our survey in 2007 on the coral colonies settling on natural substrate found that corals at Maiton Island were dominated by *Porites* and *Millepora* which comprised of 90.48 and 2.69 % of total living corals in the area, respectively. The density of unattached massive coral colonies, including *Porites lutea*, was 1.72 colonies m<sup>-2</sup>.

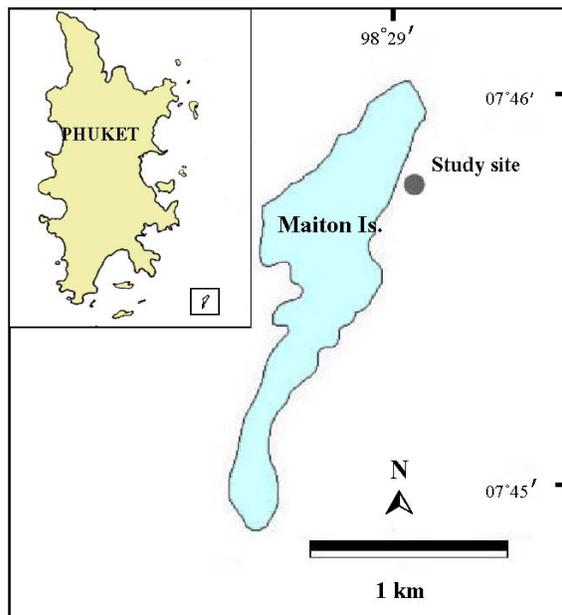


Figure 1: Study site at Maiton Island, Phuket

#### Transplantation and monitoring

1. Using a hammer and chisel, fragments of *P. lutea* were removed from intact donor colonies and divided into three different sizes, 5.0 x 5.0 cm (large fragment, FL), 3.5 x 3.5 cm (medium-size fragment, FM) and 2.5 x 2.5 cm (small fragment, FS). 45 replicate fragments of each size were generated.
2. Unattached *P. lutea* colonies, which were found on the adjacent seabed, were collected and sorted into 3 size classes as above (small colony, CS; medium-size colony, CM and large colony, CL). 30 replicates of each size were collected.
3. All fragments and unattached colonies were attached to 16 x 28 x 8 cm hollow blocks. Three corals were attached per block using quick drying cement. The blocks with the corals were placed at the same depth as corals were taken.
4. Measurement of the coral transplants was made by scuba divers. Using callipers, the maximum diameter and colony height of the living parts of all colonies

were measured every 3-4 months. Survivorship, mortality and detachment of corals from the substrates were also monitored during each survey.

#### Data analysis

Survivorship, detachment and *in-situ* mortality were calculated as percentages of initial samples under monitoring. Overall survival was defined as the percentage of corals which had suffered neither detachment nor *in-situ* mortality. Growth was measured as both increase in colony area and colony height. Growth of transplanted *P. lutea* in this study predominantly involved horizontal expansion as shown in Fig. 2. Thus colony plan area was calculated by the formula  $\pi r^2$  with assumption that colonies were circular in shape and  $r$  was equal to maximum diameter divided by 2. Regression analysis of growth pattern was done using Microsoft Office Excel 2003. Colony area increased exponentially and colony heights increased linearly. Thus for colony area, the horizontal growth constant ( $k$ ) for each treatment was calculated using equation:

$$k = (\text{LN}(A_t) - \text{LN}(A_0)) / t$$

where LN is the natural logarithm,  $A_0$  is the initial area measurement,  $A_t$  is the last area measurement available, and  $t$  is the time between measurements in years. Growth rates in terms of colony height increase were expressed as the slope of linear plots

The difference in growth, both in terms of transplant area and height, were compared using ANOVA (SPSS version 15.0). S-N-K tests were employed to determine which treatments differed.



Figure 2: *Porites lutea* colony growing on a hollow cement block two years after transplantation.

#### Results

The percentage overall survivorship, *in-situ* mortality and detachment of fragments and colonies after transplantation are shown in Fig. 3. Almost three years after transplantation, the medium-size colonies and fragments, showed the highest survivorship, followed by large fragments, large colonies and small colonies. The small colonies and fragments had very

low survivorship (23.3% and 2.2%, respectively), comprised of a high detachment rate (63.3% and 66.7%, respectively) and in-situ mortality (13.3% and 31.1%, respectively). The high detachment and in-situ mortality occurred 150-300 days after transplantation during the Southwest monsoon season (June-October 2006). Subsequently, detachment and mortality rates of small transplants were similar to other treatments.

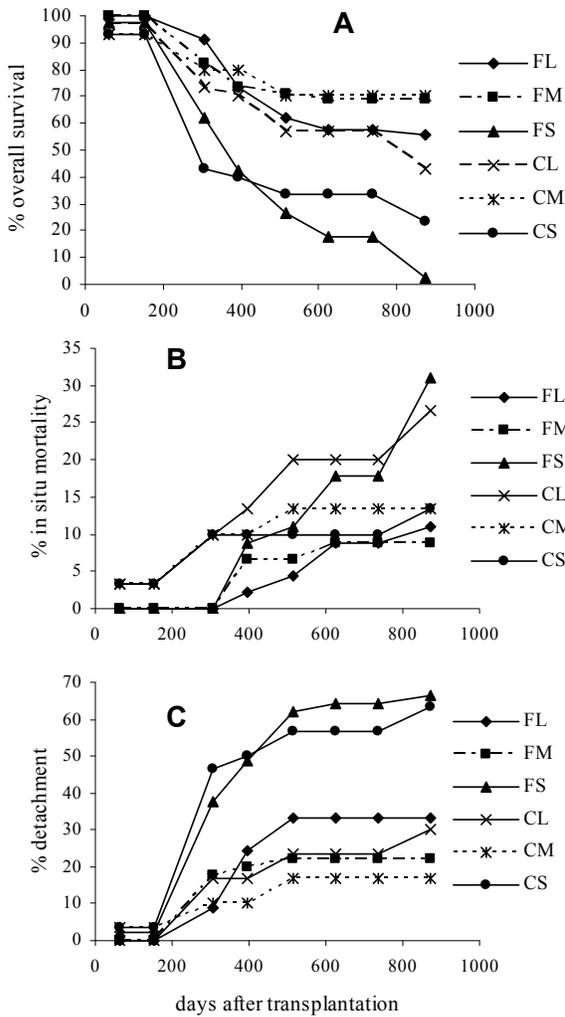


Figure 3: Percentage overall survival (A), *in situ* mortality (B) and detachment (C) of *P. lutea* fragments and colonies after transplantation.

#### Growth of the transplants

Most corals, both fragments and colonies of all sizes, started to self-attach by growing their basal plate over the cement blocks within two months of transplantation (Fig. 4).

Transplants showed a trend of exponentially increasing area with time (Fig. 5) and a trend of linear increase in height (Fig. 6). Growth rates expressed as increasing area and height per year are shown in

Table 1. The growth constant ( $k$ ) of coral fragments varied from  $1.10 \text{ yr}^{-1}$  for large fragments to  $1.79 \text{ yr}^{-1}$  for small fragments, while that of colonies varied from  $0.91 \text{ yr}^{-1}$  in large colonies to  $1.68 \text{ yr}^{-1}$  in small colonies. The growth constant of small colonies was significantly higher than that of large colonies (S-N-K,  $p = 0.021$ ).

The colony height began to increase about 6 months after transplantation. Rates of increase in colony height of coral fragments were  $0.58$ ,  $1.21$  and  $1.75 \text{ cm yr}^{-1}$  in small, medium and large fragments respectively, and were significantly different (S-N-K,  $p = 0.024$ ). Rates of height increase in colonies of different sizes did not differ significantly.



Figure 4: Transplanted colony of *P. lutea* starting to attach to cement block a few weeks after transplantation.

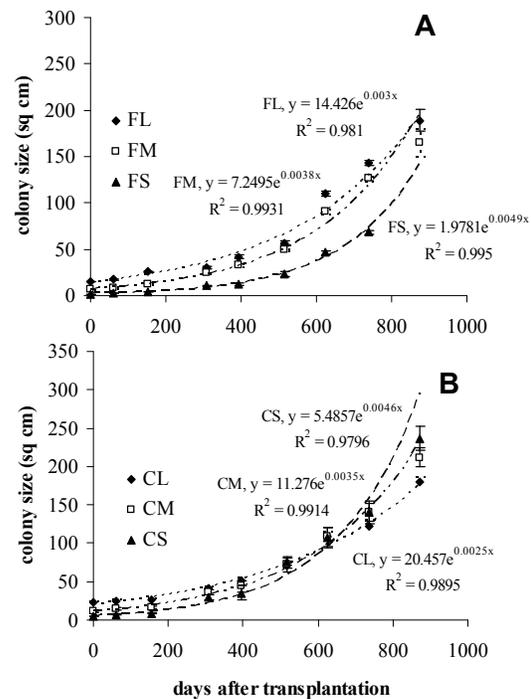


Figure 5: Growth in area of transplanted fragments (A) and colonies (B) with trendlines indicating colony growth.

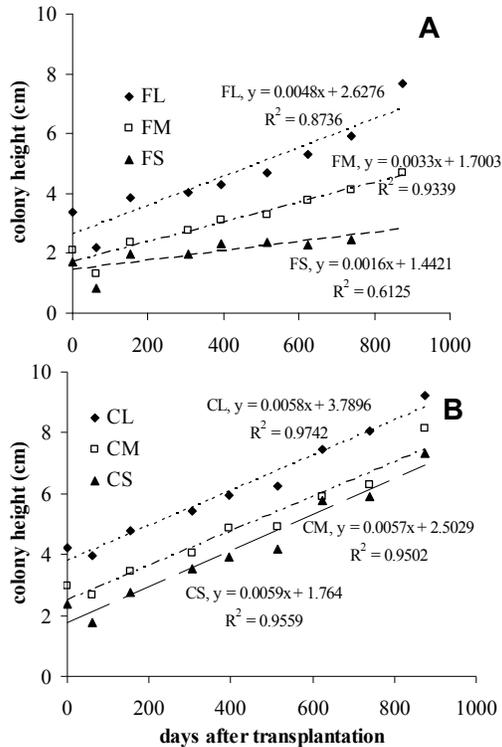


Figure 6: Colony height of transplanted fragments (A) and colonies (B) with trendlines indicating rate of increase of height in  $\text{cm d}^{-1}$ .

Table 1: Growth rates expressed as growth constant for increase in colony area and annual rate of increase in colony height of transplanted fragments and colonies

Category	Area growth constant, $k$ ( $\text{yr}^{-1}$ )	Height increase ( $\text{cm yr}^{-1}$ )
FL	1.10	1.75
FM	1.39	1.21
FS	1.79	0.58
CL	0.91	2.12
CM	1.28	2.08
CS	1.68	2.15

## Discussion

Our study found that it is possible to use fragments and unattached colonies of the massive coral, *P. lutea*, in the rehabilitation of degraded coral reefs. Instead of disturbing donor reefs by using whole large coral colonies, fragments were used. In addition attaching small loose colonies to hard substrata enhances their survivorship which assists natural recovery.

To minimize mortality and detachment of transplanted corals, an appropriate size must be used. Small fragments ( $2.5 \times 2.5$  cm) showed high detachment and did not survive well under this study. Although large fragments have a better chance of survival and grow faster than small fragments,

breaking too large fragments may put stress on intact donor colonies and affect their growth. Medium-sized fragments grew at similar rates to the large fragments while their chances of survival were higher and their use puts less stress on donor corals than large fragments. Therefore, medium-size *P. lutea* fragments ( $3.5 \times 3.5$  cm) appeared most suitable for transplantation at Maiton Island or other areas where the environmental conditions are similar. Likewise, medium-size colonies showed good survival and similar growth rates to the large-size colonies, thus no significant benefit appeared to be gained by using 5 cm as opposed to 3.5 cm colonies.

In a previous study it took at least 7 years for transplanted *Porites lutea* fragments at Maiton Island to cover fully the cement blocks and blend with the natural surroundings. The mean growth of these coral colonies was  $2 \text{ cm yr}^{-1}$  in height (Thongtham et al. 2003) which is comparable to this study (0.6 to 2.2  $\text{cm yr}^{-1}$  in height). Growth of the transplanted colonies at Maiton Island was comparable to growth of *P. lutea* (1.11 to 2.43  $\text{cm yr}^{-1}$ ) in natural coral reefs at Cape Panwa, Phuket Island (Charuchinda and Chansang 1985).

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