Survival and growth of scleractinian corals in a human-modified environment.
Tan, T. G.¹ and Chou, L. M.²

Department of Biological Sciences, The National University of Singapore
Blk S1, 14 Science Dr 4, #02-05, Singapore 117543.

ABSTRACT
In order to establish the possibility of reef restoration in areas that have undergone major physical development, several scleractinian coral genera with different growth forms (branching, submassive and foliose) were studied in the artificial canal of Sentosa Cove over a period of three months. The study involves the comparison of corals of six genera in terms of their survivorship, amount of growth and growth rates between two study sites and among the genera within the same study site. The general survivorship of all genera was more than 70% and Pocillopora sp. displayed the highest survivorship. Relative growth rates in the order of the fastest growing genus to the slowest growing genus was Pocillopora sp. > Porites sp. > Merulina sp. > Favites sp. > Goniopora sp. > Euphyllia sp. were also determined. It was concluded that study site 2 in Sentosa Cove is able to provide a more favourable condition than study site 1 for the survival and growth of scleractinian corals. Future reef restoration in the canal or environment similar to that of the cove, can consider deploying corals in the suggested aforementioned order of genera to obtain the highest survivorship and growth of corals in the cove.

INTRODUCTION
In light of the deteriorating reef status and plans for further land reclamation around the coast of Singapore, it is important to study and properly manage any marine areas that can potentially support reef lives. These areas include those that had undergone major constructions and one such area is the human-modified canal in the Sentosa Cove. To extend reef restoration beyond the open seas to human made areas, it is important to understand the environmental conditions in the human made areas for coral survivorship and growth as they lay the foundation of reefs. This study aims to determine if a human-modified coastal environment favours growth and survival of transplanted scleractinian coral fragments. Ultimately, this study seeks to provide a better understanding of ecological and economical advantages of reef restoration in areas that have undergone major physical development and provide a framework for similar future studies.

MATERIALS AND METHODS
Therefore restoration in the canal of the Sentosa Cove was of interest in this study. Four environmental parameters, temperature, salinity, nitrate level and total phosphate level, were surveyed in the Cove over the course of study. To finally determine if the canal is able to support the survival and growth of other scleractinian corals besides Oulastrea sp and Porites sp., the technique of coral transplantation was employed to introduce six other coral genera into the cove. This technique involves the introduction of coral fragments of considerable sizes, depending on the species deployed (Yap et al, 1998), into a different environment. Effects of the environmental factors on the corals were examined. The survivorship and growth of the corals in the canal would be able to give a rough indication of whether a heavily human-modified water enclosure

¹ Student
² Supervisor
habours favourable conditions for the growth of corals in general.

RESULTS

Over the entire study period, data on temperature, salinity, nitrates and total phosphates level were collected. The average salinity in the cove was 30 parts per thousands. The levels of nitrate and total phosphate in the cove were constantly less than 0.015mg/l and 0.025mg/l. The amount was less than the detection limits of APHA (American Public Health Association) standard test for water and waste water (APHA, 2005).

The average temperature at both sites was approximately 28.5ºC. A similar trend in temperature changes was noted in both SS1 and SS2 and SS1 has slightly lower temperatures. There were fluctuations in temperature changes from December 2008 to mid January 2009, followed by the gradual increase through January and a sudden increase in February. Temperature in SS1 seems to change faster and more abrupt than in SS2. However, the monthly temperature changes at both study sites were similar.

The overall survivorship of the corals was good. Survival rates of all genera in both sites were close to 90% with only Goniopora sp. at Site 1 with 67% survivorship. Comparison of relative growth of the different genera at both sites shows similar trends as the actual growth graphs. Goniopora sp. at SS1 had the highest increment in growth and Pocillopora sp. had the least increment in growth. On the contrary, Pocillopora sp. at SS1 had the highest increment in growth while Goniopora sp. had the least.

The order of genera based on exact relative growth values presented in Table 4 is


In general, corals at SS2 exhibited higher growth rates than corals at SS1 with Pocillopora sp. exhibiting the highest relative growth rate followed by Merulina sp., Favites sp., Goniopora sp. and lastly Euphyllia sp. Overall, Goniopora sp. at SS1 exhibited the highest relative growth rate (2.58%) when compared among genera.

DISCUSSION

All species transplanted in this study had more than 70% survivorship and displayed a general increasing trend at both study sites. Pocillopora sp. displayed the highest average survivorship (100%) at both study sites, followed by Euphyllia sp. (95%), Merulina sp. (95%), Goniopora (86%), Porites sp. (86%) and Favites sp. displayed the lowest survivorship at 75%. Pocillopora sp. was expected to have a higher mortality rate since they are more sensitive to transplantation (Edwards & Gomez, 2007). The high survivorship of the genus Pocillopora may be attributed to its opportunistic nature and strong competitive capabilities (Perkol-Finkel & Benayahu, 2009). Showing similar survival rates as Pocillopora sp. planted in coral nurseries in the Philippines had also shown high survivorship within the range of 85-95% (Rinkevich et al, 2008). Pocillopora sp. proved that water conditions in the cove may be similar to that of Singapore waters. Survival rate of Porites sp. in the cove (86%) was also higher than the 47% survival rate of Porites rus in the open waters of Philippines (Yap & Molina, 2003). Other species such as P. lobata, P. cylindrical has survival rate of more than 80% (Yap & Dizon, 2006). This shows that despite thriving in a seemingly less favourable condition than the open seas, Pocillopora sp. and Porites sp. were still able to obtain a similar survival rate.

The overall increasing growth trend suggests that corals deployed at both study sites are able
to grow in the Cove over a period of 3 months. However, the order of genera based on exact relative growth values (SS 1: Goniopora sp. > Euphyllia sp. > Merulina sp. > Porites sp. > Favites sp. > Pocillopora sp. and SS 2: Pocillopora sp. > Favites sp. > Merulina sp. > Euphyllia sp. > Goniopora sp.) did not fully correspond to the order of genera based on survival rates. This suggests that growth may not be dependent on survival rates and vice versa. Nevertheless, an increasing growth trend and high survival rates of these two genera were similar to their counterparts in the field suggest that water conditions in the canal are favourable to support coral survival and growth.

The growth rates compared between the two study sites were strikingly different despite the results of statistical analysis (p > 0.05). It was obvious that corals at study site 2 have a higher growth rate than corals at study site 1 in general. This may suggest that SS2 may be a more favourable environment to support coral growth.

Genera Pocillopora, Favites, and Porites also exhibited relatively high growth rates at Study site 2. The branching species, Pocillopora sp. may be more resistant to pollutants and mechanical stress (Cleary & Rachello-Dolmen, 2007). Despite having small polyps, its intensity of predatory feeding is almost five to six times greater than in the corals of the genus Favites (Titlyanov & Titlyanova, 2002). This could have explained its high growth rate in SS2. Encrusting species were also mentioned to display higher growth rates in another study (Shaish et al, 2008). Since the Favites sp. used in this study had encrusting forms, its growth rate was also expected. Favites sp. has large polyps and long tentacles that may have given the coral advantage to predatory feeding second to that of Pocillopora sp.

FUTURE STUDIES

The study on the survival and growth of scleractinians in a semi-enclosed environment such as Sentosa Cove is only preliminary. With the establishment of a favourable human-modified environment to support coral survival and growth, further studies have to be conducted in order to carry out an effective reef restoration. Since coral survivorship depends largely on its environmental conditions, detailed studies on the changes of the environmental parameters in the cove have to be conducted. Environmental factors apart from the four factors tested in this study, sedimentation rate, the amount of light, dissolved oxygen and water flow should also be considered.

Not only does sediment directly smothers corals by settling on them, sedimentation is also often associated with the amount of the light zooxanthellae is able to collect for photosynthesis. High sedimentation frequently results in mass bleaching or high mortalities as the suspended sediment blocks irradiance interfering with photosynthesis. Photosynthetic efficiency of corals is also known to be influenced by dissolved oxygen transport by its surrounding water flow (Finelli et al, 2006). The establishment of any beneficial or detrimental relationship of the environmental factors and the growth of corals in the Cove based on a more accurate data will greatly support the efficient restoration and maintenance of the reefs in the long run.

Apart from environmental conditions, relationships such as that of the acoelid flatworms and Favites sp. and the predator-prey relationships that may affect the survival and growth of the corals in the long run should also be considered in future studies. In this study, the survivorship of each species may not be an accurate representation of the actual survivorship due to a small
sample size. A small sample size results in a large sampling error and each replicate holds a relatively large percentage. Any mortality by chance could be deemed as a significant result. For example, with only eight replicates, two mortalities of *Favites sp.* resulted in having the lowest survival rate. The survival rates derived in this study can be used as a gauge for any future study involving a larger sample size.

REFERENCES


