Proceedings of the 12th International Coral Reef Symposium, Cairns, Australia, 9-13 July 2012
9A Coral bleaching and climate change

Comparing recruitment of *Pocillopora damicornis* affected by the 2010 bleaching event

Sittiporn Pengsakun, Makamas Sutthacheep, Thamasak Yeemin

Marine Biodiversity Research Group, Faculty of Science, Ramkhamhaeng University, Bangkok 10240 Thailand
Corresponding author: marine_ru@hotmail.com

Abstract. Coral bleaching, caused by high seawater temperature, occurred throughout the Gulf of Thailand in May to September 2010. This study compares recruitment of the brooding coral *Pocillopora damicornis* before, during and after the 2010 bleaching event, in a settlement plate experiment, at Khrok Island and Sak Island, in the inner Gulf of Thailand. Before the bleaching event, the averages of coral recruitment were 4.9±0.23 colonies.m^{-2} for Khrok Island and 6.8±0.51 colonies.m^{-2} for Sak Island. In contrast, during the bleaching event, there were no coral recruits at Khrok Island and the average of coral recruitment at Sak Island was only 0.62±0.02 colony.m^{-2}. Recruitment rates increased after the bleaching event (September 2010-May 2011) compared with during the bleaching event, 0.69±0.01 colony.m^{-2} for Khrok Island and 1.23±0.09 colonies.m^{-2} for Sak Island. Low density of adult colonies of *P. damicornis* in the inner Gulf of Thailand after the bleaching event would result in its low coral recruitment. Therefore recovery to the former levels of abundance of *P. damicornis* at Khrok Island and Sak Island will depend on successful settlement of planulae which is likely to be low. To give this coral species the best chance to maintain their populations in the face of coral bleaching events, additional anthropogenic stressors must be mitigated.

Key words: settlement, recruitment, coral bleaching, *Pocillopora damicornis*, Gulf of Thailand.

Introduction

Recruitment is an important factor controlling the population dynamics of corals and plays a major role in promoting the recovery of degraded coral reefs and maintaining healthy coral populations (Babcock and Mundy 1996, Fox 2004, Salinas-de-León et al. 2011). Patterns of scleractinian coral recruitment are determined by several factors, such as the level of live coral cover in the source of coral population, diversity and abundance of panulae, hydrographic condition, sedimentation, temperature, settlement inhibition by other benthic organisms, eutrophication levels, grazing intensity and light levels (Babcock and Davies 1991, Tomascik 1991, Maida et al. 1995, Mundy and Babcock 1998, Hughes and Connell 1999, Hughes et al. 2000, Birrell et al. 2005, Carpenter and Edmunds 2006, Baria et al. 2010, Tay et al. 2011). Study of coral recruitment is quite difficult because coral recruits are small sizes and they prefer to grow in cryptic habitats. Therefore, many previous studies have used artificial substrata, e.g. settlement panels, to examine coral settlement rates as they can be removed from the coral reef for microscopic identification. Newly settled juveniles can be easily detected on settlement panels as they secrete a calcium carbonate skeleton after their settlement (Babcock et al. 2003). A large number of materials have been applied in coral settlement studies, based on the cost and local availability of materials. These include: glazed and unglazed gypsum tiles, petri-dishes, brick- fired tiles, carbonic or PVC plates, rubber, concrete blocks or crushed coral rubble limestone tiles and pulverized fuel ash blocks, etc. (Tomascik 1991, Smith 1992, Yeemin and Sudara 1992, Reyes and Yap 2001, Lam 2003, Soong et al. 2003, Yeemin et al. 2006, Field et al. 2007, Schmidt-Roach et al. 2008). The position of settlement panels may affect coral settlement patterns. Scleractinian corals prefer to settle in microhabitats where they can avoid grazers and sediment, while still receiving adequate light for photosynthesis of their symbionts (Fisk and Harriott 1990, Sudara et al. 1994).

The severe mass coral bleaching, caused by high seawater temperature, occurred throughout the Gulf of Thailand in May to September 2010. One of the potential effects of coral bleaching event is reduction in reproductive output or reduction in recruitment/ survivorship of larvae (McClanahan et al. 2009). Our long-term study on coral communities in the inner Gulf of Thailand provides an opportunity to quantify impacts of the 2010 bleaching event on coral settlement and recruitment rates. The aim of this study was to compare recruitment of the brooding coral *Pocillopora damicornis* before, during and after the 2010 bleaching event, through the settlement panel experiments, at Khrok and Sak Islands, in the inner Gulf of Thailand.

Material and Methods

The study sites were located at Khrok and Sak Islands, the tourism hotspots, in the inner Gulf of Thailand (Fig. 1).

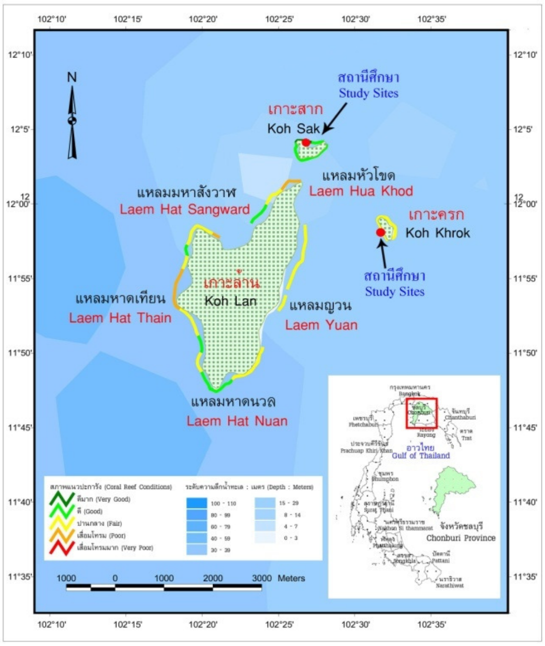
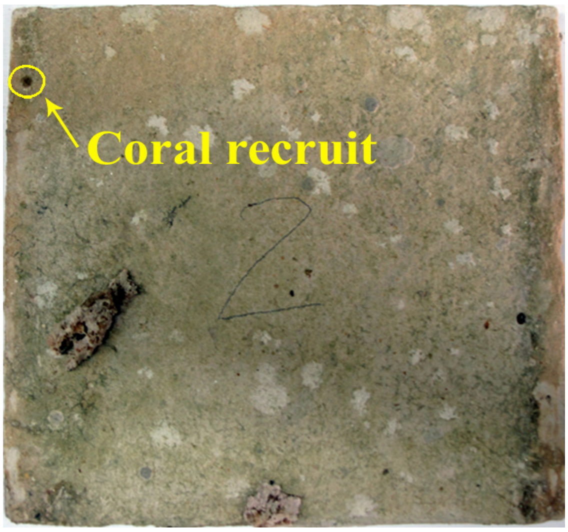


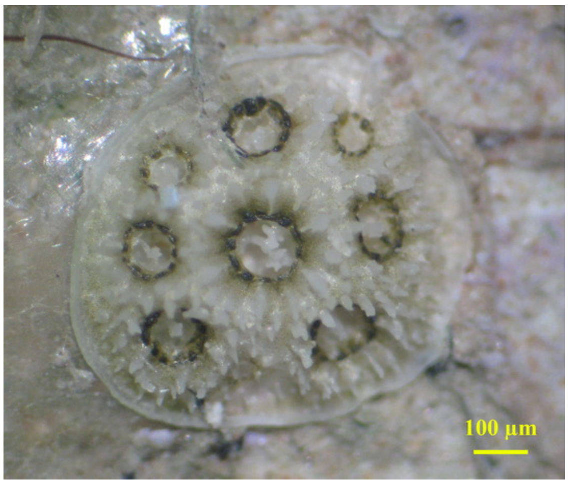
Figure 1: Map of the study sites, Khrok and Sak Islands

Settlement panels were made of locally available gypsum plates and were deployed in three periods, i.e., before the bleaching event (June 2009-March 2010), during the bleaching event (April 2010-August 2010) and after the bleaching event (September 2010-May 2011). Planulation of *P. damicornis* in the inner Gulf of Thailand occurs year-round (Janena et al. 1996). However there are no scientific results showing whether reproduction is through sexual or a sexual brooding. The panel size was 15x15 cm^2. Twelve panels were attached to the iron frames in vertical, horizontal and oblique positions, four panels for each (Fig. 2). There were three iron frames for each study site. Settlement panels were collected, labeled and transported back to the laboratory for initial search of coral recruits using a dissection microscope. All coral recruits were counted and marked. The panels were bleached in a chlorine solution and air dried for further identification of coral recruits. The recruits were identified to family or genus levels (English et al. 1997, Babcock et al. 2003). In this paper we report only the recruits of *P. damicornis*, one of the dominant recruits in the Gulf of Thailand. *P. damicornis* is the only species of Pocilloporidae found in the inner Gulf of Thailand. The coral recruit density data were analyzed with a two-way ANOVA using time and location as fixed factors. Where significant differences were established, Turkey HSD test was employed to determine which groups differed.

A. An iron frame with settlement panels



B. A settlement panel with a coral recruit



C. A recruit of *Pocillopora damicornis*

Figure 2: An Experimental panel experiment at Khrok and Sak Islands

Results

The densities of coral recruits at both study sites before, during and after the 2010 coral bleaching event differed significantly (Fig. 3, Table 1). Before the bleaching event, the averages of coral recruitment were 4.9±0.23 colonies.m^{-2} for Khrok Island and 6.8±0.51 colonies.m^{-2} for Sak Island. In contrast, during the bleaching event, there were no coral recruits at Khrok Island and the average of coral recruitment at Sak Island was only 0.62±0.02 colony.m^{-2}. The settlement panel experiments after the bleaching event (September 2010-May 2011) showed higher recruitment rates compared with during the bleaching event, 0.69±0.01 colony.m^{-2} for Khrok Island and 1.23±0.09 colonies.m^{-2} for Sak Island.

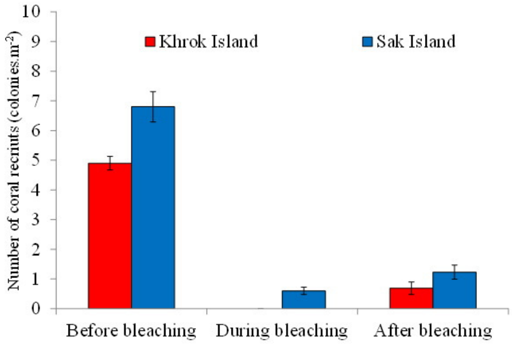


Figure 3: Densities of coral recruit before, during and after the 2010 bleaching event at Khrok and Sak Islands (mean no. colonies.m-2 ±SE).

Source of variation	df	Mean square	*p*
Station	1	0.225	0.318
Time	2	2.527	0.001*
Station X Time	2	0.020	0.908
Error	12	0.207	
Total	18	0.225	
Turkey HSD *test*			
Before bleaching versus During bleaching			0.002*
Before bleaching versus After bleaching			0.006*
*Significant difference (P<0.05) df: Degree of freedom			

Table 1: Densities of coral recruit were compared among factors surveyed before, during and after the 2010 bleaching event. Results of two-way ANOVA and Turkey HSD *test* examining the influence of time and station on recruit density. The data were square root transformed.

Discussion

We quantitatively documented a significantly higher density of coral recruits before the 2010 mass coral bleaching event. These results support the impacts of coral bleaching on reduction in recruitment/survivorship of coral larvae (Michalek-Wagner and Willis 2001, McClanahan et al. 2009). Recruitment rates of *P. damicornis* at our study sites were relatively low, in comparison to other regions (Glasson et al. 2004). Reproductive mode of *P. damicornis* can be planulae brooding or gametes spawning (Baird et al. 2009). It is recognized that *P. damicornis* in the inner Gulf of Thailand is a brooding coral (Janena et al. 1996). Further studies are needed for examining whether *P. damicornis* in the Gulf of Thailand spawns asexual planula larvae or gametes. Our results provide useful data in terms of coral settlement and recruitment in the context of coral recovery from degradation and disturbance, especially from the climate changes derived coral bleaching. As Sak and Krok Islands are located in the inner Gulf of Thailand which is near the river mouths, we suggest that coral recovery may be delayed on coral communities dominated by algal turfs, particularly those stresses by high sedimentation (Birrel et al. 2005). Low density of adult colonies of *P. damicornis* in the inner Gulf of Thailand after the bleaching event would also result in its low coral recruitments in the future. A previous review papers stated that coral recovery periods may up to 20–25 years. Coral recovery to pre-disturbance states may require decades (to restore former levels of coral cover and species diversity) to centuries (to reconstruct lost reef frameworks) (Baker et al. 2008). To give *P. damicornis* the best chance to maintain their populations in the inner Gulf of Thailand in the face of coral bleaching events, additional anthropogenic stressors must be mitigated by proper implementation of a good management plan.

Acknowledgement

We are most grateful to the staff of Marine Biodiversity Research Group, Faculty of Science, Ramkhamhaeng University for their assistance in the field. This study was funded by a budget for research promotion from the Thai Government awarded to Ramkhamhaeng University in the fiscal years B.E. 2552 – 2555.

References

Babcock R, Davies P (1991) Effects of sedimentation on settlement of Acropora–Millepora. Coral Reefs 9(4):205–208

Babcock R, Mundy C (1996) Coral recruitment: Consequences of settlement choice for early growth and survivorship in two scleractinians. J Exp Mar Biol Ecol 206:179–201

Babcock RC, Baird AH, Piromvaragorn S, Thomson DP, Willis BL (2003) Identification of scleractinian coral recruits from Indo-Pacific reefs. Zool Sci 42(1):211-226

Baker AC, Glynn PW, Riegl B (2008) Climate change and coral reef bleaching: An ecological assessment of long-term impacts, recovery trends and future outlook. Estuar Coast Shelf Sci 80: 435-471

Baird AH, Guest JR, Willis BL (2009) Systematic and biogeographical patterns in the reproductive biology of scleractinian corals. Annu Rev Ecol Evol Syst 40:551–571

Baria MVB, Guest JR, Edwards AJ, Aliño PM, Heyward AJ, Gomez ED (2010) Caging enhances post-settlement survival of juveniles of the scleractinian coral *Acropora tenuis*. J Exp Mar Biol Ecol 394:149-153

Birrell CL, McCook LJ, Willis BL (2005) Effects of algal turfs and sediment on coral settlement. Mar Pollut Bull 51(1-4): 408-414

Carpenter RC, Edmunds PJ (2006) Local and regional scale recovery of Diadema promotes recruitment of scleractinian corals. Ecol Lett 9:268–277

Field SN, Glassom D, Bythell J (2007) Effects of artificial settlement plate materials and methods of deployment on the sessile epibenthic community development in a tropical environment. Coral Reefs 26:279–289

Fisk DA, Harriott VJ (1990) Spatial and temporal variation in coral recruitment on the Great-Barrier-Reef-implications for dispersal hypotheses. Mar Biol 107:485-490

Fox HE (2004) Coral recruitment in blasted and unblasted sites in Indonesia: assessing rehabilitation potential. Mar Ecol Progr Ser 269:131–139

Glassom D, Zakai D, Chadwick-Furman NE (2004) Coral recruitment: a spatio-temporal analysis along the coastline of Eliat, Northern Red Sea. Mar Biol 144:641-651

Hughes TP, Baird AH, Dinsdale EA, Moltschaniwskyj NA, Pratchett MS, Tanner JE, Willis BL (2000) Supply-side ecology works both ways: the link between benthic adults, fecundity, and larval recruits. Ecology 81:2241-2249

Hughes TP, Connell JH (1999) Multiple stressors on coral reefs: a long-term perspective. Limnol Oceanogr 44:932-940

Janena N, Yamazato K, Yeemin T, Aranyakanon P (1996) Reproductive biology of the coral *Pocillopoora damicornis* at Sichang Island, the Gulf of Thailand. Paper presented at International Symposium on Ecology of Coral Reef Communities in the Gulf of Thailand, Sichang Island, Chonburi, Thailand.

Michalek-Wagner K, Willis BL (2001) Impacts of bleaching on the soft coral Lobophytum compactum. I. Biochemical changes in adults and their eggs. Coral Reefs 19:231-239

Lam KKY (2003) Coral recruitment onto an experimental pulverized fuel ash-concrete artificial reef. Mar Pollut Bull 46:642-653

Maida P, Sammarco W, Coll JC (1995) Effects of soft corals on scleractinian coral recruitment. 1. Directional allelopathy and inhibition of settlement. Mar Ecol Progr Ser 121:191–202

McClanahan TR, Weil E, Maina J (2009) Strong relationship between coral bleaching and growth anomalies in massive *Porites*. Glob Change Biol 15:1804-1816

Mundy CN, Babcock RC (1998) Role of light intensity and spectral quality in coral settlement: implications for depth-dependent settlement?. J Exp Mar Biol Ecol 223:235–255

Reyes MZ, Yap HT (2001) Effect of artificial substratum material and resident adults on coral settlement patterns at Danjugan Island, Philippines. B Mar Sci 69:559–566

Salinas-de-León P, Costales-Carrera A, Zeljkovic S, Smith DJ, Bell JJ (2011) Scleractinian settlement patterns to natural cleared reef substrata and artificial settlement panels on an Indonesian coral reef. Estuar Coast Shelf Sci 93:80-85

Schmidt-Roach S, Kunzmann A, Arbizu PM (2008) In situ observation of coral recruitment using fluorescence census techniques. J Exp Mar Biol Ecol 367:37-40

Smith SR (1992) Patterns of coral recruitment and post settlement mortality on Bermudas reefs – comparisons to Caribbean and Pacific reefs. Am Zool 32:663-673

Soong K, Chen MH, Chen CL, Dai CF, Fan TY, Li JJ, Fan HM (2003) Spatial and temporal variation of coral recruitment in Taiwan. Coral Reefs 22:224-228

Sudara S, Yeemin T, Amornsakchai S (1994) Recruitment of scleractinian corals at Pha-Ngan Island, Gulf of Thailand: an experimental approach. Proc 3rd ASEAN-Australia Symposium on Living Coastal Resources, vol II, pp 157-160

Tay YC, Guest JR, Chou LM, Todd PA (2011) Vertical distribution and settlement competencies in broadcast spawning coral larvae: implications for dispersal models. J Exp Mar Biol Ecol 409: 324-330

Tomascik T (1991) Settlement-patterns of Caribbean scleractinian corals on artificial substrata along a eutrophication gradient, Barbados, West-Indies. Mar Ecol Prog Ser 77:261–269

Yeemin T, Sudara S (1992) The role of coral recruitment in problems of coral reef development: a perspective view. Proc of Marine Science: Living Coastal Resources, vol VI, pp 15-25

Yeemin T, Sutthacheep M, Pettongma R (2006) Coral reef restoration projects in Thailand. Ocean Coast Manage 49:562-575