ORIGINAL PAPER

Demographic composition of juvenile corals on shallow reef flats and reef slopes in Mu Ko Ang Thong National Park, the Western Gulf of Thailand

Charernmee Chamchoy[a] , Makamas Sutthacheep[a] Chainarong Ruengthong[b], Chaiyut Klingklao[b], Sittiporn Pengsakun[a], Wanlaya Klinthong[a], Thamasak Yeemin*

[a] Marine Biodiversity Research Group, Department of Biology, Faculty of Science, Ramkhamhaeng University, Huamark, Bangkok, Thailand
[b] Chumphon Marine National Park Operation Center 1, Department of National Parks, Wildlife and Plant Conservation, Chumphon Province

*Corresponding author: *thamasakyeemin@hotmail.com*

Received: 26 April 2021 / Revised: 28 April 2021 / Accepted: 29 April 2021

Abstract: Juvenile corals are the one influencing factor in the coral reefs. Those juvenile corals are potentials for coral recovery. In this research, we quantified how the population of juvenile corals (<50 mm) was influenced by coral community structure in shallow reef flat and reef slope areas. This research examined the composition and abundance of juvenile corals on natural substrates in shallow reef flats and reef slopes at Mu Ko Angthong, the Western Gulf of Thailand, in 2019. Quadrats 16x16 cm^2 each were applied randomly to observe juvenile corals on available substrates through SCUBA diving. The visible juvenile corals were counted and identified at the genus level. The density of juvenile corals on the shallow reef flats (9.09-26.05 individuals m^{-2}) was higher than those on reef slopes (3.59-18.63 individuals m^{-2}) in all study sites, except for Ko Sam Sao (E). Twelve genera of juvenile corals were founded. The highest densities of juvenile corals were recorded at Ko Sam Sao (E) and Ko Sam Sao (N), both on the shallow reef flats and reef slopes. The findings indicate that the shallow reef flats might play a potential resource for active coral restoration projects in Thailand.

Keywords: juvenile coral, reef flat, reef slope, Gulf of Thailand

1. Introduction

Coral reefs are the ecosystems recognized as the forest of the sea, with high biological diversity. They show a high gross primary production rate because of the nutrient cycling processes among reef organisms (Crossland et al., 1991). Nowadays, the percentage of live coral covers decreased due to environmental stresses, i.e., elevated seawater temperature and increased solar irradiance (Lesser and Farrell, 2004; Heron et al., 2016; Eakin et al., 2019). Moreover, a lot of sediments and nutrients, pollutants (Fabricius, 2005; Møller et al., 2015), plastic debris (Moore, 2008), heavy metals have been discharged into the oceans (Prouty et al., 2013). These pressures cause coral deterioration fostering global society to take action. Hence, coral restoration projects have been increasingly implemented using different techniques, aiming to minimize accelerating coral reef degradation (Hein et al., 2019).

Also, the natural recovery of corals plays a significant role in the health of the coral reef ecosystem. One of the mechanisms of coral recovery is the settlement of coral larvae on available substrates (the size of coral recruits are often ≤1 mm in diameter) (Babcock et al., 2003) and successful recruitment and growth of juvenile corals, which their sizes are smaller than 5 mm in diameter (Miller et a., 2000). Coral recruitment is an essential process for the recovery of coral populations after experiencing natural and anthropogenic disturbances (Roth and Knowlton, 2009; Doropoulos et al., 2015; Edmunds et al., 2015). Several papers focus on juvenile corals at different aspects such as the composition and density of juvenile corals (Bak and Engel,1979; Yeemin et al., 1992; Chiappone and Sullivan, 1996; Edmunds, 2000; Ruiz-Zarate and Arias-Gonzalez, 2004; Vidal et al., 2005; Sutthacheep et al., 2011; Yeemin et al., 2012, 2013; Putthayakool et al., 2014; Chamchoy et al., 2015, 2016), the mortality of juvenile corals (Smith, 1997;

Miller et al., 2000; Webster and Smith, 2000; Glassom and Chadwick, 2006), effects of other benthic or environmental stress on growth and survival of juvenile corals (Wittenberg and Hunte, 1992; Edmunds and Carpenter, 2001; Edmunds et al., 2004; Box and Mumby, 2007).

However, available information on juvenile corals for some aspects is still insufficient, making it difficult to determine correct size-frequency distributions and to construct correct coral population models (Roth and Knowlton, 2009). Therefore, this research aims to determine the composition and abundance of juvenile corals on available substrates on shallow reef flats and reef slopes at Mu Ko Ang Thong National Park, the Western Gulf of Thailand. We hypothesized that the differences influence the abundance of juvenile corals in depth (shallow reef flats and reef slopes).

2. Materials and Methods

2.1 Study sites

Mu Ko Ang Thong National Park is located in Suratthani Province, the western Gulf of Thailand (9°37'57.13'' N, 99°40'20.30''E). This archipelago is approximately 750 km south of Bangkok and about 56 km away from the Tapee River. The islands are surrounded by shallow and turbid waters, with an average depth of about 10 meters, greatly affected by the freshwater flow out from the mainland Tapi River. Four study sites were examined, i.e., Ko Sam Sao (W), Ko Sam Sao (N), Ko Sam Sao (E), Ko Wua Kantang, Ko Hindap, and Ko Thaiphlao (Figureure 1)

.

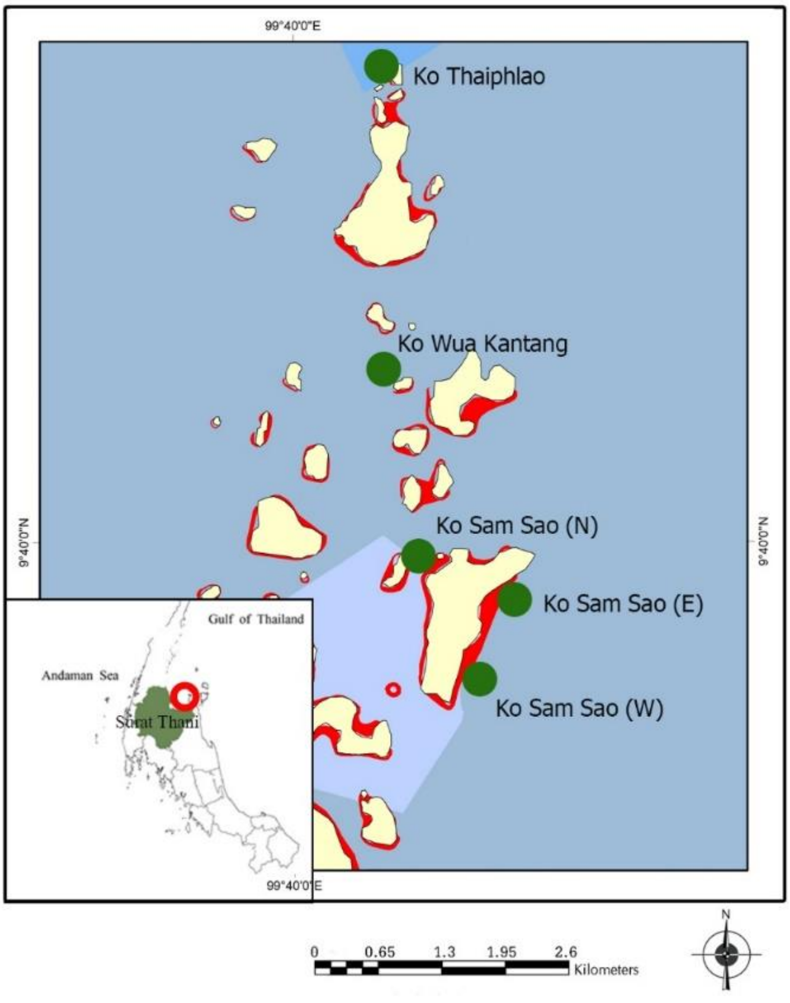


Figure 1. Map of the study sites at Mu Ko Ang Thong National Park

2.2 Coral community surveys

The study was conducted on coral communities in shallow reef flats and reef slopes in April 2019, which have depths of about 1-3 m and 3-7 m, respectively. At each study site, live coral cover and benthic components were recorded in three permanent belt-transects of 30×1 m^2, and scleractinian corals (>5 cm diameter) were identified to genus level using the identification guides by Veron (2000). The average percent cover of live coral, dead coral, rubble, sand, and other benthic components were calculated. For the juvenile coral (1-5 cm diameter), quadrats (16x16 cm^2 each) were randomly placed on available substrates (dead coral, rubble, and rock), and visible coral recruits were counted and identified at the genus level. The average density of juvenile corals was expressed as the number of juvenile corals per square meter.

2.3 Data Analysis

The data of available substrate and juvenile corals density were tested for normality and were transformed by square root to meet the assumptions of the parametric test to conducting the analyses. The one-way ANOVA was used to detect a significant difference in available substrate and density of juvenile coral among coral reef zone and study sites. Where significant differences were found, the Tukey HSD (honestly significant difference) test was employed to determine which reef sites statistically differed. Pearson's correlation was also analyzed to investigate the relationship between the juvenile densities and available substrates. All analyses were performed using R Software.

3. Results

The benthic components (including live corals and dead corals) are shown in Figure 2. The percentages of live coral cover in shallow reef flats ranged from 33.10±4.02 to 68.33 ±8.04 at Ko Taiphlao and the west of Ko Samsao, respectively, and in reef slopes ranged from 52.86± 6.22 to 61.82± 7.28 at the east of Ko Samsao and the north of Ko Samsao, respectively.

The percentages of available substrate cover in shallow reef flats were in the range from 26.67±3.20 to 47.01±5.56. The highest percentage of available substrate cover was found at Ko Taiphlao (47.01%), while the lowest one was recorded at the west of Ko Samsao.

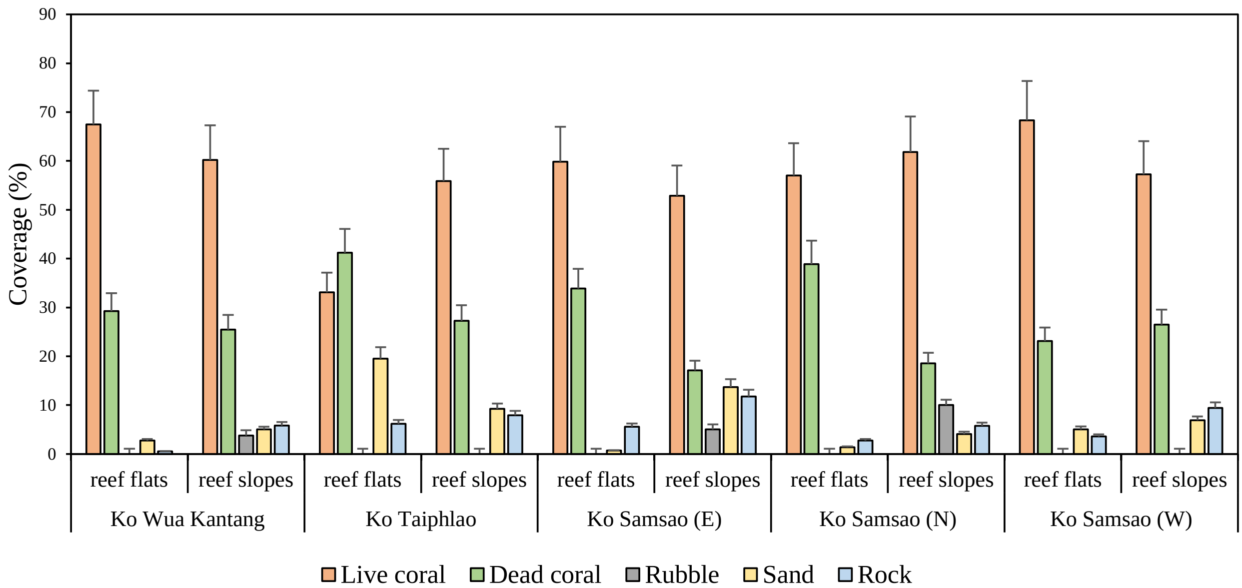


Figure 2. Average percentage cover of live corals, dead corals, and other benthic components on shallow reef flats and reef slopes at each study site. Error bars indicate standard deviation..

In reef slopes, the percentages of available substrate cover ranged from 33.83±3.98 to 35.90 ±4.22. The highest percentage of available substrate cover was found at the west of Ko Samsao, whereas the lowest one was recorded at the east of Ko Samsao (26.67%) (Figure 3).

The results from two-way ANOVA showed the significance of differences in available substrate among study sites ($F_{(4,20)}$=5. 074; *p*=0.005) (Table 1). The multiple comparisons using Tukey HSD illustrated that the available substrate in Ko Wua Kantang was significantly different from that found in Ko Taiphlao (*p*=0.017). The available substrate at Ko Taiphlao was significantly different from that found at the west of Ko Samsao (*p*=0.006). There was a statistically significant interaction between the effects of zone and study site on available substate (F (4, 20) =5.957, p = .0003), indicating that the available substrate varied depending on the type of reef zone and study sites. The averages of available substrate cover in shallow reef flats at Ko Taiphlao, Ko Samsao (E), and Ko Samsao (N) were higher than those in reef slopes. On the other hand, averages of available substrate cover in shallow reef flats at Ko Wua Kantang and Ko Samsao (W) were lower than in reef slopes (Figure 4).

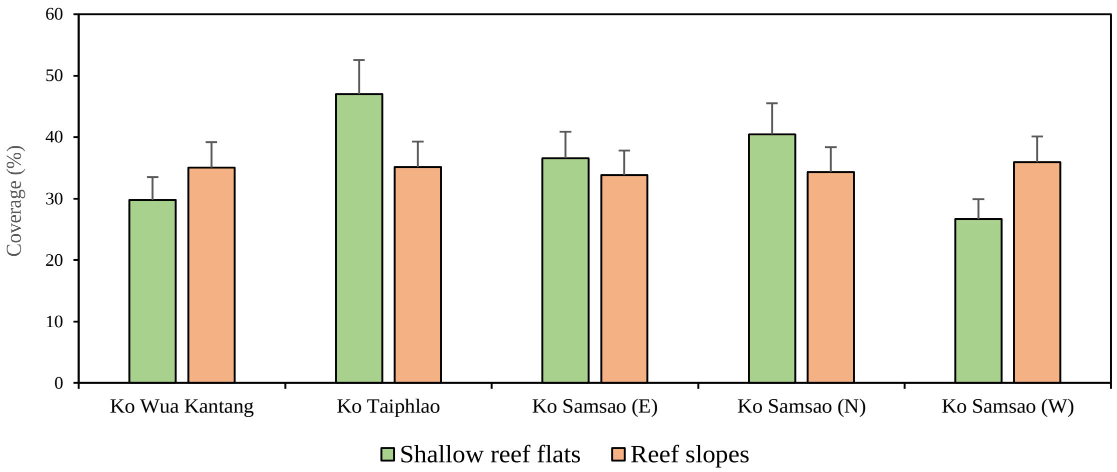


Figure 3. Percentage cover of an available substrate on shallow reef flats and reef slopes at each study site. Error bars indicate standard deviation

Table 1. Two-way analyses of variance (ANOVA) and the multiple comparisons illustrate the significance of differences in available substrate among coral reef zone and study sites.

Source of variation	df	Mean Square	F	*P*
Two-way ANOVA test				
Coral reef zone	1	11.584	.632	.436
Study site	4	93.055	5.074	.005**
Coral reef zone * Study site	4	109.254	5.957	.003**
Error	20	18.339		
Total	30			
Tukey HSD				
Ko Wua Kantang vs Ko Taiphlao				0.017*
Ko Taiphlao vs Ko Samsao (W)				0.006**

df: degree of freedom.
* Significant difference (*p*<0.05)
** Significant difference (*p*<0.01)

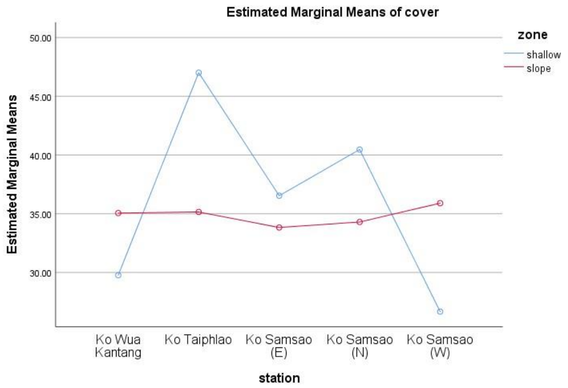


Figure 4. Estimated marginal means of available substrate

The densities of juvenile corals on the shallow reef flats (9.09-26.05 juveniles/m^2) were significantly higher than those on reef slopes (3.59-18.63 juveniles/m^2) except for the east of Ko Sam Sao and Ko Taiphao (p<0.05) (Figure 5). A total of 12 genera of juvenile corals were commonly observed in shallow reef flats, while 11 genera in reef slopes. The genera of juvenile corals found in shallow reef flats and reef slopes were *Pocillopora*, *Lobophyllon*, *Favites*, *Goniastrea*, *Leptastrea*, *Porites*, *Platygyra*, *Pavona*, *Turbinaria*, *Pseudosiderastrea tayamai*, *Goniopora*, *Favia*, *Oulastrea crispata*, and *Diploastrea heliopora* (Figures 6 and 7). Results of two-way ANOVA revealed that the significant differences in densities of juvenile corals between coral reef zones ($F_{(4,20)}$ =10.394; p=0.004) and among study sites ($F_{(4,20)}$ =7.124; p=0.001) were detected (Table 2). The multiple comparisons using Tukey HSD illustrated that the available substrate in Ko Wua Kantang was significantly different from that found in the east of Ko Samsao (p=0.043) and the north of Ko Samsao (p=0.03). The available substrate at Ko Taiphlao was significantly different from those found at the east of Ko Samsao (p=0.027) and the north of Ko Samsao (p=0.020). The juvenile coral density at the west of Ko Samsao was significantly different from those found at the east of Ko Samsao (p=0.011) and the north of Ko Samsao (p=0.008).

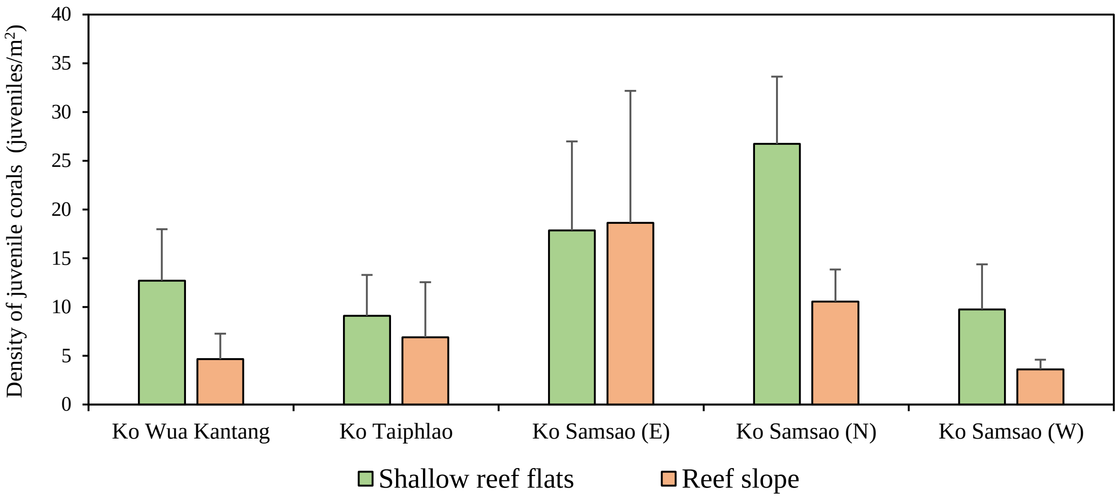


Figure 5. The density of juvenile corals at each study site. Error bars indicate standard deviation.

Pocillopora sp.

Porites sp.

Favites sp.

Figure 6. Dominant juvenile corals on available substrate at the study sites

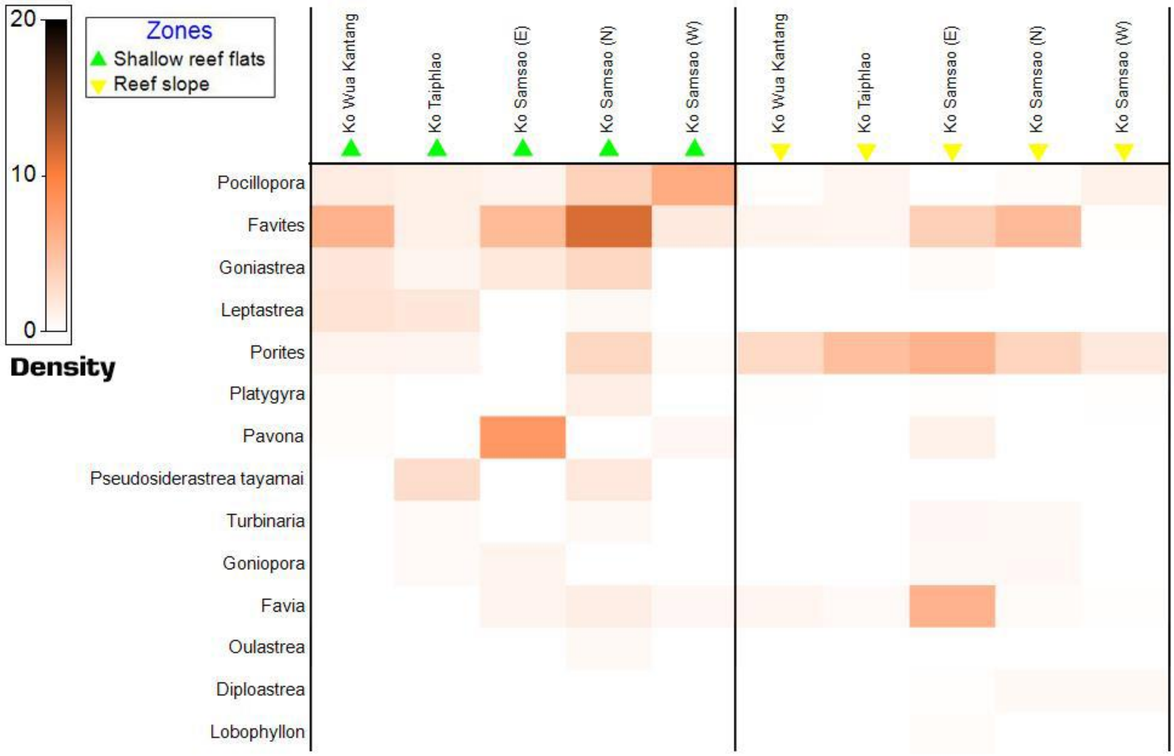


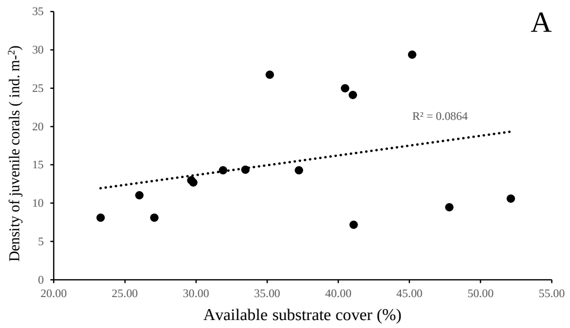
Figure 7. Species composition of juvenile corals at each study site

Table 2. Two-way analyses of variance (ANOVA) and multiple comparisons were illustrating the significance of differences in density of juvenile corals among coral reef zone and study sites

Source of variation	df	Mean Square	F	*P*
Two-way ANOVA test				
Coral reef zone	1	304.072	10.394	.004**
Study site	4	208.395	7.124	.001**
Zone * Station	4	62.822	2.147	.112
Error	20	29.254		
Total	30			
<u>Tukey HSD</u>				
Ko Wua Kantang vs Ko Samsao (E)				0.043*
Ko Wua Kantang vs Ko Samsao (N)				0.033*
Ko Taiphlao vs Ko Samsao (E)				0.027*
Ko Taiphlao vs Ko Samsao (N)				0.020*
Ko Samsao (W) vs Ko Samsao (E)				0.011*
Ko Samsao (W) vs Ko Samsao (N)				0.008**

df: degree of freedom.
* Significant difference ($p<0.05$)
** Significant difference ($p<0.01$)

The densities of juvenile corals increased with an increase of available substrate in both shallow reef flats and reef slopes. However, the positive correlations were not statistically significant in both reef flats (r=0.294, p=0.288) and reef slopes (r=0.364, p=0.182) because of the high variation of juvenile coral densities (Figure 8).



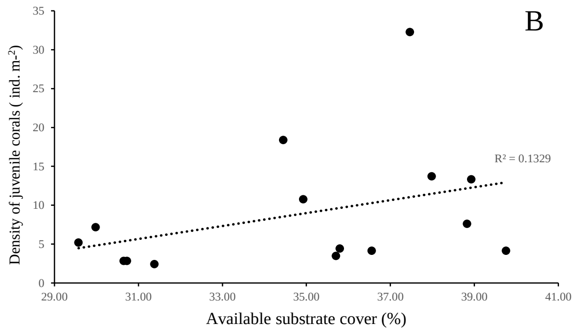


Figure 8. Relationships between the available substrate and density of juvenile corals in shallow reef flats (A) and reef slopes (B)

4. Discussion

Juvenile coral densities have been proposed as a crucial predictor of coral reef recovery from mass bleaching events (Hughes et al., 2010; Gilmour et al., 2013; Graham et al., 2015; Dajka et al., 2019). The present study shows that the highest survival of juvenile corals (shallow reef flat and reef slope) were recorded 37.32 individuals m^{-2}, at the north of Ko Samsao, in the Mu Ko Ang Thong National Park, dominated by juvenile corals *Favites* spp. following by *Pocillopora* spp. and *Goniastrea* spp., respectively. This result agrees with previous observation conducted by Putthayakool et al. (2017) in Mu Ko Ang Thong National Park in 2015, reporting that the density of juvenile corals ranged from 8.22 ±1.66 individuals m^{-2} at the east of Wau Talap Island to 37.38 ± 2.98 individuals m^{-2} at the north of Sam Sao Island, and the dominant species include Faviidae was dominant at all study sites.

In this study, juvenile coral colonies were observed using naked eyes; it might cause errors leading to underestimation. Applying modern survey techniques like fluorescence census techniques may increase the accuracy of juvenile coral observation (Piniak et al., 2005; Baird and Selih, 2006; Schmidt-Roach et al., 2008; Roth and Knowlton, 2009). The juvenile coral density at shallow reef flats was relatively high compared with reef slopes at all stations except for the east of Ko Samsao. This indicates that coral recruitments seem to be more successful on available substrates in shallow reef flats than reef slops due to environmental factors such as water currents, wave action (Graham et al., 2014; Doropoulos et al., 2015).

Although no significant association was detected due to the high variation of data, there would be possible associations between juvenile densities and available substrates in shallow reef flats (r = 0.2939) or reef slope (r = 0.36). ur results suggest that the available substrate is one of the crucial parameters that can induce coral recruits to settle down and increase juvenile corals density. Several factors affecting the abundance of coral recruitment, growth, and the survival of juvenile corals include grazer effects such as fishes in the family Pomacentridae (Casey et al., 2015) or sea urchins, illumination condition, and the available substrate, which are covered by select few species of crustose coralline algae (Babcock and Mundy, 1996; Harrington et al., 2004; Price, 2010; Ritson-Williams et al., 2010). Unstable substrates such as rubble are likely to make major coral recruits die-offs (Fox et al., 2003; Chong-Seng et al., 2014).

The coral recruits experiencing disturbances showing mortality rates after settlement of 67-

99 % in their first year (Smith, 1992; Babcock and Mundy, 1996; Dunstan and Johnson, 1998; Wilson and Harrison, 2005; Graham et al., 2013). Mortality rates of juvenile coral gradually reduce with coral growth, and the mortality rate of many corals reduces once they have reached their sizes of more than 5 cm (Doropoulos et al., 2015), and those surviving juvenile corals can grow to reach reproductive sizes and contribute to the adult population (Hughes et al., 2010; Gilmour et al., 2013). These findings are necessary for understanding the critical role of juvenile corals in managing coral recovery after overcoming environmental stresses in the future.

Acknowledgments

We are most grateful to the staff of Marine National Park Operation Center Chumphon, Department of National Parks, Wildlife, and Plant Conservation. The staff of Marine Biodiversity Research Group, Faculty of Science, Ramkhamhaeng university assistance in the field. This research was funded by the National Science and Technology Development Agency (NSTDA) to Ramkhamhaeng University.

References

Babcock R, Mundy C (1996) Coral recruitment: consequences of settlement choice for early growth and survivorship in two scleractinians. Journal of Experimental Marine Biology and Ecology 206(1-2):179-201

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

Baird AH, Salih A, Trevor-Jones A (2006) Fluorescence census techniques for the early detection of coral recruits. Coral Reefs 25(1):73-76

Bak RPM, Engel MS (1979) Distribution, abundance and survival of juvenile hermatypic corals (Scleractinia) and the importance of life history strategies in the parent coral community. Marine Biology 54(4):341-352

Box SJ, Mumby PJ (2007) Effect of macroalgal competition on growth and survival of juvenile Caribbean corals. Marine Ecology Progress Series 342:139-149

Casey JM, Choat JH, Connolly SR (2015) Coupled dynamics of territorial damselfishes and juvenile corals on the reef crest. Coral Reefs 34(1):1-11

Chamchoy C, Yeemin T, Sutthacheep M, Klinthong W, Niamsiri R (2016) Contrasting abundance of juvenile corals at two national parks in the Andaman Sea. Proceedings the 13th International Coral Reef Symposium, Honolulu, Hawaii, pp 503-514

Chamchoy C, Yeemin T, Sutthacheep M, Pengsakun S, Klinthong W, Samsuvan W (2015) Abundance of juvenile corals following the 2010 coral bleaching event at Mu Ko Phi Phi, the Andaman Sea. Proceedings the 41st Congress on Science and Technology of Thailand (STT41), Suranaree University of Technology, Nakhon Ratchasima, Thailand, pp 456-460

Chiappone M, Sullivan KM (1996) Distribution, abundance and species composition of juvenile scleractinian corals in the Florida Reef Tract. Bulletin of Marine Science 58(2):555-569

Chong-Seng KM, Graham NAJ, Pratchett MS (2014) Bottlenecks to coral recovery in the Seychelles. Coral Reefs 33(2):449-461

Crossland CJ, Hatcher BG, SV Smith (1991) Role of coral reefs in global ocean production. Coral Reefs 10(2):55-64

Dajka JC, Wilson SK, Robinson JP, Chong-Seng KM, Harris A, Graham NA (2019) Uncovering drivers of juvenile coral density following mass bleaching. Coral Reefs 38(4):637-649

Doropoulos C, Ward S, Roff G, González-Rivero M, Mumby PJ (2015) Linking demographic processes of juvenile corals to benthic recovery trajectories in two common reef habitats. PLoS One 10(5):e0128535

Dunstan PK, Johnson CR (1998) Spatio-temporal variation in coral recruitment at different scales on Heron Reef, southern Great Barrier Reef. Coral Reefs 17(1):71-81

Eakin CM, Sweatman HPA, Brainard RE (2019) The 2014-2017 global-scale coral bleaching event: insights and impacts. Coral Reefs 38(4):539-545

Edmunds PJ (2000) Patterns in the distribution of juvenile corals and coral reef community structure in St. John, US Virgin Islands. Marine Ecology Progress Series 202:113-124

Edmunds PJ, Bruno JF, Carlon DB (2004) Effects of depth and microhabitat on growth and survivorship of juvenile corals in the Florida Keys. Marine Ecology Progress Series 278:115-124

Edmunds PJ, Carpenter RC (2001) Recovery of Diadema antillarum reduces macroalgal cover and increases abundance of juvenile corals on a Caribbean reef. Proceedings of the National Academy of Sciences 98(9): 5067-5071

Edmunds PJ, Steneck R, Albright R, Carpenter RC, Chui APY, Fan TY, & Gates RD (2015) Geographic variation in long-term trajectories of change in coral recruitment: a global-to-local perspective. Marine and Freshwater Research 66(7):609-622

Fabricius K E (2005) Effects of terrestrial runoff on the ecology of corals and coral reefs: Review and synthesis. Marine Pollution Bulletin 50(2):125-146

Fox HE, Pet JS, Dahuri R, Caldwell RL (2003) Recovery in rubble fields: long-term impacts of blast fishing. Marine Pollution Bulletin 46(8):1024-1031

Gilmour JP, Smith LD, Heyward AJ, Baird AH, Pratchett MS (2013) Recovery of an Isolated Coral Reef System Following Severe Disturbance. Science 340(6128):69-71

Glassom D, Chadwick NE (2006) Recruitment, growth and mortality of juvenile corals at Eilat, northern Red Sea. Marine Ecology Progress Series 318:111-122

Graham EM, Baird AH, Willis BL, Connolly SR (2013) Effects of delayed settlement on post-settlement growth and survival of scleractinian coral larvae. Oecologia 173(2):431-438

Graham NA, Chong-Seng KM, Huchery C, Januchowski-Hartley FA, Nash KL (2014) Coral reef community composition in the context of disturbance history on the Great Barrier Reef, Australia. PloS One 9(7):e101204

Graham NA, Jennings S, MacNeil MA, Mouillot D, Wilson SK (2015) Predicting climate-driven regime shifts versus rebound potential in coral reefs. Nature 518(7537):94-97

Harrington L, Fabricius K, De'ath G, Negri A (2004) Recognition and selection of settlement substrata determine post-settlement survival in corals. Ecology 85(12):3428-3437

Hein MY, Birtles A, Willis BL, Gardiner N, Beeden R, Marshall NA (2019) Coral restoration: Socio-ecological perspectives of benefits and limitations. Biological Conservation 229:14-25

Heron SF, Maynard JA, Van Hooidon R, Eakin CM (2016) Warming trends and bleaching stress of the world's coral reefs 1985-2012. Scientific Reports 6(1):1-14

Hughes TP, Graham NAJ, Jackson JBC, Mumby PJ, Steneck RS (2010) Rising to the challenge of sustaining coral reef resilience. Trends in Ecology & Evolution 25(11):633-642

Lesser MP, Farrell JH (2004) Exposure to solar radiation increases damage to both host tissues and algal symbionts of corals during thermal stress. Coral Reefs 23(3):367-377

Miller MW, Weil E, Szmant AM (2000) Coral recruitment and juvenile mortality as structuring factors for reef benthic communities in Biscayne National Park, USA. Coral Reefs 19(2):115-123

Møller AP, Flensted-Jensen E, Laursen K, Mardal W (2015) Fertilizer leakage to the marine environment, ecosystem effects and population trends of waterbirds in Denmark. Ecosystems 18(1):30-44

Moore CJ (2008) Synthetic polymers in the marine environment: A rapidly increasing, long-term threat. Environmental Research 108(2):131-139

Piniak GA, Fogarty ND, Addison CM, Kenworthy WJ (2005) Fluorescence census techniques for coral recruits. Coral Reefs 24(3):496-500

Price N (2010) Habitat selection, facilitation, and biotic settlement cues affect distribution and performance of coral recruits in French Polynesia. Oecologia 163(3):747-758

Prouty NG, Goodkin NF, Jones R, Lamborg CH, Storlazzi CD, Hughen KA (2013) Environmental assessment of metal exposure to corals living in Castle Harbour, Bermuda. Marine Chemistry 154:55-66

Putthayakool J, Yeemin T, Samsuvan W, van Long N, Vo ST, Sutthacheep M (2014) A comparison between composition and density of juvenile corals of Nha Trang, Viet Nam and Rayong Province, Thailand. Proceedings of the 40th Congress on Science and Technology of Thailand (STT40), Khon Kaen University, Khon Kaen, Thailand, pp 732 – 736

Putthayakool J, Yeemin T, Sutthachee M, Ruangthong C, Samsuvan W, Niamsiri R, Klinthong W (2017) Composition and density of juvenile corals in Mu Ko Angthong national park in the western gulf of Thailand. Proceedings the 43th Congress on Science and Technology of Thailand (STT43), Chulalongkorn University, Bangkok, Thailand, pp 288-292

Ritson-Williams R, Paul VJ, Arnold SN, Steneck RS (2010) Larval settlement preferences and post-settlement survival of the threatened Caribbean corals Acropora palmata and A. cervicornis. Coral Reefs 29(1):71-81

Roth MS, Knowlton N (2009) Distribution, abundance, and microhabitat characterization of small juvenile corals at Palmyra Atoll. Marine Ecology Progress Series 376:133-142

Ruiz-Zarate MA, Arias-Gonzalez JE (2004) Spatial study of juvenile corals in the northern region of the Mesoameri- can Barrier Reef System (MBRS). Coral Reefs 23(4):584-594

Schmidt-Roach S, Kunzmann A, Arbizu PM (2008) In situ observation of coral recruitment using fluorescence census techniques. Journal of Experimental Marine Biology and Ecology 367(1):37-40

Smith SR (1992) Patterns of coral recruitment and post-settlement mortality on Bermuda's reefs: comparisons to

Caribbean and Pacific reefs. American Zoologist 32(6):663-673

Smith SR (1997) Patterns of coral settlement, recruitment and juvenile mortality with depth at Conch Reef, Florida. Proceedings the 8th International Coral Reef Symposium Vol. 2, Smithsonian Tropical Research Institute, Panama, pp 1197-1202

Sutthacheep M, Saenghaisuk C, Sangmanee K, Suantha P, Chueliang P, Yeemin T (2011) Composition and abundance of juvenile coral colonies at Mu Koh Rang, eastern Gulf of Thailand following the 2010 bleaching event. Proceedings the 37th Congress on Science and Technology of Thailand (STT37), Convention Grand & Convention center at Central World, Bangkok, Thailand, p 4

Vidal AM, Villamil CM, Acosta A (2005) Composition and density of juvenile corals at two deep reefs in San Andrés Island, Colombian Caribbean. Boletín de Investigaciones Marinas y Costeras-INVEMAR 34(1):211-225

Webster G, Smith SR (2000) Reduced juvenile coral populations on reefs affected by sewage discharge in Bermuda. Proceedings the 9th International Coral Reef Symposium Vol. 2, Bali, Indonesia, pp 1041-1046

Wilson J, Harrison P (2005) Post-settlement mortality and growth of newly settled reef corals in a subtropical environment. Coral Reefs 24(3):418-421

Wittenberg M, Hunte W (1992) Effects of eutrophication and sedimentation on juvenile corals. Marine Biology 112(1):131-138

Yeemin T, Klinthong W, Sutthacheep M (2013) Diversity and abundance of juvenile corals at Ko Yak and Hin Rap after the 2010 coral bleaching event. Proceedings the 39th Congress on Science and Technology of Thailand, Bangkok International Trade & Exhibition Centre (BITEC), Bangkok, Thailand, p 5

Yeemin T, Saenghaisuk C, Yucharoe M, Klinthong W, Sutthacheep M (2012) Impact of the 2010 coral bleaching event on survival of juvenile coral colonies in the Similan Islands, on the Andaman Sea coast of Thailand. Phuket Marine Biological Center Research Bulletin 70:93-102

Yeemin T, Sudara S, Amornsakchai S (1992) Distribution and abundance of juvenile corals at Pha-Ngan Island, Tao Island and Nang-Yuan Island. Marine Science: Living Coastal Resources 6:63-67