ORIGINAL PAPER

Assessing abundance and composition of juvenile corals in marine national parks in the Eastern Gulf of Thailand

Makamas Sutthacheep[a, *], Thamasak Yeemin[a], Chainarong Ruangthong[b], Charernmee Chamchoy[a], Sittiporn Pengsakun[a], Wanlaya Klintong[a]

[a]Marine Biodiversity Research Group, Department of Biology, Faculty of Science, Ramkhamhaeng University, Huamark, Bangkok 10240, Thailand
[b]Chumphon Marine National Park Operation Center 1, Department of National Parks, Wildlife and Plant Conservation, Chumphon Province

*Corresponding author: *smakamas@hotmail.com*

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Abstract. Coral recruitment is an important factor influencing the natural recovery of degraded reefs. This study aimed to quantitatively examine the abundance and composition of juvenile corals from major reef groups in the Eastern Gulf of Thailand. The field studies were carried out at 15 reef sites in Khao Leam Ya - Mu Ko Samet Nation Park, Rayong Province, and Mu Ko Chang Nation Park, Trat Province. The highest density of juvenile corals was found at Ao Lungdum in Mu Ko Samet (37.5 juvenile corals /m^2). High densities of juvenile corals were recorded at Ao Lungdum and Ao Kiu Na Nok in Mu Ko Samet and Hin Gurk Ma, Ko Bai Dang, and Ko Yak Yai in Mu Ko Chang, and high dissimilarities were found between and within sites. The dominant juvenile corals were *Pocillopora*, *Porites*, *Favites*, *Fungia* and *Turbinaria*. Juvenile corals densities in the study sites are higher than those found in the Andaman Sea, indicating a high recovery potential in the Eastern Gulf of Thailand. In addition, substrate availability and type, coupled with the high sediment load, are important factors controlling juvenile coral density in the Gulf of Thailand. This study provides necessary information for coral reef management plans and coral restoration projects.

Keywords: abundance, coral recruitment, Gulf of Thailand, management

1. Introduction

patial and temporal variation in coral recruitment patterns is important in understanding coral population dynamics and reef resilience in response to anthropogenic and natural disturbances (Hughes et al., 2010; Yeemin et al., 2012a; Salinas-de-León et al., 2013; Yucharoen et al., 2015). The capacity of coral reefs to recover from degradation and maintain their ecosystem services is defined as coral reef resilience (Mumby et al., 2007). Recruitment pattern is recognized as one of the critical factors controlling the ecology of marine benthic organisms. It plays a significant role in maintaining coral reef populations and recovery following disturbances (Connell et al., 1997; Hughes et al., 2000; Salinas-de-León et al., 2013; Johns et al., 2014). Coral recruitment is affected by several factors such as live coral cover on the reefs, abundance and diversity of planula larvae, recruitment cues, inhibition and competition from other benthic organisms, grazing intensity, hydrodynamic condition, reef connectivity, temperature, light intensity, nutrients, and sedimentation (Sammarco, 1980; Benayahu & Loya, 1985; Potts et al., 1985; Babcock & Davies, 1991; Tomascik, 1991; Maida et al., 1995; Roberts, 1997; Mundy & Babcock, 1998; Hughes et al., 2000; Harrington et al., 2004; Amar et al., 2007; Nozawa & Harrison, 2007; Salinas-de-León et al., 2013; Yeemin et al., 2013). The succession of coral recruitment and juvenile survivorship plays an important role in maintaining coral populations under natural conditions and population recovery following mass mortality from bleaching events (Hughes et al., 2002; Yeemin et al., 2013; Yucharoen et al., 2015).

Therefore, coral recruitment is used as a bioindicator for a coral reef health condition, recovery rate, and resilience potential after several environmental stress such as bleaching events. A high coral recruitment rate or high juvenile corals density on natural substrates can lead to fast coral recovery of degraded reefs after coral bleaching events and anthropogenic disturbances (Yeemin et al., 2010). Coral reefs management are requires to supporting ecosystem processes that lower sensitivity, promote recovery, and enhance coral adaptive capacity to bleaching by reducing other human impacts (Anthony et al., 2015). This study aims to compare the abundance and composition of juvenile corals on natural substrates and coral recovery trends at Khao Leam Ya - Mu Ko Samet Nation Park and Mu Ko Chang Nation Park, the Eastern Gulf of Thailand.

2. Materials and Methods

The coral communities were conducted in the national parks in the Eastern Gulf of Thailand, comprising fifteen study sites from two groups of coral communities. Eight reef sites from Mu Ko Samet, (Ao Kiu Na Nok, Ao Kiu Na Nai, Ao Pla Tom, Ao Phrao (s), Ao Lung Dam, Ko Kudi, Ko Chan, Ko Khangkhao) and seven reef sites from Mu Ko Chang (Ko Wai, Ko Bai Dang, Ko Thong Lang, Ko Thain, Hin Gurk Maa, Ko Yak Yai, Ko Yak Lek) (Figure 1).

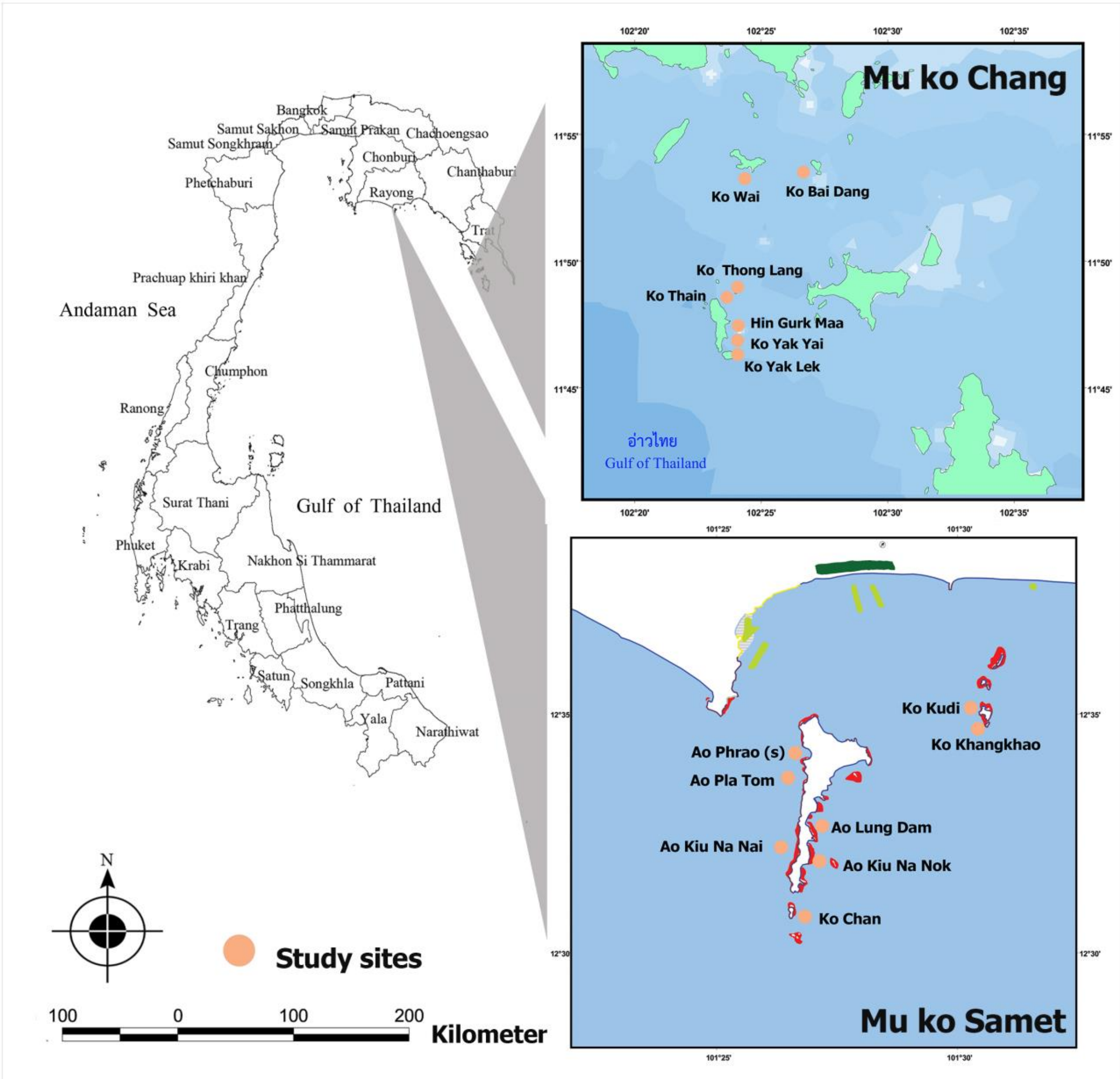

Figure 1. The location of study sites in Khao Leam Ya - Mu Ko Samet Nation Park and Mu Ko Chang Nation Park, the Eastern Gulf of Thailand.

The coral community surveys were conducted in 2018. Coral communities were found at approximately 3-7 m in depth. At each study site, quadrats (16x16 cm^2) were randomly placed on substrates using SCUBA diving. All visible coral recruits (≤ 5 cm in diameter) were counted and identified to genera level. Live coral cover at each study site was also quantified using three belt-transects of 30 x 1 m, and coral colonies (≥5 cm in diameter) were counted, and their coverage was quantitatively estimated.

The data were analyzed using one-way ANOVA to detect if the juvenile coral density is significantly different between the study sites, using PRIMER version 7.0. The difference in the taxonomy composition of corals between Mu Ko Samet and Mu Ko Chang was tested by analyzing similarities (ANOSIM). The coral species contributing most to the dissimilarity between the study sites were identified by similarity percentage (SIMPER) analyses.

3. Results

The percentages of live coral cover ranged from 7.3 to 71.7. The highest percentages of live coral cover in Mu Ko Samet were found at Ko Chan (71.7±10.8) while the lowest coverage was observed at Ao Pla Tom (29.42±4.1), and the highest percentages of live coral cover in Mu Ko Chang were found at Ko Thong Lang (71.2±5.6) while the lowest coverage was observed at Ko Wai (25.9±8.9) (Figure 2). Juvenile coral densities varied from 7.3 to 37.5 juvenile corals /m^2. The highest density of juvenile corals in Mu Ko Samet was found at Ao Lung Dam (37.5±7.14) while the lowest density was recorded at Ko Kudi (7.3±1.4), and the density of juvenile corals in Mu Ko Chang were found at Hin Gurk Maa (25.9±4.9) while the lowest density was recorded at Ko Yak Lek (11.1±2.1) (Figure 3). The percentages of live coral cover and juvenile densities varied significantly among sites ($p<0.05$) (Table 1). The dominant species of juvenile corals found in both regions were *Porites*, *Fungia*, *Favites*, *Oulastrea*, *Favia*, *Symphyllia* and *Pavona* (Figure 4). In terms of the size-frequency distribution, most juvenile corals in Mu Ko Samet were in a range of 1.6 – 2.0 centimeters compared to 2.1 – 2.5 centimeters in Mu Ko Chang (Figure 5)

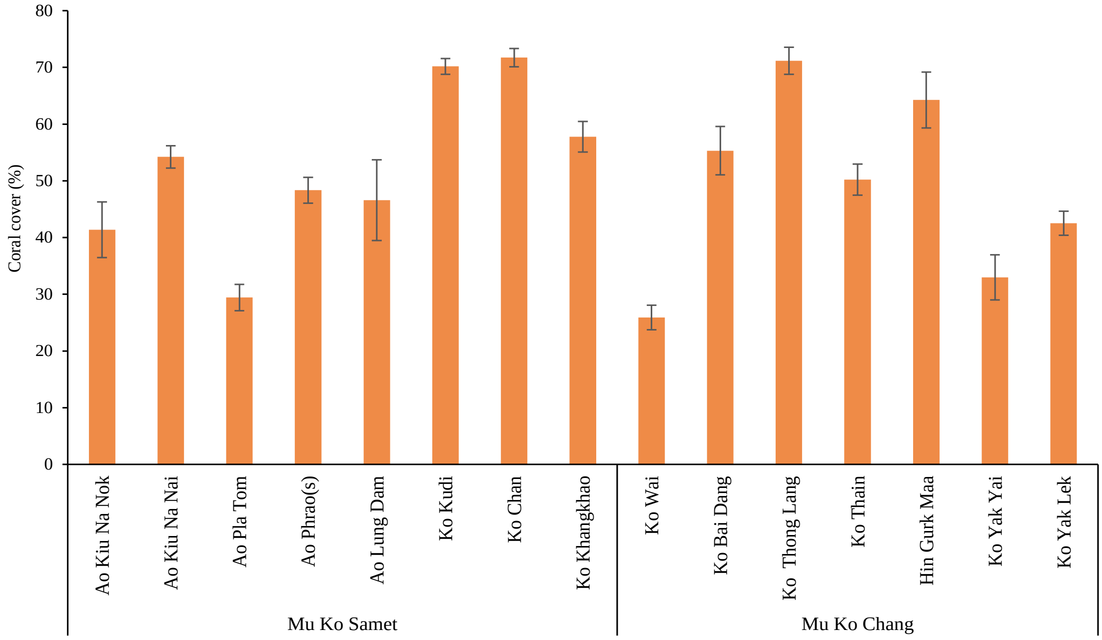

Figure 2. Live coral cover at the study sites (mean ± SD)

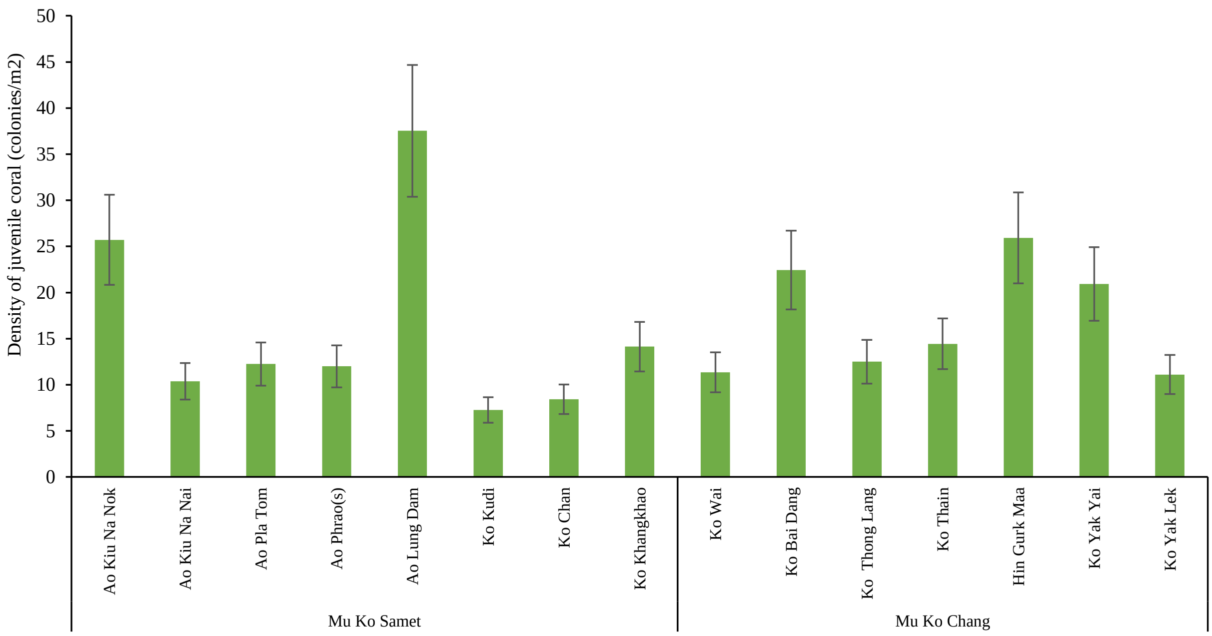

Figure 3. Densities of juvenile corals (mean ± SD) on an available substrate at the study site

Table 1. Results of one-way ANOVA examining the influence of site on live coral cover and densities of juvenile corals

Source of variation	df	Sum square	Mean square	F value	p
One-way ANOVA test					
Live coral cover					
Sites	14	9229.41	659.24	13.48	.001
Within sites	30	1466.99	48.90		
Total	44	10696.40			
Densities of juvenile corals					
Sites	14	2937.79	209.84	17.33	.001
Within sites	30	363.32	12.11		
Total	44	3301.11			

*Significant difference (p<0.05), df: Degree of freedom

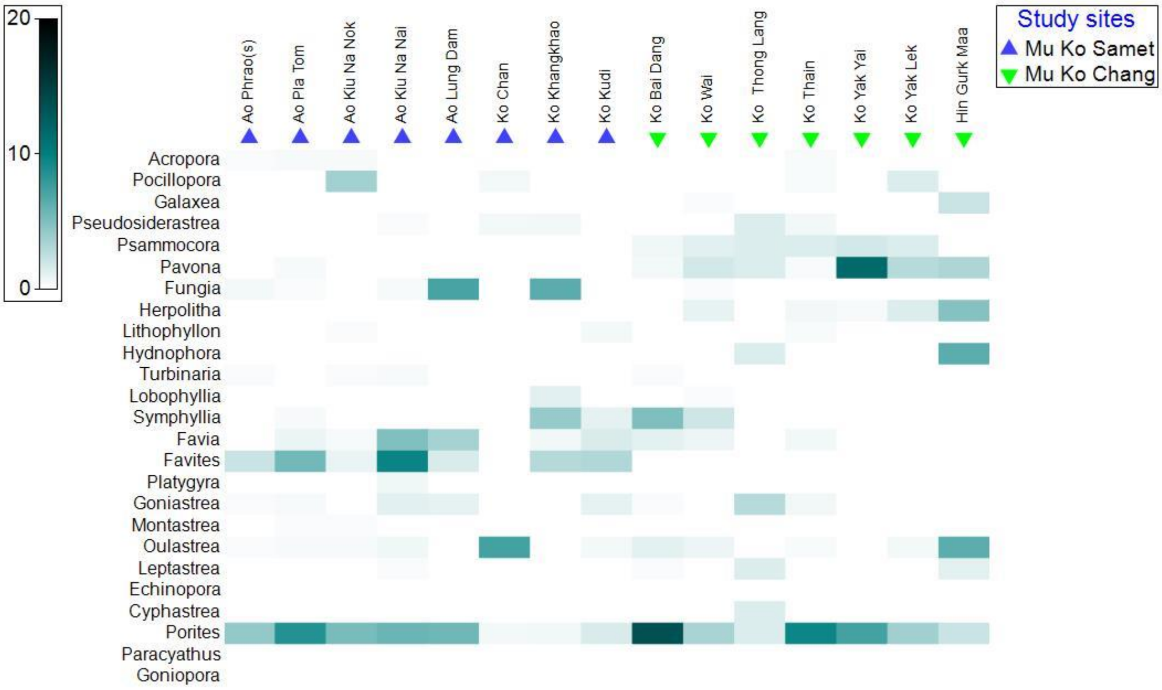

Figure 4. Composition of juvenile corals genera at each study site

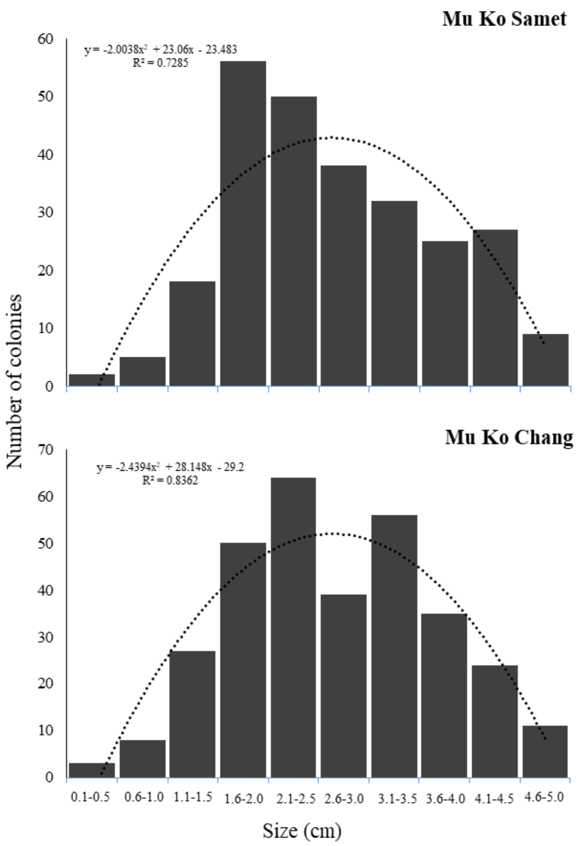

Figure 5. Size-class frequency distribution of juvenile corals on available substrate

Analysis of Similarities (ANOSIM) indicated significant differences in the composition of juvenile corals between Ko Samet and Mu Ko Chang ($R = 0.367$, $p < 0.05$). The average similarity of juvenile corals within the areas varied from 34.92% in Ko Samet to 37.35% in Mu Ko Chang, whereas between Ko Samet and Mu Ko Chang dissimilarities, it was 74.88% (Similarity Percentage (SIMPER) analyses, Table 2).

The first two components of a PCA explained more than 50% of the variation of thre seven dominant species of juvenile corals. The first axis, PC1 was responsible for 33.1 % of the variation with PCA loadings indicating that *Porites* spp. (0.929) is largely responsible for driving direction the differences in the positive. Differences in *Pavona* spp. (0.143), *Symphyllia* spp. (0.105), *Favia* spp. (0.079) and *Favites* spp. (0.077) also contributed to differences in the positive direction, with *Oulastrea* spp. (-0.283) and *Fungia* spp. (-0.112) driving negative differences on the PC1 axis. The second axis, PC2, was responsible for 27.5 % of the variation. PC2 differentiated between the reef sites, with *Favites* spp. (0.581) and *Pavona* spp. (0.-0.662) driving the differences (Figure 6)

Table 2. Similarity percentage (SIMPER) analysis composition of juvenile corals at the study sites

SIMPER	Contribution %
Mu Ko Samet and Mu Ko Chang	
Porites spp.	18.28
Favites spp.	12.98
Pavona spp.	12.74
Oulastrea spp.	7.97
Fungia spp.	7.28
Symphyllia spp.	5.82
Favia spp.	5.44

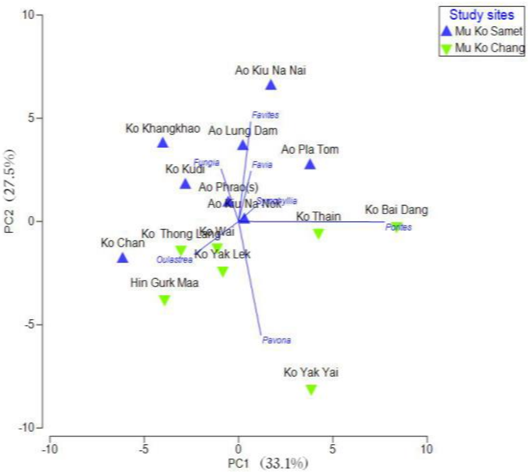

Figure 6. Principal components analysis (PCA) of relative abundance of six genera of juvenile corals across 2 study sites in the Eastern Gulf of Thailand, showing both scores and vector loadings.

4. Discussion

The coral reefs in the Gulf of Thailand have experienced severe coral bleaching events during the last two decades. Moreover, the coral reefs are degraded by the impacts of coastal development, sedimentation, destructive fishing, and the expansion of tourism on coral reefs. (Sutthacheep et al., 2013; Yeemin et al., 2013). The densities of juvenile corals have been proposed as important for understanding its natural recovery potential and to be able to predict the structure and dynamics of the reef (Hughes et al., 2010; Gilmour et al., 2013; Graham et al., 2015). Results exhibited in this study, where the density of juvenile corals at Mu Ko Samet and Mu Ko Chang ranged of 7.27-37.53 juvenile corals /m^2, which is similar to Mu Ko Angthong where 8.22 to 37.38 colonies/m^2 were found in past studies (Putthayakool et al., 2017). In the Andaman Sea, the density of juvenile corals at Similan Islands varied around 0.14-0.66 colonies/ m^2, while Daeng Island showed < 0.5 juvenile corals/ m^2 (Yeemin et al., 2010, Yeemin et al., 2012), which are lower than our results. Moreover, overseas research in the Indo-Pacific showed the density of juvenile corals, ranging from 0.8 to 11 juveniles/m^2 (Hoey et al., 2011; Trapon et al., 2013); on the other hand, the Red Sea displays a much higher density, with 42– 173 juvenile corals/ m^2 recorded (Glassom & Chadwick, 2006)

Dead corals play an important role in the coral larval settlement in the coral community because their surfaces are complex and provide a suitable substrate for community structure (Harriott & Fisk, 1987; Nozawa et al., 2011). Furthermore, several studies showed dead corals, i.e., Acropora tables were attractive to coral larvae (Loch et al., 2004). The frequency and abundance of coral recruitment are affected by the physical and biological features of their environment and habitat (Edmunds et al., 2004; Roth and Knowlton 2009; Vermeij et al., 2009; Bernal-Sotelo & Acosta, 2012). However, these dead corals may not be stable in the long-term. The dead branching or laminar/table corals might be broken by physical factors. The relationship between the density of juvenile corals and substrates type may reflect that having more substrate to settle is a good indicator for connectivity between sites, and the amount of larval supply from neighbor reefs.

The live corals from local reefs are the main sources supplying coral larvae to impacted areas. Both in broadcast-spawning and brooding corals from the interconnected reef, potentially explained the dynamics of larval supply, even those with an obligate planktonic phase (Figueiredo et al., 2013). Recovery of coral populations is often based on a combination of newly settling larval recruits, growth, propagation of surviving corals and arrival of larvae from distant, interconnected reef ecosystems. (Hughes & Tanner, 2000; Doropoulos et al., 2015). The populations exhibiting higher recruitment rates are more likely to show higher potential for recovery and resilience from intense mortality events and recurrent disturbances (Riegl & Purkis, 2009; Muko et al., 2014).

This study provides necessary information regarding coral recruitment and recovery from climate changes driven bleaching events to establish management plans for effective resource utilization in the Eastern Gulf of Thailand. Variation in patterns of larval survival and recruitment will lead to population connectivity within and among reefs. We propose further research on population genetics that may better understand larval supply and recruitment dynamics of corals in the Eastern Gulf of Thailand.

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