Assessing population densities of *Pocillopora acuta* on shallow reef flats in the Western Gulf of Thailand

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Abstract. Shallow reef flats are under extreme conditions with exposed light and high seawater temperature. The scleractinian coral *Pocillopora acuta* is one of the most abundant corals and widely distributes in the Indo-Pacific. The coral *P. acuta* is adapted to environmental changes and can survive under physiologically stressed that make them suitable to use in coral restoration projects. Therefore, this study aimed to assess the population densities of *P. acuta* on shallow reef flats in the Western Gulf of Thailand. The live coral *P. acuta* cover was determined by using permanent-belt transects, and the size of *P. acuta* was recorded. This study was conducted in 2018. The results revealed that the highest abundance of *P. acuta* was found at Ko Sam Sao (West) (12.38±1.53%) and Hat Mae Hadd (12.32±1.53%), which was significantly different from other study sites. In addition, Ko Phangan also showed high abundance of *P. acuta*. Most colonies of *P. acuta* were in a size class 15-30 cm, which are suitable to be breeders or fragmentation for the coral restoration project. This study provides important data of *P. acuta* distribution and abundance that can be applied to coral restoration and conservation in Thailand

Keywords: reef flat, distribution, *Pocillopora acuta*, Gulf of Thailand

1. Introduction

Coral reef ecosystems are global biodiversity hotspts that are the most diverse and productive ecosystems in the oceans. They are essential spawning, nursery, breeding, and feeding grounds for numerous organisms (Hoegh-Guldberg et al., 2007; Pandolfi et al., 2011; Hughes et al., 2017). Coral reef ecosystems are highly affected by changes in seawater carbonate chemistry, including those related to ocean acidification and climate changes (Hoegh-Guldberg et al., 2017). Increased sea surface temperatures and salinity from altered rainfall and increased sea level resulting from weather patterns changes (Mimura, 2013). Corals exposed during daylight hours are subjected to the most ultraviolet radiation, which can overheat and dry out the coral tissues and cause physiological stress. The corals will expel their symbiotic zooxanthellae, which leads to bleaching and subsequent mortality.

Shallow reef flats are in an extreme environment with high temperatures and light intensity that some vulnerable corals cannot survive in these conditions. The scleractinian coral *P. damicornis* is widespread in the Indo-Pacific Ocean, and it is one of the most abundant and widely distributed of species in the world (Pinzón et al., 2013). The coral *P. damicornis* has stronger defenses against bleaching and is better adapted to environmental changes than most other coral species (Carpenter et al., 2008).

However, *P. damicornis* is the only *Pocillopora* species detected along with mainland Japan to date, and is rare in the South China Sea and southern Japan. (Pinzón et al., 2013). The evidence show that most 'damicornis-like' corals in the southwestern South China Sea region are actually *P. acuta* instead of *P. damicornis* (Poquita-Du et al., 2017). This study aimed to assess the distribution and abundance of *P. acuta* on shallow reef flats in, Mu Ko Chumphon, Mu Ko Ang Thong, Ko Samui, Ko Tao, Ko Phangan, and Prachuap

Khiri Khan Province, the Western Gulf of Thailand.

2. Materials and Methods

2.1 Study sites

The study sites are located in the Western Gulf of Thailand including Prachuap Khiri Khan Province, Mu Ko Chumphon (Chumphon Province), Mu Ko Ang Thong, Ko Samui, Ko Tao and Ko Phangan (Surat Thani Province) (Table 1 and Figure 1). The coral communities on shallow reef flats were about 0.5-2 m in depth.

2.2 Data collection

At each station, a total of the study area 90 m^2, 3 replicates of a 30×1 m within permanent belt transect at shallow reef flat (0.5-2 m in depth) were investigated. The transects were laid parallel to the shoreline (English et al., 1997). Live coral cover and colony sizes of *P. acuta* were recorded. Photographs were also taken by using a digital camera (Olympus TG-5). This study was conducted during March to December 2018.

Table 1. Location of study sites in the Gulf of Thailand

Location	Sites	Latitude	Longitude
Prachuap Khiri Khan	Ko Chan (East)	11°37'14.82"	99°46'29.53"
	Ko Chan (West)	11°37'20.67"	99°46'22.13"
	Ko Sing	11°03'20.28"	99°31'33.54"
	Ko Sang	11°01'58.36"	99°31'00.61"
Mu Ko Chumphon	Ko Kula	10°15'35.87"	99°15'20.99"
	Ko Mattra	10°24'06.96"	99°21'05.22"
	Ko Lawa	10°21'43.71"	99°18'28.39"
	Ko Rang Kachiu	10°19'30.31"	99°17'56.81"
Ko Tao	Ao Leuk	10°04'12.72"	99°50'27.28"
	Hin Wong	10°06'13.49"	99°50'52.47"
	Hat Sairee	10°07'23.34"	99°50'09.59"
	Ao Muang	10°06'01.69"	99°49'32.95"
Ko Samui	Ko Ra Hin	09°34'30.25"	100°00'40.27"
	Ko Taen	09°22'02.43"	99°55'55.82"
	Ao Thong Ta Noad	09°24'48.59"	99°58'26.65"
Mu Ko Ang Thong	Ko Samsao (North)	09°39'16.39"	99°40'54.85"
	Ko Samsao (West)	09°39'55.32"	99°40'48.46"
	Ko Wua Kantang	09°40'21.49"	99°40'47.59"
	Ko Hindap	09°40'48.39"	99°41'06.46"
	Ko Thaiphlao	09°42'22.43"	99°40'33.24"
Ko Phangan	Ko Kong Than Sadet	09°45'56.49"	100°04'28.09"
	Hat Chalok Lum	09°47'34.11"	100°00'36.55"
	Hat Thong Lang	09°48'00.58"	99°59'18.34"
	Hat Mae Haad	09°47'50.95"	99°58'43.19"
	Hat Khom	09°47'55.26"	100°00'52.10"

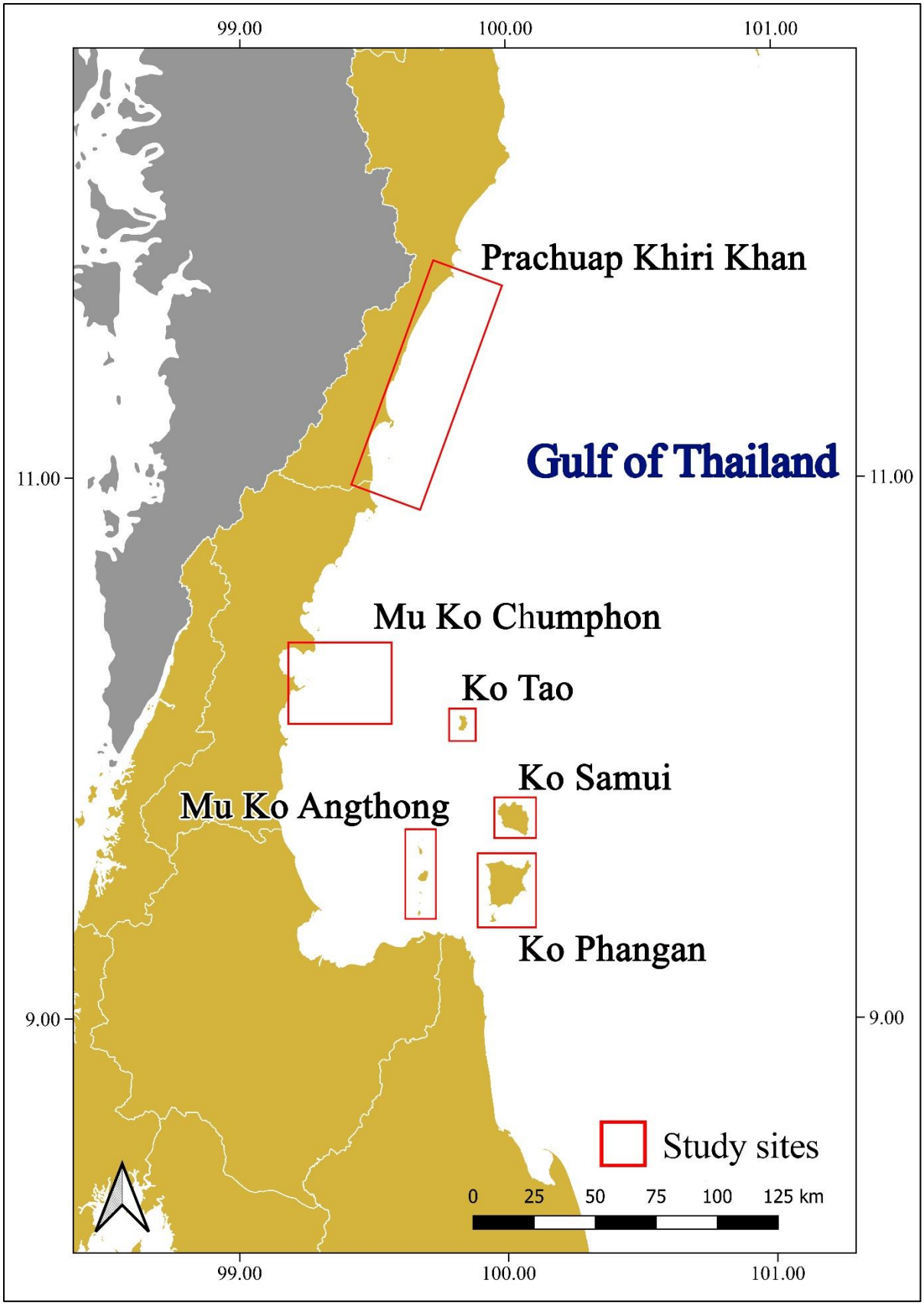

Figure 1. The study sites in the Western Gulf of Thailand

2.3 Statistical analysis

A one-way ANOVA was used to perform the differences in the coverage of live coral *P. acuta* among study sites under R program version 3.5.2. with package "Vegan". Where significant differences were found, the Tukey HSD test was employed to determine which reef sites differed.

3. Results

The corals *P. acuta* were found at the 25 study sites. The live coral cover of *P. acuta* was significantly different among the study sites (one-way ANOVA $p<0.001$, Table 2.). The highest live coral cover of *P. acuta* was found at the West of Ko Samsao (12.38 ± 1.53%) and Hat Mae Hadd (12.32±1.53%) and was significantly different from other study sites, whereas the lowest one was found at Ko Wua Kantang (0.09±0.01%) as shown in Figure 3.

There were four size classes of *P. acuta* found in the Gulf of Thailand i.e., < 15 cm, 15-30 cm, 31- 45, and >45 cm. Most colonies of *P. acuta* were in a size class 15-30 cm. The high percentage of small colonies (<15 cm) of *P. acuta* was only found at Ko Tao. On the other hand, high proportion (36%) of the large colonies (> 30 cm) was observed at Mu Ko Chumphon. (Figure 4).

Figure 2. Underwater photographs of *P. acuta* at Ko Rang Kachiu in Mu Ko Chumphon

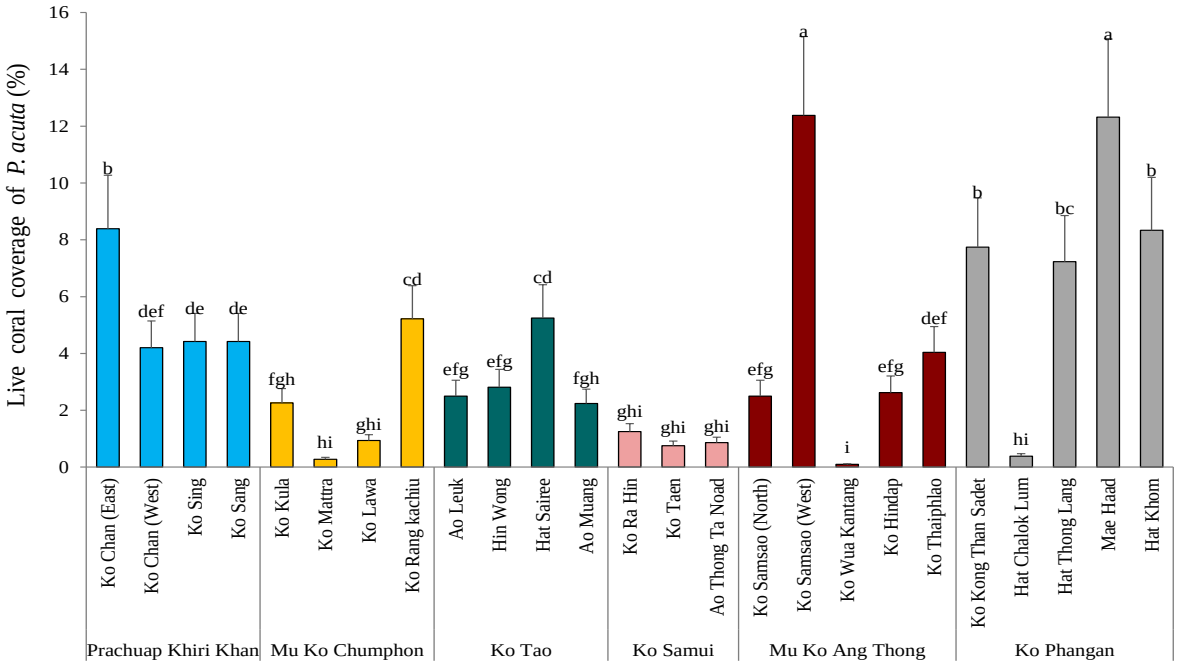

Figure 3. Live *P. acuta* cover at the study sites

Table 2. Results of one-way ANOVA and the Tukey HSD test examining the variation of *P. acuta* coverage among study sites

Source of Variance	df	Mean square	F	*p*-value
Between groups	24	33.349	22.874	< 0.001*
Within groups	50	1.458		
Total	74			

* Significant difference ($p < 0.05$)

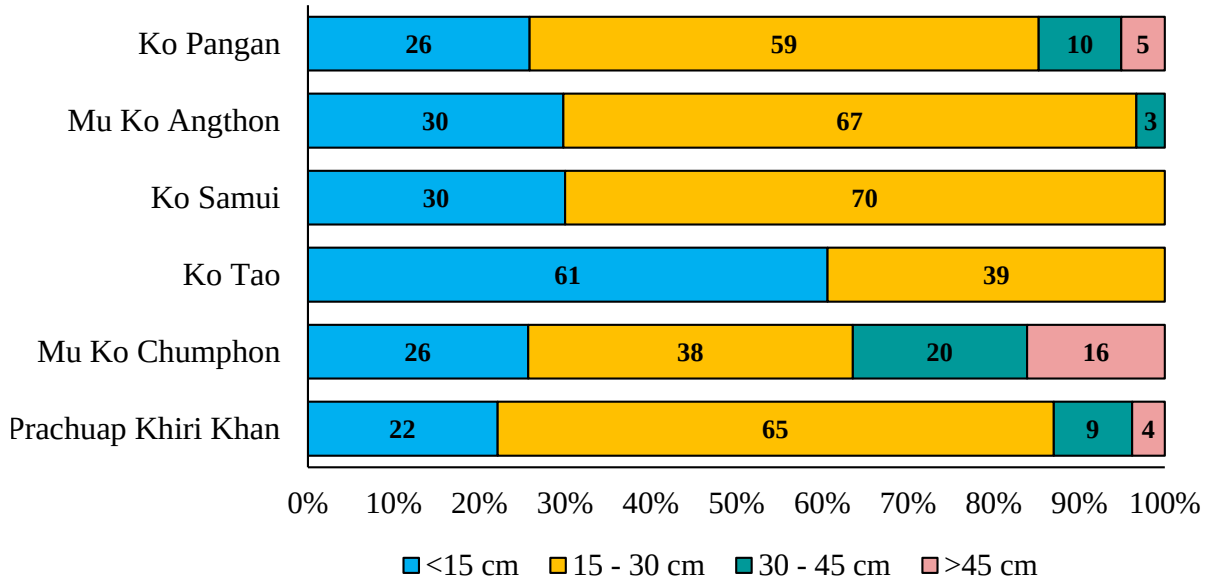

Figure 4. Percentage of size classes of *P. acuta* at the study sites

4. Discussion

This study contributes to the limited data that have emerged from the South China Sea region on the identity of *Pocillopora* species. The recently-revised species *P. acuta* is described to have a wide distribution reaching from the central Pacific to the Indian Ocean (Schmidt-Roach et al., 2014). Our results reveal that the coral *P. acuta* is found in all study sites and have shown the high cover at Ko Chan (West), Ko Samsao (North), Ko Kong Than Sadet, Hat Thong Lang, Hat Mae Haad and Hat Khom. The coral *P. acuta* colonies are commonly found in the shallows (0-4 m) but generally do not exist beyond 6 m depth. They grow in numerous types of habitats including on artificial substrates such as seawalls and pontoons (Toh et al., 2017), and serve as habitat for diverse ectosymbiont communities (Lee & Sin, 2009). This species is hermaphroditic and also has been documented to brood monthly, more or less the new moon periods (Chou & Quek, 1993; Yeoh, 2010; Kerr et al., 2011; Toh et al., 2013).

Size frequency distribution of colonies can provide insights into the recovery process from large-scale disturbance events. However, the correlation of age and size is complicated in fragmenting corals such as *P. acuta*. In addition, asexual reproduction via fragmentation of the coral *P. acuta*, as well as sexual planula larvae leading to populations of both asexual and sexual origin, e.g., in the Philippine Sea, Singapore, and the Okinawa Islands (Poquita et al., 2017; Nakajima et al., 2018). Sexual reproduction in the Eastern Pacific of corals pocilloporids appears via spawning in female and male gametes into the water column where fertilization occurs (Glynn et al., 1991).

In the inner Gulf of Thailand, Pengsakun et al. (2012) monitored 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. However, 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 of *P. damicornis* increased after the bleaching event 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. They also found that low density of adult colonies of *P. damicornis* after the bleaching event can lead to low coral recruitment and recovery.

The coral *P. acuta* are able to settle and grow on natural reefs and artificial substrates (Toh et al., 2017). Consequently, they are widely utilized in reef restoration research projects (Ng et al., 2016). The coral *P. acuta* is critical for achieving species diversity targets in local and regional restoration efforts (Mace, 2004; Wheeler, 2004). Similar to other corals, *Pocillopora* is threatened by habitat loss and climate change. This study provides important data of *P. acuta* distribution and abundance in the Western Gulf of Thailand that can be applied to coral restoration and conservation projects.

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