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The abundance of macroalgae and herbivory in some degraded reefs and coral recovery at Samui Islands

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Abstract. Coral reefs are recognized as essential ecosystems that harbor thousands of species, providing food and livelihoods for people who live near coastal areas in Thailand. Nowadays, coral reefs were degraded by several factors, especially from climate change and local anthropogenic stressors. Samui Islands are a popular tourism destination. Consequently, coastal development is increased in recent years. Macroalgae are considered as a factor limiting the resilience of coral communities by competing with coral for space and light. Therefore, this study aimed to evaluate the macroalgal covers from three degraded reef areas at Samui Islands. This study was conducted in March 2020. The coverage of seaweeds was estimated using random quadrat sampling. Our results showed that a total of 15 species were found in this study. Our results revealed that the highest coverage was found in Tan Island (58.75±10.64%), followed by Tong Tanote Beach and Phangka Beach (45.17±9.87% and 36.60±13.21%, respectively). The brown seaweeds belonging to the family Sargassaceae were the dominant species at all reef sites, include *Sargassum swartzii* (5.23-9.23%), *Turbinaria decurrents* (1.16-19.54%), and *Turbinaria conoides* (8.53-19.12%). These seaweeds are native species in reef ecosystems. Particularly they were abundant species in these areas. However, the overgrowth of macroalgae can be a potential threat to corals that can be outcompeted. Therefore, proper management strategies are necessarily needed for coral mortality prevention, enhancing coral recovery, and maintaining coral reef ecosystems.

Keywords: brown algae, reef degradation, management, diversity

1. Introduction

Coral reefs face the pressures from the cumulative impacts of climate change and local anthropogenic stressors globally that making coral mortality and reef degradation have been documented worldwide (Houk et al., 2014). Coastal and nearshore coral reefs are especially at risk as a result of chronic stressors such as increased sediment and nutrient loads and pollution that have been linked to increasing macroalgal cover and declining coral cover (Browne et al., 2015; Cheal et al., 2010; De'ath & Fabricius, 2010; Thompson et al., 2017). Moreover, some areas may be further complicated by naturally low levels of herbivory (Wismer et al., 2009; Cheal et al., 2012).

In shallow reef habitats, macroalgae are a part of coral reef ecosystems naturally and protect other organisms from sunlight radiation or predators. For example, coral reefs without canopy-forming brown alga Sargassum encountered more bleaching than corals under canopy-forming (Jompa and McCook, 1998; Fulton et al., 2016). Moreover, macroalgae can reduce dissolved CO_2 levels by their photosynthesis and locally relieve ocean acidification (Kang et al., 2016). On the other hand, the proliferation and overgrowth of macroalgae in previously coral-dominated areas are concerned due to their harmful effect, such as reduced production of coral gametes, inhibited larval recruitment, and reduced juvenile coral growth and survival (Cetz-Navarro et al., 2015; Fong et al., 2019; Hughes et al., 2007; Marimuthu et al., 2016; Webster et al., 2015). Given these effects of macroalgae, it is needed to evaluate whether levels of algae are natural due to anthropogenic impacts.

Last decades, Samui Island was recognized as the most popular travel destination in Thailand, which has developed from a backpacker tourist destination to the most upscale tourist destination. Consequently, coral reefs at Samui Islands are facing several problems from tourism development, such as coastal development and boat transportation. Tan Island is near Samui Island that was affected by the effects as well (Pongponrat, 2009; Yeemin et al., 2013). Therefore, this study aims to evaluate the macroalgal composition and abundance of herbivory in degraded reef areas at the Samui Islands.

2. Materials and Methods

2.1 Study sites and *data collection*

The study was conducted on coral communities at Samui Islands in March 2020 by using SCUBA diving. A total of three study sites were located at Phangka Beach (9°25'48" N, 99°55'52" E), Tong Tanote Beach (9°24'56" N, 99°56'18" E), and Tan Island (9°23'06" N, 99°56'48" E) as shown in Figure 1. The coral communities at study sites were approximately 1–4 m in depths. Afterward, the shallow community is attributed to higher turbidity and more impact from coastal development and boat transportation in the proximity (Yeemin et al., 2013). The seaweed coverage at each study site was estimated using a random quadrat (50 cm^2 quadrat) with 30 replicates on degraded reef areas. The macroalgal species were observed in the quadrat, and unknown algal specimens were collected and transported to the laboratory for identification using algal taxonomic identification guides (Coppejans et al., 2010). At the study sites, the 30 meters of transects have lied across coral reef with three replicates (English et al., 1997). The abundance of herbivore reef fishes was recorded and counted in a 2 m wide transect (200 m^2) and identified to species level in situ with the further aid of underwater photographs and guided books for ambiguous taxa (Allen et al., 2015). In addition, the sea urchin censuses comprised the same area (100x1 m) in which all sea urchins were counted as individual/unit areas.

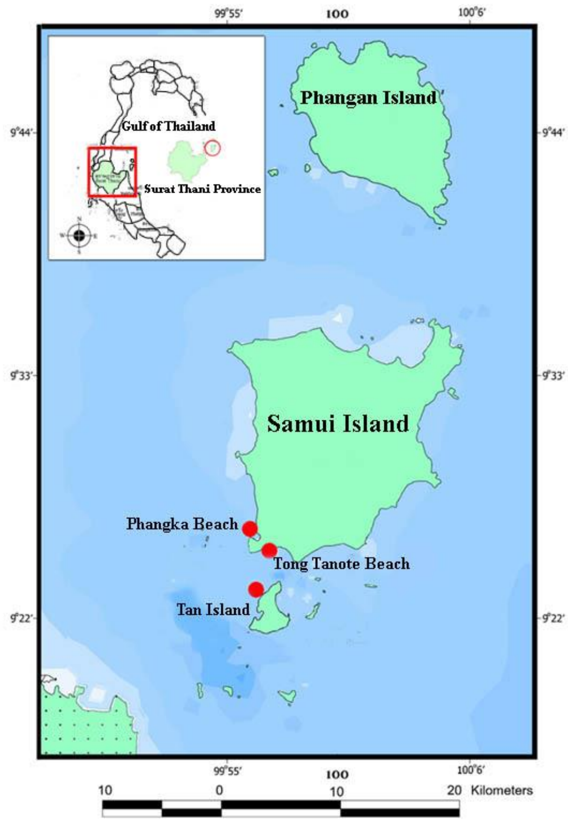

Figure 1. Location of three study sites at Samui Islands

2.2 Statistical analyses

The coverage of macroalgae at each study site was expressed in mean ± standard derivation. Duncan's new multiple range tests were used to perform the difference of macroalgal covers among study sites and the difference of species composition at each study site in R program version 3.6.2.

3. Results

A total of 15 species were recorded in this study, composed of one taxa from division Chlorophyta, nine taxa from class phaeophyceae, and five taxa from division Rhodophyta. All taxa were found at Tong Tanote Beach, while *Rhipidosiphon sp., Carnistrocarpus cervicornis, and Galaxuara* sp. were not found at both Phangka Beach and Tan Island, as shown in Table 1. The results revealed that the highest coverage was found in Tan Island (58.75±10.64%). However, the coverage of seaweeds at Tan Island was not significantly different from the macroalgal covers at Tong Tanote Beach and Phangka Beach

(45.17±9.87% and 36.60±13.21%, respectively) (Figure 2.).

In this study, the red alga *J. adhaerens* and *J. ungulata* were not calculated in species composition because they are epiphytic species on *Turbinaria* spp. The brown alga is belonging to the family sargassaceae, particularly *Turbinaria* spp. exhibited high cover at all study sites (Figure 6). The brown alga *Turbinaria conoides* was showed high coverage at Tong Tanote Beach with a significant difference (p=0.05) (Figure 3). The highest percent coverage of seaweeds was found in Sargassum swartzii (9.23±4.17%) at Phangka Beach but did not significantly different with *Turbinaria conoides*, *Lobophora* spp., Padina sp. and Sargassum sp. (Figure 4). whereas the brown alga *Turbinaria decurrens* exhibited high covers with 19.54±7.89% at Tan Island, followed by the brown alga *T. conoides* (14.53±8.23%) and *Padina australis* (9.58±4.25%), respectively (Figure 5)

Table 1. Diversity of seaweeds among study sites

Type	Species	Tong Tanote Beach	Phangka Beach	Tan Island
Green algae	*Rhipidosiphon* sp.	√		
Brown algae	*Carnistrocarpus cervicornis*	√		
	Dictyota ciliolata	√		√
	Lobophora spp.	√	√	√
	Padina sp.	√	√	
	Padina australis	√		√
	Sargassum swartzii	√	√	√
	Sargassum sp.	√	√	√
	Turbinaria decurrens	√	√	√
	Turbinaria conoides	√	√	√
Red algae	*Amphiroa* sp.	√	√	√
	Ceratodiction spongiosum	√	√	√
	Galaxuara sp.	√		
	Jania adhaerens	√	√	√
	Jania ungulata	√	√	√

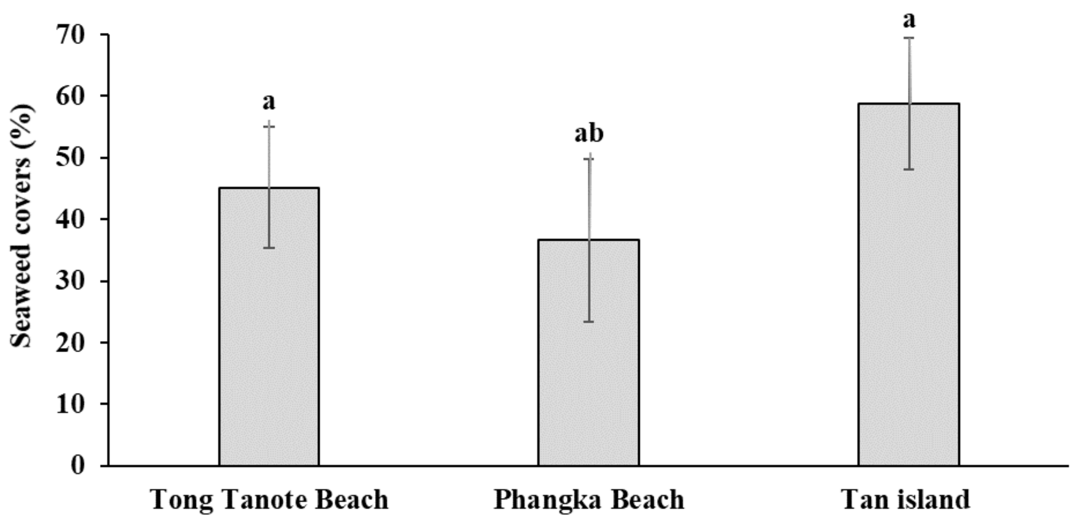

Figure 2. Percentage of algal covers at study sites

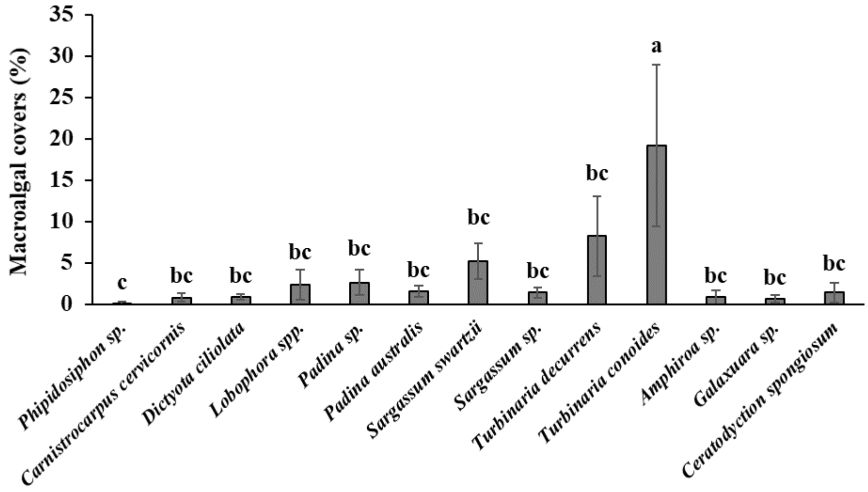

Figure 3. Species composition of seaweeds in coral reefs at Tong Tanote Beach

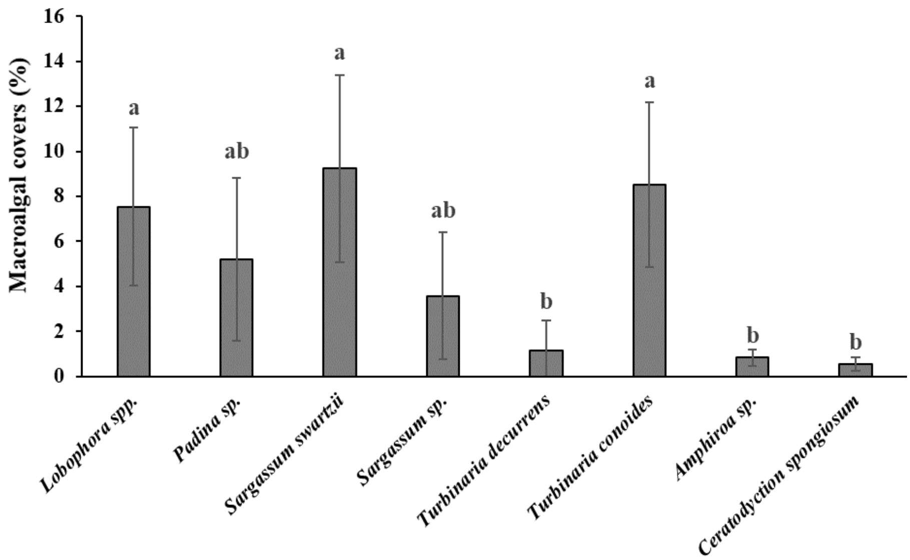

Figure 4. Species composition of seaweeds in coral reefs at Phangka Beach

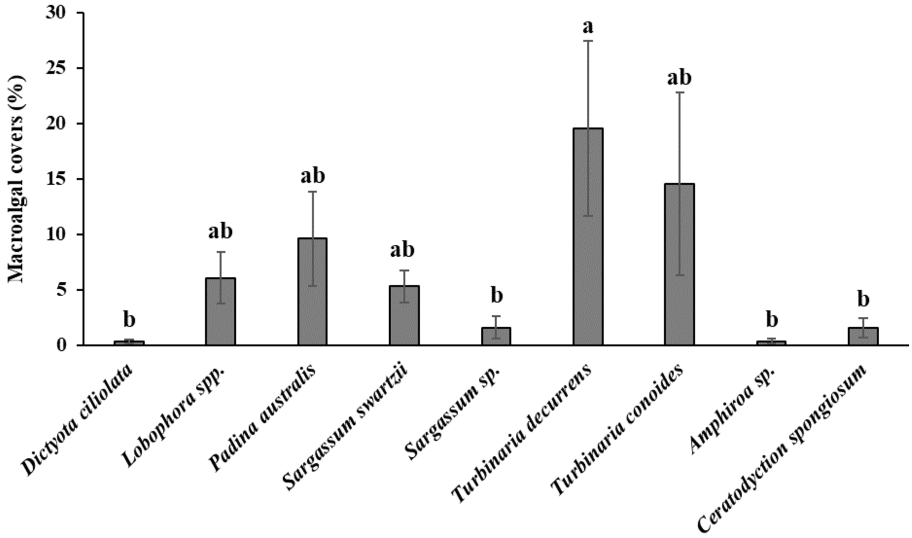

Figure 5. Species composition of seaweeds in coral reefs at Tan Island

Table 2. The abundance of herbivore reef fish and sea urchins among study sites

Species	Abundance of herbivores (individuals/100 m^2)		
	Phangka Beach	**Tong Tanote Beach**	**Tan Island**
Herbivorous fishes			
Scarus ghobban	-	0.18±0.47	-
Scarus rivulatus	-	0.18±0.47	0.92±1.70
Siganus canaliculatus	-	111.11±40.82	-
Siganus guttatus	-	0.18±0.47	-
Siganus javus	-	1.29±1.88	-
Siganus virgatus	-	0.18±0.47	-
Omnivorous fishes			
Abudefduf bengalensis	0.18±0.47	0.37±0.47	-
Abudefduf sexfasciatus	-	-	2.41±4.71
Abudefduf vagiensis	-	4.07±5.55	4.62±4.99
Neoglyphidodon nigroris	-	0.92±1.24	1.29±1.24
Sea urchin			
Diademma setosum	-	-	44.44±3.86

Figure 6. Overgrowth of *Tubinaria* spp. (A) Competing space between macroalgae and corals, (B) macroalgal cover on natural ground at Tan Island

Eleven species of herbivorous and omnivorous animals were found in this study include ten fish species and one sea urchin species (Table 2). All herbivorous fish were found at Tong Tanote Beach, which is the most abundant of *Siganus canaliculatus* (111.11±40.82 individuals/100 m^2) with significantly different from others herbivorous fish areas. In contrast, none of the herbivorous fish was found at Phangka Beach. The sea urchin, *Diademma setosum*, was only found at Tan Island (14.81±3.86 individuals/100 m^2).

4. Discussion

Coral reefs in Thailand support human activities that are divided into three main categories: tourism and recreation, fisheries-related uses, and other uses. There has been a significant change in the pattern of coral reef use as traditional fishing is gradually replaced by tourism activities. (Yeemin et al., 2006). At study sites, the most dominant coral species were dominated by *Pavona frondifera*, *Pachyseris rugosa*, and *Porites lutea* (Yeemin et al., 2009). A total of 60 species of macroalgae were recorded in these areas, comprising 23 species of Chlorophyta, 19 species of Ochrophyta, 16 species of Rhodophyta, and two species of Cyanophyta (Coppejans et al., 2010; Prathep et al., 2011). Among the study site, the brown algal genus *Padina*, *Sargassum*, and *Turbinaria* were commonly found (Titioatchasai et al., 2019).

Macroalgae are an important component of coral reef ecosystems naturally, which their composition and covers vary with latitude and longitude, depth, and water quality (De'ath & Fabricius, 2010). The cover of macroalgae tends to be high on inshore reef flats and low when the increasing distance from the coast and depth. In addition, the macroalgal cover is positively correlated with dissolved nutrients (Fabricius et al., 2005). Furthermore, high sedimentation can combine with macroalgae to cause higher coral mortality and provide conditions supporting macroalgae outcompete corals (Nugues and Roberts, 2003). Samui Islands has a high sedimentation rate and nutrient loads due to the impact of coastal activities and boat transportation (Yeemin et al., 2013). In this study, the high macroalgal cover might have resulted from the cumulative nutrients and sedimentation that cause coral mortality.

Herbivory is an important factor that controls macroalgal dominance over corals. Increasing algal biomass and a phase shift from algal turfs to macroalgae assemblages follow the displacement of herbivorous fishes (Hughes et al., 2007). On the other hand, the recovery of herbivore populations in marine protected areas can decrease the cover of macroalgae and enhanced coral recruitment (Mumby et al., 2007). The most dominant omnivorous fish, *Abudefduf vaigiensis*, *Abudefduf bengalensis*, *Abudefduf sexfasciatus*, and *Neoglyphidodon nigroris* has been recorded at Tan Island (Titioatchasai et al., 2019). Phangka Beach has fish diversity, and abundance lower than other sites due to the coral community in this area is 1–1.5 in depth. Moreover, the abundance of herbivorous fish in this area is quite low. Studies suggest that the abundance of herbivorous fishes is inversely correlated with the water clarity. Consequently, grazing pressure of algal communities in coastal areas can be released by declining water quality (Cheal et al., 2013; Wenger et al., 2015).

Our results suggest that coral recovery is a challenging task. The proper land use management strategies and suitable coastal development are needed to prevent pollution and excess nutrients and sediment from land runoff, including effective fisheries management, to replenish herbivorous fish populations (McClanahan et al., 2009; Wolinski et al., 2009). Some studies suggest that macroalgae removal on coral reefs can increase the abundance of fish species, herbivore bite rates, coral recruitment, and coral settlements (Bulleri et al., 2018; Mumby et al., 2007; McClanahan et al., 2000; 2001). The coral reef degradation areas need prevention and mitigation from multiple causes (Yeemin et al., 2006). Our study provides valuable insights high macroalgal cover in reef degradation areas and further implications for encouraging coral recovery and its resilience in a changing environment.

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