ORIGINAL PAPER

Population densities of a sea urchin *Diadema setosum* on shallow reef flats in the Gulf of Thailand

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Abstract. The sea urchin, *Diadema setosum*, is a dominant invertebrate on coral communities in the Western Gulf of Thailand. The *D. setosum* plays a crucial role in coral communities such as macroalgae controlled. The abundance of *D. setosum* can influence coral reef communities, however the study of *D. setosum* population densities on shallow reef flats is very limited Therefore, this study aimed to investigate the abundance of *D. setosum* in the Western Gulf of Thailand. A total of 23 study sites in the Western Gulf of Thailand included Mu Ko Angthong, Mu Ko Chumphon, Phangan, Prachuap Khiri Khan coast, Ko Samui, and Ko Tao were investigated during 2017 – 2018. The highest density of *D. setosum* was found at Mu Ko Chumphon (5.97 ± 2.09 ind./m^2) and the lowest one was found at Mu Ko Phangan. Our results showed the most density of *D. setosum* found at Hin Pae, Mu Ko Chumphon that might be resulting from escaping predator fishes. Anthropogenic activities through overfishing and impacts of global warming can influence the population of *D. setosum* as well. The mitigation of sea urchin population changes is needed. Several management strategies have been implemented, such as harvesting of sea urchin, and the implementation of marine protected areas. This study can imply to coastal and coral reef management strategies.

Keywords: anthropogenic, fisheries, sea urchin, shallow reef flats, tourism, Gulf of Thailand

1. Introduction

Coral reef flat can be determined as an extensive shallow water area of the reef (Done, 1983). Most areas are shallow and intertidal coral communities (Scope´litis et al., 2011) and usually the shallowest submerged portion of a coral reef (Bellwood et al., 2018). Various physical and biological factors can affect coral reef flat communities, whereas the shallowest of them can be exposed to air, high temperature, and light intensity during low tides (Hoegh Guldberg and Fine 2004; Done, 2011). The benthic communities in shallow reef flats are often covered by sediment-laden algal turfs (Purcell and Bellwood, 2001).

The sea urchin, *Diadema setosum*, is a general macrobenthos and wildly distribute in the coral community (Lessios et al., 2001), especially in the Gulf of Thailand (Sakai et al., 1986; Tsuchiya et al., 1986; Yeemin et al., 2009). The feeding behavior of sea urchin affects bioerosion in the coral communities (Dumont et al., 2013). They feed on macroalgae that grow on substrates and also endolithic algae that live associated with a coral skeleton (Bak, 1994; Carreiro-Silva and McClanahan, 2001). Their grazing behavior can also determine the biomass, diversity, and productivity of macrophyte communities (Lawrence, 1975; Lawrence and Sammarco, 1982; Harrold and Pearse, 1987). The sea urchins *Diadema* were dominant herbivores in southern Taiwan (Nozawa et al., 2020). The other researchers found high sea urchin densities (6 individuals/m^2) (Ruengsawang and Yeemin 2000; Dumont et al.2013; Qiu et al. 2014). Due to *D. setosum* plays a crucial role in coral communities, the present study aimed to study the population densities of the sea urchin *D. setosum* on shallow reef flats in the Western Gulf of Thailand. Moreover, we considered *D. setosum* with environmental factors (transparency and suspended solids) or anthropogenic activities (fisheries and tourism).

2. Materials and Methods

2.1 Study sites

The abundance of Diadema setosum was undertaken across many coral communities in the Western Gulf of Thailand during 2017-2018. Twenty-three study sites from six reef groups (Mu Ko Angthong, Mu Ko Chumphon, Ko Phangan, Prachuap Khiri Khan Province, Ko Samui, and Ko Tao) were investigated, as showed in Figure 1 and Table 1. Each study site was classified into two anthropogenic activities (i.e., tourism or fisheries).

2.2 Diadema setosum densities and environmental factors

The population densities of *D. setosum* were observed with three belt-transects (30x1 m for each) by SCUBA diving on shallow reef flats (English et al., 1997). Environmental factors as transparency and suspended solid were measured. The compression of population densities between tourism and fisheries areas was statistically analyzed. We hypothesize that anthropogenic activities lead to severe coral damage, such as unregulated tourism, reef fisheries, and illegal fishing gears. These factors cause sediment accumulation and the spread of macroalgae, consequently increase the number of sea urchins. One Way ANOVA was used to compare population densities of sea urchins between tourism and fisheries areas.

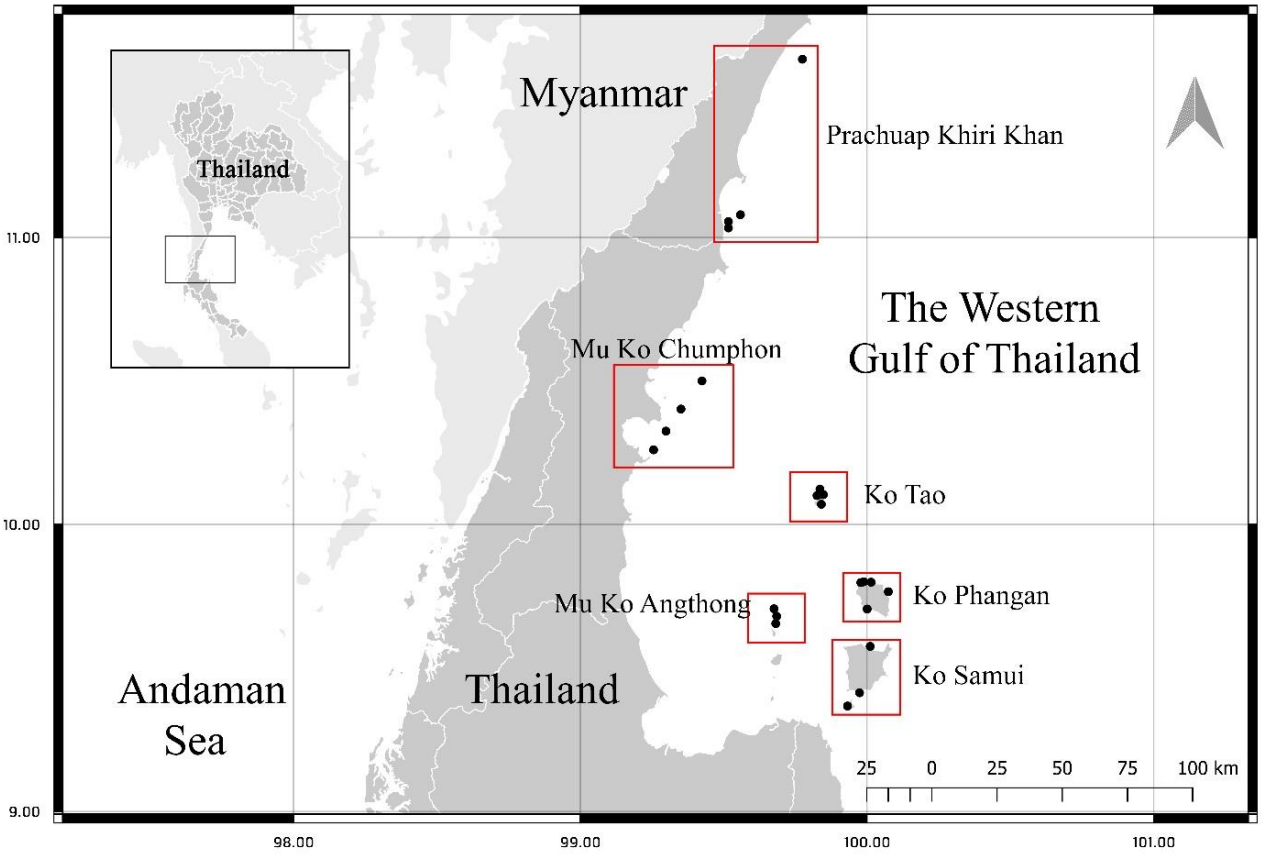


Figure 1.Error! Reference source not found. Location of study sites at Mu Ko Angthong, Mu Ko Chumphon, Ko Phangan, Prachuap Khiri Khan Province, Ko Samui, and Ko Tao in the Western Gulf of Thailand

Table 1 Locations of study sites

Study sites	Latitude (N)	Longitude (E)
Mu Ko Angthong		
Ko Hindub	9° 40' 48.39"	99° 41' 6.46"
Ko Samsao	9° 39' 16.39"	99° 40' 54.85"
Ko Tay-plow	9°42'22.43"	99°40'33.24"
Mu Ko Chumphon		
Ko Matra	10°24' 6.96"	99° 21' 5.22"
Ko Kula	10°15' 35.87"	99° 15' 20.99"
Ko Rangka-jew	10°19'30.31"	99°17'56.81"
Hin Pae	10°29'60.0"	99°25'28.3"
Ko Phangan		
Ko Kong Than-Sadet	9°45'56.49"	100° 4'28.09"
Had Khom	9°47' 55.26"	100° 0' 52.10"
Had Thong lang	9°48' 0.58"	99° 59' 18.34"
Had Maehaad	9°47' 50.95"	99° 58' 43.19"
Ao Tong-Sala	9°42'18.78"	100° 0'2.54"
Prachuap Khiri Khan area		
Ko Sing	11°03'18.32"	99°31'0.61"
Ko Chan	11°37'14.82"	99°46'29.53"
Ao Muk (Ko Talu)	11°04'44.09"	99°33'31.86"
Ko Sang	11°01'58.36"	99°31'0.61"
Ko Samui		
Ko Rahin	9°34'30.25"	100° 0'40.27"
Ao Tong Tanod	9°22'2.43"	99°55'55.82"
Ko Tean	9°24'48.59"	99°58'26.65"
Ko Tao		
Ao Luek	10° 4'12.72"	99°50'27.28"
Ao Muang	10° 6' 1.69"	99° 49' 32.95"
Had Sairee	10° 7' 23.34"	99° 50' 9.59"
Hin Wong	10° 6'13.49"	99°50'52.47"

3. Results

3.1 Population densities of Diadema setosum

The densities of *D. setosum* in each study site were showed in Figure 2. *D. setosum* were found at all study sites of Mu Ko Angthong, Mu Ko Chumphon, and Prachuap Khiri Khan, and was found at some study sites in Ko Phangan, Ko Samui, and Ko Tao. The highest density of *D. setosum* was found at Hin Pae, Mu Ko Chumphon (5.97 ± 2.09 ind./m^2), while no sea urchins were observed in coral communities of Ko Phangan (Hat Khom, Hat Thong lang, and Hat Maehaad), Ko Samui (Ko Ra Hin), and Ko Tao (Ao Leuk, and Ao Muang).

3.2 Environmental factors and anthropogenic activities

Environmental factors, i.e., transparency and suspended solids and anthropogenic activities, are showed in Table 2. The anthropogenic activities in this study are classified into two types (fisheries and tourism). The highest transparency of seawater was observed at Ao Leuk (2.8 m), the site with tourism activities. The low transparency figures were detected at Ko Sing, Ao Muk, and Ko Sang (0.8 m), the areas with fisheries activities.

The high suspended solids were detected at the study sites in Prachuap Khiri Khan Province with much different among study sites. The highest suspended solids were observed at Ko Sing (25.73 mg/L), followed by Ko Sang (22.65 mg/L) and Ko Chan (20.16 mg/L). The study sites in Prachuap Khiri Khan Province were affected by fisheries activities. On the other hand, the lowest suspended solids were observed at the study sites in Ko Tao, with tourism activities.

The results of anthropogenic activities have shown in Figure 3. Densities of *D. setosum* in fisheries areas were significantly higher than in tourism areas (p = 0.022). In terms of the suspended solids, the fisheries areas were significantly higher than the tourism areas (p<0.001). The transparency in tourism areas showed higher than in fisheries areas but not showed a significantly difference.

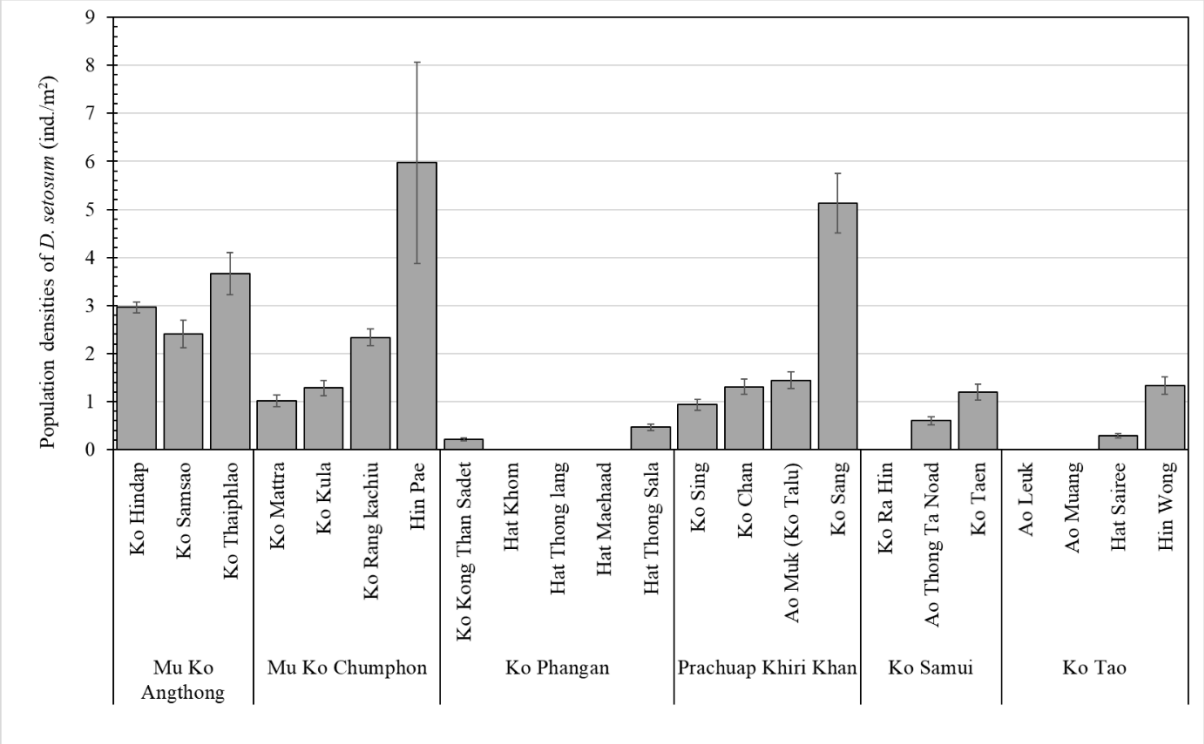


Figure 2. Population densities of *D. setosum* at the study sites

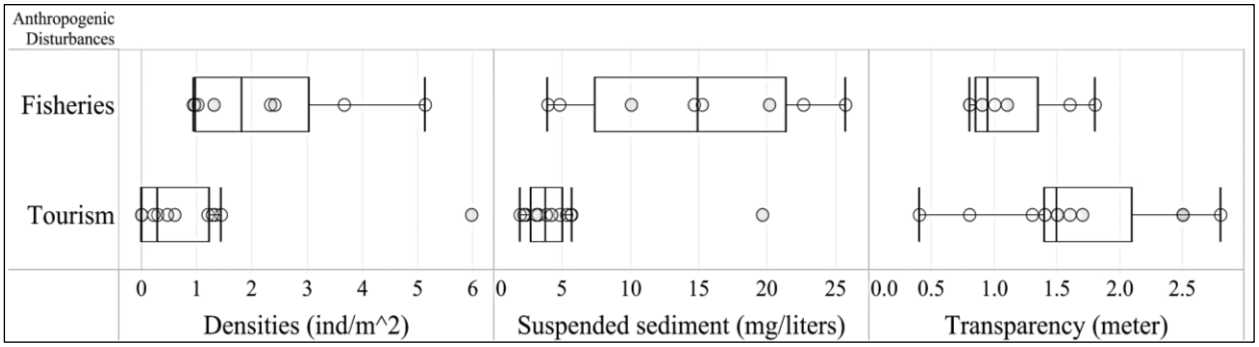
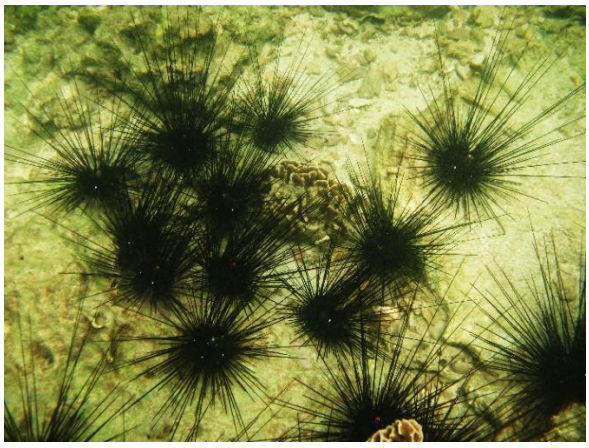


Figure 3 *Diadema setosum* densities, suspended solids, and transparency on the anthropogenic activities area in the Western Gulf of Thailand

Table 2 Environmental factors and anthropogenic activities at each study site

Study sites	Transparency (meters)	Suspended solids (mg/L)	Anthropogenic activities
Mu Ko Angthong			
Ko Hindap	1.0	14.65	Tourism *
Ko Samsao	1.1	10.05	Tourism *
Ko Thaiphlao	0.9	15.24	Tourism *
Mu Ko Chumphon			
Ko Mattra	1.6	4.80	Fisheries
Ko Kula	1.5	5.30	Tourism
Ko Rang kachiu	1.8	3.94	Fisheries
Hin Pae	0.4	4.21	Tourism
Ko Phangan			
Ko Kong Than Sadet	1.3	3.08	Tourism
Hat Khom	1.4	5.68	Tourism
Hat Thong lang	1.5	3.82	Tourism
Hat Maehaad	1.6	3.24	Tourism
Hat Thong Sala	1.4	3.11	Tourism
Prachuap Khiri Khan			
Ko Sing	0.8	25.73	Fisheries
Ko Chan	0.9	20.16	Fisheries
Ao Muk (Ko Talu)	0.8	19.65	Tourism
Ko Sang	0.8	22.65	Fisheries
Ko Samui			
Ko Ra Hin	1.4	4.20	Tourism
Ao Thong Ta Noad	1.5	4.80	Tourism
Ko Taen	1.7	5.60	Tourism
Ko Tao			
Ao Leuk	2.8	1.90	Tourism
Ao Muang	2.5	2.16	Tourism
Hat Sairee	2.5	2.34	Tourism
Hin Wong	2.5	2.24	Tourism

* = Marine protected areas



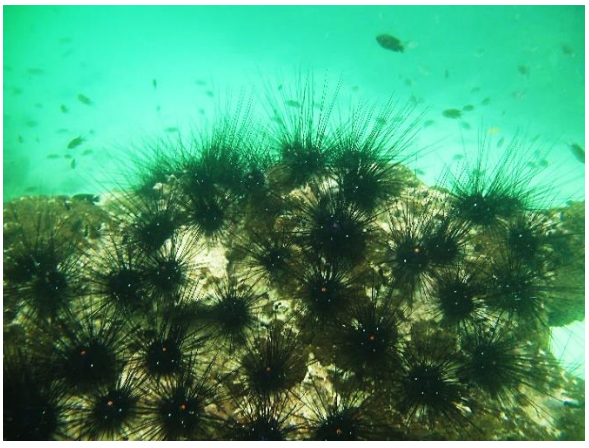


Figure 4 Abundance of *D. setosum* at the study sites

4. Discussion

This study investigated the population density of the sea urchin *Diadema setosum* on the coral reef in the Gulf of Thailand. The result showed the most density of *D. setosum* showed at Hin Pae, Mu Ko Chumphon. Sea urchins were blooming cause escaping from predator fishes (e.g., Wolffish, Norwegian coastal cod, Haddock), and Sea otter (Estes et al. 1998; Jack son et al. 2001; Steneck et al. 2004), including snail (*Cassis* sp.) (Hall et al., 2017). However, *D. setosum* density dramatically decreases at Khang Khao Island, inner Gulf of Thailand, from 16.0±1.0 ind./m^2 (in 2010) to 5.2±1.4 ind./m^2 (in 2011) cause disturbances of the freshwater runoff from heavy flooding in 2011 (Sangmanee et al., 2012).

Reduced larval supply and subsequent low recruitment success of a sea urchin can decrease its population density. The hydrodynamic conditions, particularly wave height, wave velocity, currents, and suspended particles in the water column, influence larval transport and the settlement of *Diadema antillarum* to a western Caribbean coral reef (Maldonado-Sánchez et al. 2019).

Anthropogenic activities through overfishing or impacts of global warming decrease marine ecosystem resilience and increase the catastrophic ecosystem shifts, resulting in high population density of sea urchin. Mitigation of the effects of sea urchin population changes is needed. Therefore, several management strategies have been implemented, such as sea urchin reduction, harvesting of sea urchin, and the implementation of marine protected areas. In contrast, some coral reefs have a low population density of sea urchins, such as Caribbean coral reefs affected by sea urchin mass mortality. Reintroduction of juvenile sea urchins was carried out. The impact of global warming is an urgent issue that needs management actions at the global scale to control the population density of sea urchins (Hernández, 2017). Our research provides a baseline data of sea urchins that could imply coral reef management strategies.

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