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Impacts of natural disturbances on the population dynamics of the sea urchin *Diadema setosum* at Khang Khao Island, the Upper Gulf of Thailand

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Abstract. The sea urchin, *Diadema setosum*, is a dominant species commonly found in coral communities in the Upper Gulf of Thailand. It plays a major role in the bioerosion of coral reefs by feeding on epilithic algae, enabling coral settlement and growth. This research aims to study the population dynamics of the sea urchin *D. setosum* and the change of bioerosion rates at Khang Khao Island, Chonburi Province. Field surveys were conducted during 1998 - 2016 using the belt transect method (50m x 1m). The results revealed that population densities *of D. setosum* varied among years (One-way ANOVA, $p<0.05$). The highest density was found in 2009 (11.34 ind./m^2), while the lowest density was detected in 2011 (4.02 ind./m^2) because of the impact of strong freshwater runoffs, followed by a recovery in 2012. The average bioerosion rates observed in 1998 (1.05±0.33kg $CaCO_3/m^2$/year) were significantly lower than that observed in 2016 (2.55±1.07kg $CaCO_3/m^2$/year) (t-test, $p<0.01$), reflecting that the higher bioerosion rate is related to an increased sea urchin's population, as well as body size. This study provides baseline data on the population dynamics of *D. setosum* in relation to reef bioerosion as a proxy for the management of coral reef ecosystems.

Keywords: Population dynamics, *Diadema setosum*, Khang Khao Island, Bioerosion

1. Introduction

Coral reef communities hold the largest marine biodiversity on earth, especially in the Indo-west Pacific region (Coppard and Campbell, 2007). Coral reef ecosystems are increasingly being threatened by a variety of human originated impacts such as global warming, over fishing, pollution, and tourist development (Heron et al., 2017). Among these threats, the degradation of coral reef is widely reported, for example, in Papua New Guinea (Jones et al., 2004), Indonesia (Edinger et al., 1998), Great Barrier Reef (Ortiz et al., 2018), Caribbean, and Western Atlantic (Lirman and Schopmeyer, 2016). Sea urchins and some fish are grazing animals known to play an important role in coral reef ecosystems, especially affecting the changes of distribution, relative abundance, and species composition of marine algae (McClanahan et al., 1994; O'Leary et al., 2013). Moreover, sea urchin grazing activities also enhance coral settlement, growth, and re-colonization, eliminating competition with other organisms (Pearson, 1981; Lirman, 2001; McClanahan et al., 2002).

The long-spined sea urchin, *Diadema setosum*, is a dominant marine invertebrate easily found in coral reef communities in the Upper Gulf of Thailand (Sakai et al., 1986; Tsuchiya et al., 1986; Yeemin et al., 2009). The species lives on hard substrates and feeds on algae living in coral, dead or live sessile invertebrates, etc., resulting in bioerosion of coral reefs (Glynn, 1979; Ruengsawang and Yeemin, 2000; Dumont et al., 2013; Glynn and Manzello, 2015). Therefore, this research aims to study the population dynamics of the sea urchin *D. setosum* and the change of bioerosion rates at Khang Khao Island, Chonburi Province, Thailand.

2. Materials and Methods

2.1 Study site and data collection

Three different study sites were selected around Khang Khao Island, (latitude 13°06′24″N to 13°07′00″N and longitude 100°08′45″E to 100°49′00″E), where coral communities in shallow water areas, with a depth of 4-6 m, can be found. Field surveys were conducted in 1998, 2009-2012, and 2016. The density of sea urchin was recorded along a 50 m long and 1 m wide belt-transect. The sea urchin samples were preserved in 10% buffered formalin with seawater and transferred to the laboratory. The diameter without spines of all sea urchin samples was measured, with vernier calipers to the nearest millimeters.

2.2 *Estimating the rates of bioerosion*

As described by Conand et al. (1997), to estimate the $CaCO_3$ contents in *D. setosum* specimens were first dissected to evaluate the quantity of $CaCO_3$ for calculating the bioerosion rates. Next, the guts and its contents were ashed at 550 °C for 5 hours in a muffle furnace to destroy the organic matter. As the refractory complex organic compounds are not destroyed, $CaCO_3$ was then determined by HCl digestion of samples followed by titration of the remaining HCl by sodium hydroxide.

2.3 Data analysis

The normality and homogeneity of variances of the data were tested before examining the influence of time using one-way ANOVA. Tukey HSD test was applied to test significant differences between groups in R Program version 3.3.2 with package "vegan'. Two Sample t-test in R program was used to perform population density, body size, and total bioerosion rates analysis.

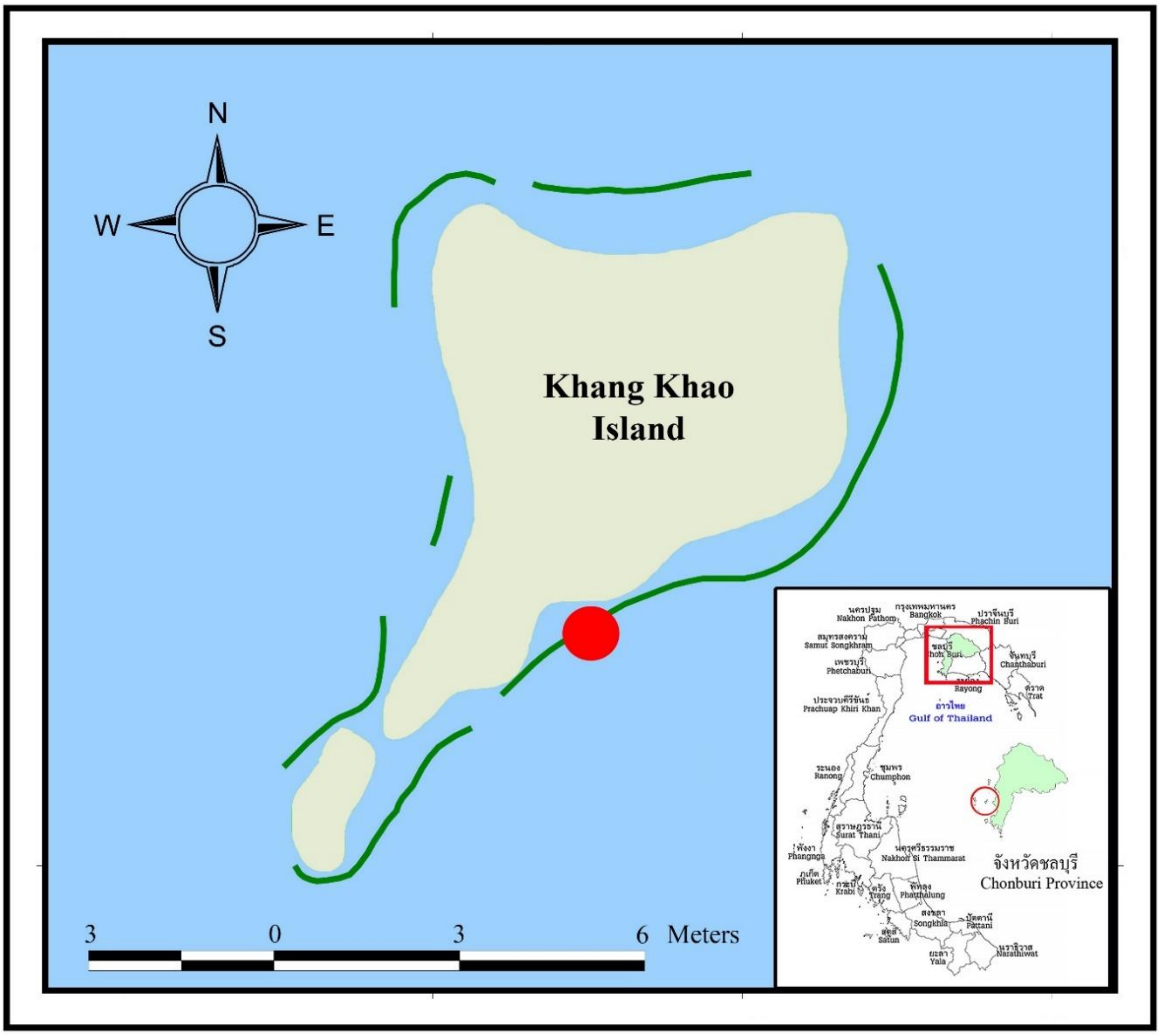

Figure 1. Location of Khang Khao Island, Chonburi Province, Thailand

3. Results

The population density of *D. setosum* at Khang Khao island varied among years (One-way ANOVA, $p < 0.05$). The highest density was found in 2009 (11.35±1.36 ind./m^2), while the lowest density was detected in 2011 (4.02±0.55 ind./m^2).

The density of *D. setosum* in 2016 was higher than in 1998 but did not differ significantly ($p > 0.05$). The body size of *D. setosum* in 1998 was significantly smaller than in 2016 ($p<0.01$). Moreover, the average bioerosion rates observed in 1998 (1.05±0.33 kg $CaCO_3/m^2$) was significantly lower than that observed in 2016 (2.55±1.07 kg $CaCO_3/m^2$) (Table 2)

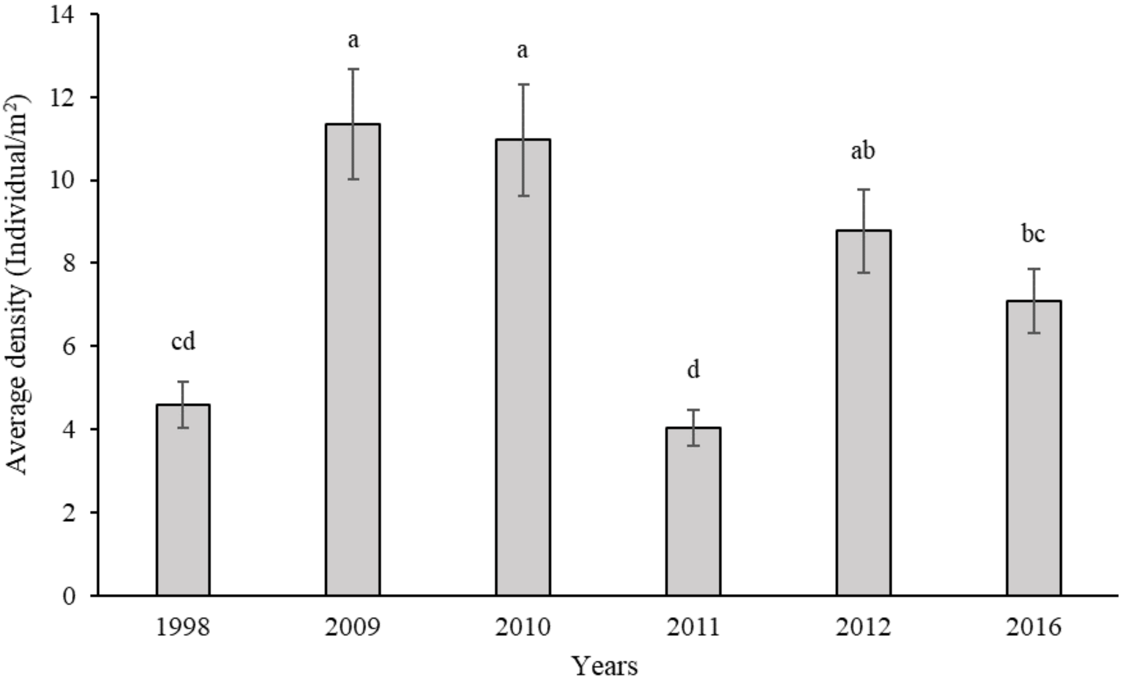

Figure 2. The average density of *D. setosum* at Khang Khao Island during in 1998-2016

Table 1. One-way ANOVA summary of *D. setosum* population density

Source of variation	Df	Sum square	Mean square	F value	Pr(>F)
One-way ANOVA test					
times	5	145.983	29.1965	29.496	0.000***
Within times	12	11.878	0.9899		

Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1, df: Degree of freedom

Table 2. Density and body size of *D. setosum* and their bioerosion rates

D. setosum	Years		Two Sample t-test (p-value)
	1998	2016	
Body size (cm)	4.00±0.31	5.19±0.62	0.001
Total bioerosion rates (kg $CaCO_3/m^2$/year)	1.05±0.33	2.55±1.07	0.000

Value is express as mean ± standard deviation: Population density and bioerosion rates (n=9), body size (n=30)

4. Discussion

The increase in population density of *D. setosum*, almost three times from 1998 to 2009, is a possible result of warmer temperatures (Bronstein et al., 2016). Previous reports suggest that during outbreaks, the species can reach up to 30-150 ind./m^2, resulting in high bioerosion rates (Carreiro-Silva and McClanahan, 2001). The salinity in the upper Gulf varies widely between dry and wet seasons (which extends from July to December), in 2011 local salinity decreased to10.10±0.79 psu versus an average of 31-33 psu in normal circumstances. This could explain why the density of *D. setosum* in dramatically decreased from 2010 to 2011 (4.03±0.48 ind./m^2) while recovering again the following year (8.77±1.05 ind./m^2). The spatial distribution of *D. setosum* depends on several factors such as currents, depth, exposure, and sediments (Graham and Nash, 2013; Dumas et al., 2007). Thus, the declining population of *D. setosum* in 2016 might be their migration to the deeper sandy bottom (Sangmanee et al., 2012). However, further investigation of a declining population of *D. setosum* is needed to find out the real reason.

Reef degradation o through bioerosion is often associated with several reasons, such as high sea urchin abundance (Bak, 1990) or direct coral predation (Glynn et al., 1979; Peyrot-Clausade et al., 2000) . Bioerosion rates attributed to *D. setosum* can reach up to 3.90 ± 0.15 kg $CaCO_3$/m^2/ year (Bronstein and Loya, 2014), even at lower population densities (5.72 ± 0.87 ind./m^2) and body sizes (47.52 ± 1.15 mm) when compared to our study. However, the dimension of echinoid grazing, and consequently the bioerosion and herbivory rates, are determined by three variables: echinoid species, body size, and population densities (Bak, 1994). It also depends on coral reefs complexity and their habitat (Bronstein and Loya, 2014). The sea urchin changing and their bioerosion rates of this study indicate any crucial information.

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