Population density of crown of thorns starfish in dive sites of Thailand

M. Thummasan, T. Yeemin, W. Samsuvan, K. Sangmanee, J. Putthayakool, M. Sutthacheep, P. Yeemin

Abstract The crown-of-thorns starfish *Acanthaster planci* is one of the major threats of coral reef degradation worldwide, especially in the Indo-Pacific region. Economic benefits from marine tourism are at risk due to damage caused by the coral-feeding starfish. This study aimed to investigate distribution and abundance of *A. planci* at 67 dive sites in the Gulf of Thailand and the Andaman Sea during 2013 – 2015. The surveys illustrated that the occurrence of *A. planci* in dive sites of Thailand, both in the Gulf of Thailand and the Andaman Sea, was not significantly different. The population densities of *A. planci* from this study, except at Ko Ngam Yai, Mu Ko Chumphon, the Western Gulf of Thailand and Ao Losama, Mu Ko Phi Phi, the Andaman Sea, are still much lower than that causes the outbreaks in other regions. The severe destruction of coral communities in Thailand caused by *A. planci* was not clearly recorded. This study contributes the important background information for establishing the management strategies to prevent the outbreaks of *A. planci* in dive sites of Thailand.

Keywords: *Acanthaster planci*, population density, coral reef, tourism, Thailand

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Introduction

Coral reefs are one of the most valuable ecosystems in tropical oceans. The ecological functions of coral reefs are very crucial for other marine organisms and also provide several important ecosystem services to human, particularly coral reef tourism, which is recognized as an important economic sector for tropical countries (Cesar and van Beukering 2004; Laurans et al. 2013; Dunning 2015). Coral reef ecosystems have been increasingly facing anthropogenic and natural disturbances at different spatial and temporal scales. An economic analysis of coral reefs at Mu Ko Phi Phi in the Andaman Sea of Thailand represents an annual value of THB 8216.4 million (USD 205.41 million) (Seenprachawong 2016). Mortality rates of scleractinian corals are significantly increasing because of the multiple effects of disturbances, such as overfishing, land-based pollution, sedimentation, coastal development, climate changing and biological predation resulting in a widespread degradation of coral reefs (Crabbe and Smith 2005; Hughes et al. 2010). The crown-of-thorns starfish, *Acanthaster planci* is one of the major biological threats of coral reef degradation worldwide, especially in the Indo-Pacific region (Birkeland 1982; Birkeland and Lucas 1990; Pratchett 2010; Lane 2011; Pratchett et al. 2014). Recent outbreaks of *A. planci* have been reported, such as Indonesia (Baird et al. 2013; Plass-Johnson et al. 2015), Papua New Guinea (Pratchett et al. 2009), French Polynesia (Kayal et al. 2012), Australia (Osborne et al. 2011) Maldives (Saponari et al. 2015) an isolated and unpopulated reef atoll in the Chagos Archipelago (Roche et al. 2015). However, information of *A. planci* in Thai waters is relatively limited. The infestation of *A. planci* on coral communities in the Gulf of Thailand was firstly reported in 1973 (Piyakarnchana 1982). The outbreaks of *A. planci* were observed causing severe damages to coral reefs in the Andaman Sea during 1984 – 1986 (Chansang et al. 1986). In economic point of view, the outbreaks of A. planci reduce the aesthetic value of coral reefs, thereby negative impact on economies that depend on this tourism sector including tour boat operations, diving expeditions, eco-tourism etc. could be risky. Consequently, control and eradication programs have been established in several countries to manage *A. planci* impacts for ecological and economic reasons (Birkeland and Lucus 1990). Recently, the surveys on *A. planci* populations from coral communities in Thailand were carried out in 2015 (Thummasan et al. 2015). The study on *A. planci* spawning along the island of Ko Tao, the Gulf of Thailand was also investigated in the mid-September of 2014 (Scott et al. 2015).

Two principal hypotheses that account for starfish outbreaks are predatory removal resulting from over-fishing and terrestrial runoff leading to high nutrient levels and eutrophication of coastal water (Endean 1976; Birkeland 1982; Dulvy et al. 2004; Brodie et al. 2005; Roche et al. 2015). Elevated seawater temperature is experimentally illustrated as a significant co-factor promoting *A. planci* outbreaks (Uthicke et al. 2015). The outbreaks of *A. planci* could potentially cause mortality of corals, reduction of biodiversity and productivity of coral reefs and weakness of reef structure (Kayal et al. 2012). As scientific information and surveys on the distribution and population density of *A. planci* in the Gulf of Thailand and the Andaman Sea is still limited. There is little awareness of *A. planci* impacts on coral reefs in Thai waters. The aim of this study was to investigate the distribution patterns and population densities of *A. planci* at dive sites, snorkeling and scuba, in the Gulf of Thailand and the Andaman Sea for reassessing information on its prevalence to support dive tourism management.

Materials and methods

The surveys of population densities of *A. planci* were conducted on coral communities in 67 reef sites (40 in the Gulf of Thailand and 27 in the Andaman Sea) which are well-known diving sites in Thailand during 2013–2015 (Fig.1, Table 1). Scuba divers, trained researchers, counted the number of *A. planci* at each dive site using random observations and a belt-transect method. The abundant patterns of *A. planci* derived from each dive site were presented. Average abundance data for each site were square-root transformed (x+0.5) and used to construct a Bray–Curtis resemblance matrix illustrating site-to-site similarities. This matrix was then applied through hierarchical clustering and non-metric dimensional scaling (nMDS) method using the PRIMER version 7.0. The One-way ANOVA with Fisher's LSD was also performed to test the effects of diving activities (snorkeling and scuba) on the population densities of *A. planci.*

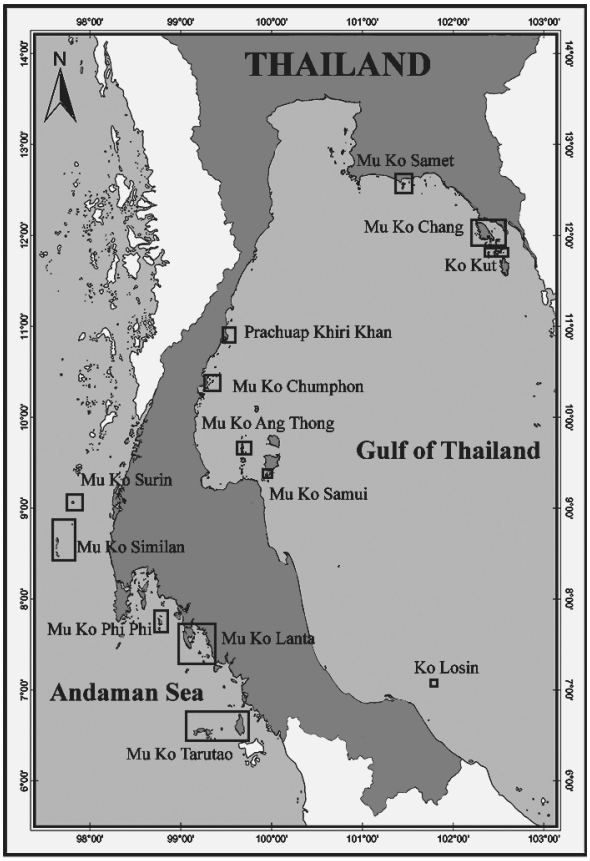

Fig. 1 The map showing dive sites in the Gulf of Thailand and the Andaman Sea

Table 1 The surveyed dive sites in the Gulf of Thailand and the Andaman Sea during 2013 –2015

Island	Location	Number of dive site
Ko Kut	Eastern Gulf of Thailand	3
Mu Ko Chang	Eastern Gulf of Thailand	8
Mu Ko Samet	Eastern Gulf of Thailand	10
Prachuap Khiri Khan	Western Gulf of Thailand	5
Mu Ko Chumphon	Western Gulf of Thailand	6
Mu Ko Ang Thong	Western Gulf of Thailand	3
Mu Ko Samui	Western Gulf of Thailand	1
Ko Losin	Western Gulf of Thailand	4
Mu Ko Surin	Northern Andaman Sea	7
Mu Ko Similan	Northern Andaman Sea	11
Mu Ko Phi Phi	Southern Andaman Sea	3
Mu Ko Lanta	Southern Andaman Sea	4
Mu Ko Tarutao	Southern Andaman Sea	2
Total		67

Results

The surveys showed that two different morphs of *A. planci* were found on some coral communities in the Gulf of Thailand and the Andaman Sea. The pale green color *A. planci* was mostly found in the Gulf of Thailand, while the one with brilliant purple was found in the Andaman Sea (Fig. 2). Generally, the occurrence of *A. planci* in the Gulf of Thailand and the Andaman Sea was not different. The pattern of differences among the dive sites is more clearly illustrated by the dendrogram and nMDS ordination plot shown in

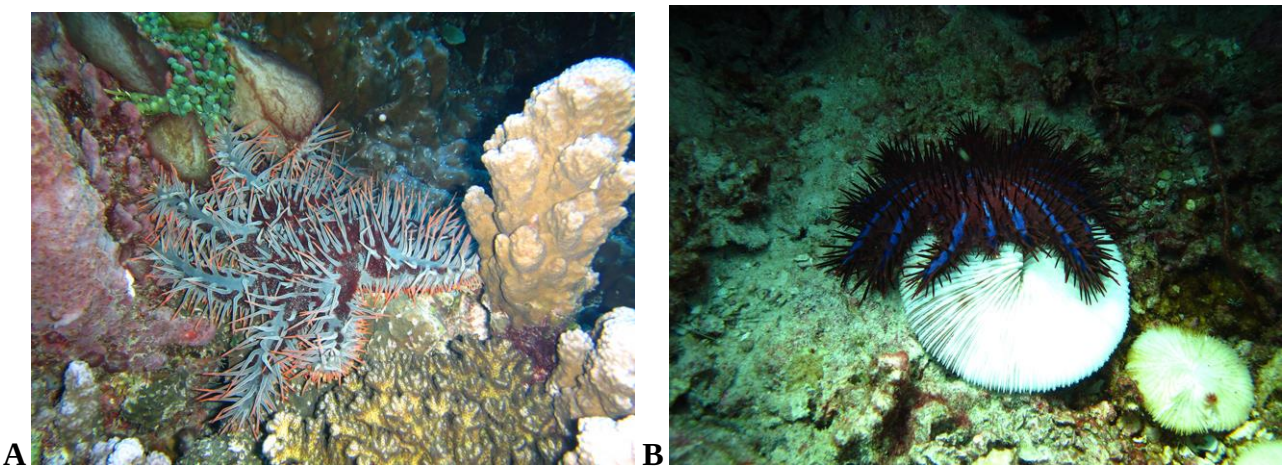

Fig. 2 Dominant morphs of *A. planci* found in the A) Gulf of Thailand and the B) Andaman Sea

Figs. 3, 4 which is derived from the group averages. The occurrence of *A. planci* could be categorized into three groups: abundance, common and rare, based on the similarity of 90%. The 'abundance' refers to the reef sites having population density over 1 individual per 1000 m^2. The 'common' means that the population density is in a range of 0.6-1 individual per 1000 m^2, while the areas where the population density is 0.1-0.5 individual per 1000 m^2 would be classified as 'rare'. Among the 67 dive sites, only two dive sites were categorized as abundance, i.e. Ko Ngam Yai, Mu Ko Chumphon, the Western Gulf of Thailand and Ao Losama, Mu Ko Phi Phi, the Andaman Sea. Three dive sites were classified as common including Ko Losin of the Western Gulf of Thailand, Hin Maung, Mu Ko Lanta and Fantasy rock, Mu Ko Similan of the Andaman Sea while eight dive sites were classified as rare. The abundance of *A. planci* was locally observed. Interestingly, the highest density of *A. planci* was observed in Ko Ngam Yai, Chumphon Province and Ao Losama,

Krabi Province, which was accounted for 2.0±1.5 and 1.3±1.5 individuals per 1000 m^2, respectively. In contrast, the *A. planci* were not found in 54 dive sites during our surveys.

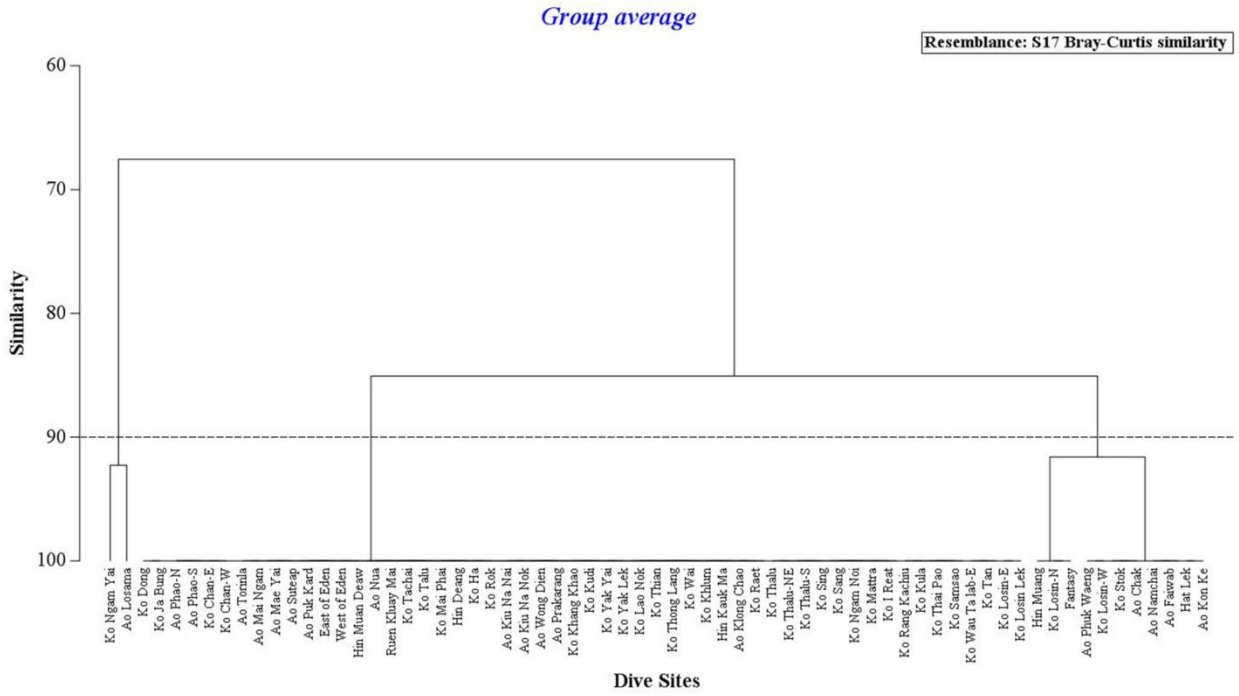

Fig. 3 Dendrogram for hierarchical clustering of 67 dive sites, using complete linkage of Bray-Curtis Similarities of *A. planci* density. The data were square-root transformed

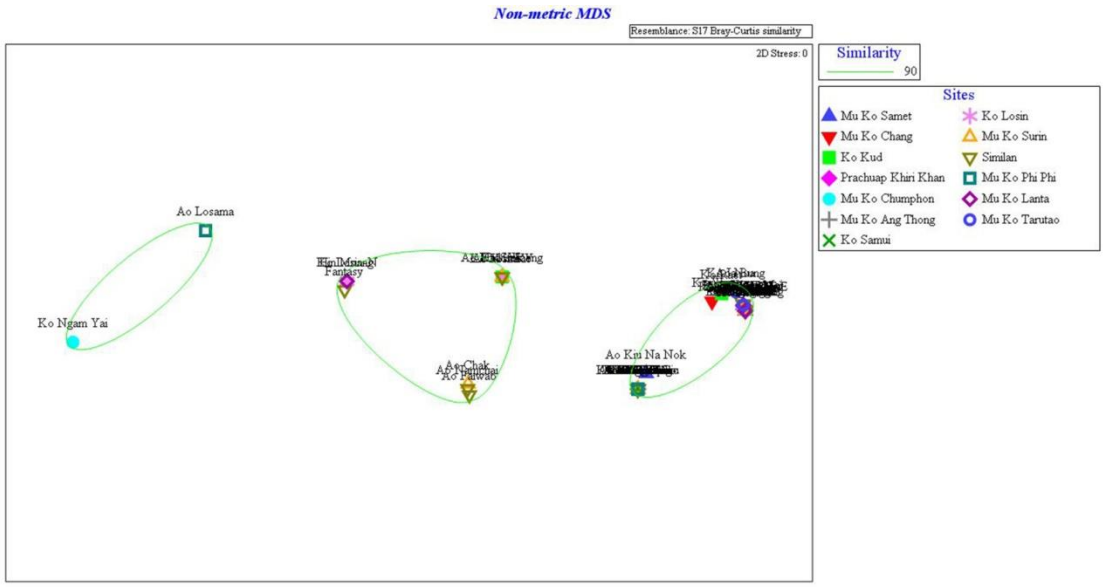

Fig. 4 Two-dimensional MDS configuration of *A. planci* densities from 67 diving sites of both the Gulf of Thailand and the Andaman Sea

In order to investigate the effect of diving activities on abundance of *A. planci* among dive sites, the study sites were categorized based on the types of activities (snorkeling, scuba, and both snorkeling and scuba) found in certain areas. The multiple comparison tests revealed the significant effect on population densities of crown of thorns starfish. The study sites where both snorkeling and scuba diving tended to show lower density of *A. planci* than that in the areas where either snorkeling or scuba are found (Table 2).

Table 2 Results from one-way ANOVA tests for differences in abundance of crown of thorns starfish among grouped diving sites (snorkeling, scuba, and both snorkeling and scuba)

Sources of Variation	***SS***	***df***	***F***	***p-value***
Within group	0.242	10	4.221	0.047*
Between group	0.287	2		
Error	0.529	12		
Multiple comparison				
Snorkeling *vs* scuba diving				0.643
Snorkeling *vs* Both[a]				0.037*

Scuba diving *vs* Both[a]	0.023*

[a]Both means snorkeling and scuba diving are found in certain areas, *$p<0.05$

Discussion

The population densities of *A. planci* at most dive sites in Thai waters, both the Gulf of Thailand and the Andaman Sea, were quite low. The severe destruction of coral communities in Thai waters caused by *A. planci* was not clearly observed during the last three decades (Piyakarnchana 1982; Chansang et al. 1986). However, partial colony mortality of massive *Porites* caused by *A. planci* feeding was obvious found at Ko Ngam Yai (Western Gulf of Thailand) and Ao Losama (the Andaman Sea). The deterioration of coral communities in the Gulf of Thailand and the Andaman Sea were mostly affected by the coral bleaching events and several anthropogenic disturbances such as heavy sedimentation from coastal development, tourism related activities and land-based pollution (Yeemin et al. 2006; Yeemin et al. 2009; Sutthacheep et al 2013; Yeemin et al. 2013). However, knowledge on distribution patterns, population dynamics and environmental factors controlling outbreaks of *A. planci* are very important for managing coral reefs in Thailand but this information are still limited (Thummasan et al. 2015).

The population densities of *A. planci* from the present study, except at Ko Ngam Yai and Ao Losama, are still below that causes the outbreaks in other regions of the world (Kayal et al. 2012; Plass-Johnson et al. 2015). The *A. planci* population density over 1,000 individuals per km^2 is considered to be indicative of an outbreak (Keesing and Lucas 1992; Moran and De'ath 1992; Roche et al. 2015). Therefore Ko Ngam Yai and Ao Losama have potential of *A. planci* outbreaks. Percentages of live coral cover at both reef sites were less than 20% with high percentages of dead corals and rubble (Charernmee et al. 2015; Yeemin unpublished data). Previous research has noted the under-reporting of *A. planci* outbreaks in Indonesia, although the significant impact on live coral that they can have (Baird et al. 2013; Plass-Johnson et al. 2015). As Ko Ngam Yai is located in the Mu Ko Chumphon National Park and Ao Losama is in the jurisdiction of Hat Noppharat Thara-Mu Ko Phi Phi National Park, the Thailand's marine national park authority should pay attention on the *A. planci* outbreaks and its impacts on coral reef ecosystems. An effective coral reef monitoring program should be done in some coral communities in order to prevent the outbreak of the crown-of-thorn starfish in the future. This study provides the important background information for

establishing the management strategies to prevent the outbreaks of *A. planci* in the Gulf of Thailand and the Andaman Sea.

Acknowledgements

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