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Size structure and preyed corals of *Acanthaster planci* (crown-of-thorns sea star) in Lungui Island, Dimataling, Southern Philippines

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Abstract

Outbreaks of *Acanthaster planci* are one of the major contributors to coral reef degradation, particularly in Indo-Pacific region. Correct assessment of its impact on coral reef ecosystems requires an understanding to its biology and ecology. This present study was conducted to determine the abundance, size structure and preyed corals of *A. planci* in Lungui Island, Dimataling, Southern Philippines. Four replicates of 50 × 4 m belt transects were laid in each of three sampling stations. A total of 112 *A. planci* individuals were recorded, whose body sizes varied significantly between the three stations ($H = 3.401$; $p = 0.0180$ at $\alpha = 0.05$) ranging from 120 to 270 mm. All detected *A. planci* individuals were observed foraging on corals. Five preyed coral genera were identified through morphology-based identification, where *Pocillopora* was the most preyed coral genus, foraged by 28.57% of total *A. planci* individuals. Although the number of *A. planci* individuals in Lungui Island has not reached the outbreak threshold level, its presence in the area should not be overlooked. In fact, this raises a need for continuous monitoring of its population level in these local reef areas of the coastal waters of Dimataling, Southern Philippines.

Key words: *Acanthaster planci*, coastal waters, coral reef degradation, preyed corals, size structure.

Introduction

Corallivorous organisms are of interest in the context of the increasing threats to coral reef ecosystems due to its feeding behavior, which primarily affects the survival and growth of corals (Turner 1994; Hughes 2003). One corallivorous organism known for its capacity to cause large-scale devastation on coral reefs is the *Acanthaster planci*, crown-of-thorns sea star (Pratchett 2001; Pratchett et al. 2014). Ecologically, *A. planci* does not threaten coral reefs at densities of < 1500 individuals km^{-2} (Moran, De'ath 1992), but rather creates a space within the corals where other marine organisms can settle (Haines 2015). However, if its population reaches the outbreak threshold level of > 1500 individuals km^{-2} (Miller et al. 2009), corals are preyed intensely causing extensive coral mortality that eventually shifts the complexity of coral reef structures (Posada et al. 2014).

A review of the impact of disturbances to coral reefs showed that outbreaks of *A. planci* were more damaging and extensive compared to other natural and anthropogenic disturbances (Trapon et al. 2011). Therefore, disturbances caused by the outbreaks of *A. planci* are one of the major contributors to coral reef degradation in Indo-Pacific region (De'ath et al. 2012).

Outbreaks of *A. planci* population remain a poorly understood phenomenon (Houk et al. 2007), whether this phenomenon is caused by overfishing of predators (Vine 1973), terrestrial run off (Birkland 1982), or fluctuating current paths (Yamaguchi 1987). These hypotheses were raised a long time ago by many scientists and are still under debate up to date (Deaker et al. 2020). Whatever the cause may be, outbreaks must be followed by successful reproduction (Bos et al. 2013). Thus, during outbreaks a variety of techniques have been used to potentially control its populations, such as cutting them into pieces (Barker, Scheibling 2008), manual removal (Lin et al. 2008), and injecting them with copper sulphate and sodium bisulfate (Johnsons et al. 1990). These methods, among others, have focused on mitigating the *A. planci* population, but outbreaks of its population still remain one of the major threats in coral reef ecosystems (Posada et al. 2014).

In a local management point of view, such as in the Philippines, there are certain instances that even at normal population densities, *A. planci* populations are improperly removed from coral reefs without proper assessment. This is due to the consideration that, once *A. planci* is observed in coral reefs, it may already require immediate action to lessen its impact. However, this substandard management practice due to lack of scientific knowledge on the biology and ecology of *A. planci* (de Dios et al. 2014) can result in ineffective control of *A. planci* populations in the long term (Haines 2015). Therefore, initial survey to determine the abundance of *A. planci* should be done first before removing them in a coral reef ecosystem (Moran, De'ath 1992).

The aim of this study was to determine the abundance, size structure and preyed corals of *A. planci* in Lungui Island, Dimataling, Southern Philippines to initially assess their population size in the island. Results obtained herein could provide additional information to further understand the corallivorous nature of *A. planci* especially those inhabiting in the coastal waters of Dimataling, Southern Philippines.

Materials and methods

Study site description

The island of Lungui (7.5400° N, 123.2686° E) is located in the municipality of Dimataling, Southern Philippines (Fig. 1). The island is bounded on the north by the Municipality of Dinas and on the east by Illana Bay and Municipality of Tabina and on the west by the Municipalities of Margosatubig and Vincenzo Sagun and on the south by the Municipality of Pitogo and Maligay Bay (Moro Gulf). Estimation of the total area and the total coral cover and assemblages of Lungui Island was greatly hindered by a lack of data from the local government unit, an indication that there has been no previous scientific assessments conducted within this island. Thus, we documented the composition of coral communities in most of the island through careful field observation only, but we did not include the abundance of corals due to time constraints and resource availability, hence we recognize that there are caveats in our study.

The analysis of substrate type, conducted in the Regional Soils Laboratory, Department of Agriculture, Zamboanga City, Philippines, revealed that the intertidal areas of Lungui Island are characterized by sandy substrate. Just like other islands, the shorelines of Lungui Island have flat and sandy beaches that are submerged with seawater during high tide and exposed to the air during low tide. Based on field observation, the inshore reef of Lungui Island, located at approximately 15 m away from the sandy beach, is characterized by slightly sloping patchy corals with water depth ranging from 2 to 12 m and dominated by different hard and stony corals such as *Acropora, Echinopora, Favites, Pocillopora* and *Porites*.

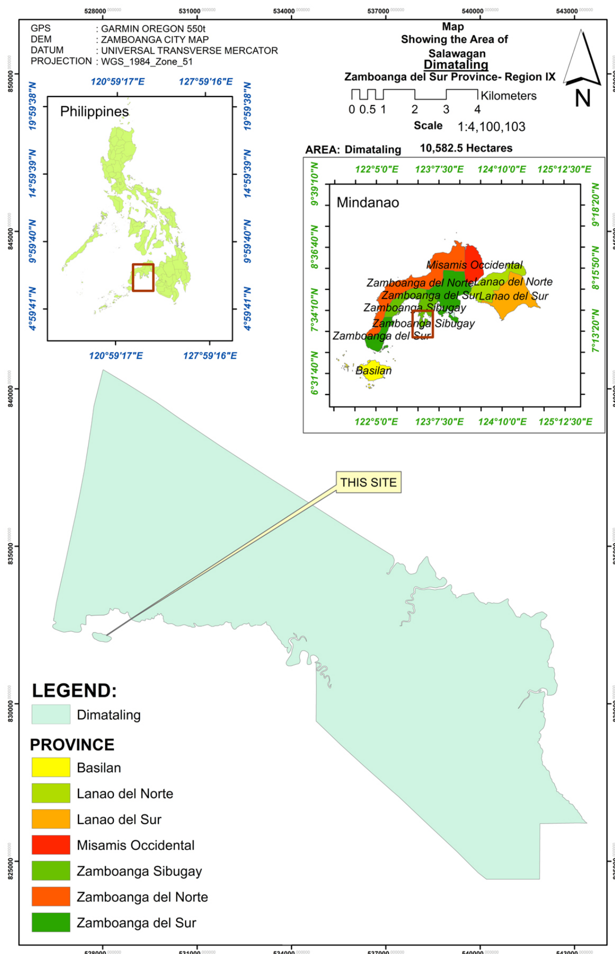

Fig. 1. Map of Dimataling, Southern Philippines showing the location of Lungui Island.

Field survey

We divided the study site into three sampling stations at 100 m intervals. The first station is in the western part of the island, while the second station is in the northern to eastern part, and the third station is in the southern part of the island. We surveyed the *A. planci* individuals specifically in the inshore reef of Lungui Island for four months (June to September, 2018). In each of the sampling station, we laid four replicates of 50 × 4 m belt transects from the selected starting points following Pratchett et al. (2009), having a total of 12 surveyed transects during the course of the study.

There were two local divers assigned in each of the sampling station to carefully search for *A. planci* individuals. Aside from recording its abundance, we also recorded the size of every *A. planci* detected as well as the water depth where *A. planci* individuals are found within each transect. The detected *A. planci* individuals were measured in a flat sandy substrate adjacent to the corals where they were found. Sizes of *A. planci* were measured as the maximum body diameter and distance between the farthest tips of the opposite arms on the aboral side of the body, as described by Pratchett (2005), using a ruler and readings were obtained in millimeter (mm). Moreover, the water depth was estimated by the local divers using a meter stick. Once *A. planci* was recorded, we carefully collected and removed using hand gloves and wooden sticks (Bruckner 2013) to apply a depletive sampling rule.

Difference in the mean body size of *A. planci* between the three sampling stations was tested using a Kruskal-Wallis Test at α = 0.05 using Paleontological Statistics (PAST) Software Package version 3.17 (Hammer et al. 2001). The size structure of *A. planci* was plotted using a frequency distribution histogram.

Assessment of foraged corals

Prior to the removal of *A. planci* individuals on the corals where they are attached, we first assessed the corals foraged upon by *A. planci* based on actual observation *in situ*. If the cardiac stomach of *A. planci* (located in the center of the oral side of its body) was clearly everted and engulfed around the surface of the coral prey, it was considered as feeding, otherwise, if this was not observed it was regarded as non-feeding (Pratchett 2001; Gil, Zaixso 2008; Scheibling, Metaxas 2008).

The corals foraged upon by *A. planci* were carefully photo-documented *in situ* in a 1 × 1 m frame using an underwater camera. The distance between the camera and the foraged corals was sufficient to fit the whole structure into one photo (the entire close-up structure of corals was also included). These photos were used as a guide for morphology-based identification. The foraged corals were identified up to the genus level using a Coral Identification Manual (Venkataraman, Satyanarayana 2012), and with the help of coral experts.

Results

Abundance and size structure

A total of 112 *A. planci* individuals were recorded in Lungui Island. All individuals represented a colour morph of purple with orange spines (Fig. 2). Thirty five percent of the total sightings were recorded in the second station, while 33.05% of the total *A. planci* individuals were found in the first station, and only 31.25% in the third station.

The majority of *A. planci* individuals (43%) were found at depths ranging from 7 to 8 m (Fig. 3). Few individuals (19.64%) were found at 2 to 5 m depth. Only 9.82% of the individuals were found at > 10 depths and the maximum depth where *A. planci* are observed was 12 m. Small individuals (< 160 mm diameter) were found at depths ranging from 2 to 8 m, whereas large individuals (> 200 mm diameter) were found at 5 to 12 m depth. The largest *A. planci* recorded in Lungui Island (270 mm diameter) was found at 11 m depth.

The diameter of *A. planci* measured in Lungui Island ranged from 120 to 270 mm. However, most *A. planci* individuals (87.5%) were between 150 to 230 mm diameter, while only a small proportion of individuals were < 150 mm (7.14%) and > 230 mm (5.36%). The overall size frequency distribution had a noticeable single mode (180 to 210 mm diameter), and the size structure was approximately distributed around a mean size of 188.04 mm diameter (Fig.

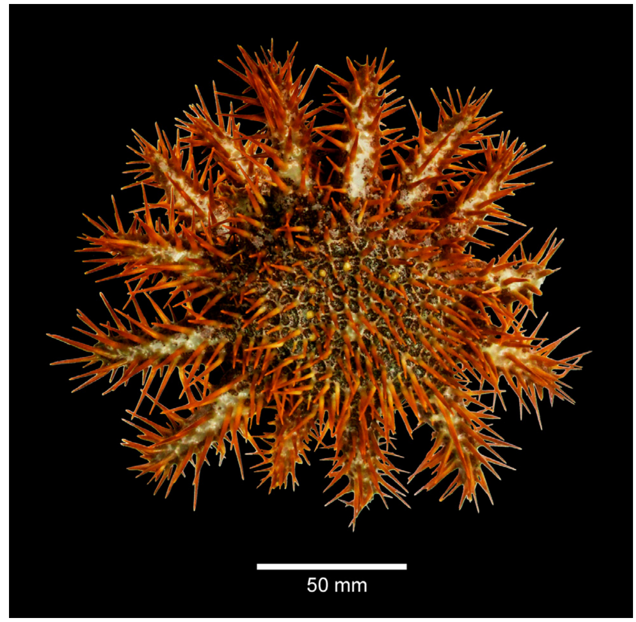

Fig. 2. *Acanthaster planci* found in Lungui Island, Dimataling, Southern Philippines showing its aboral surface.

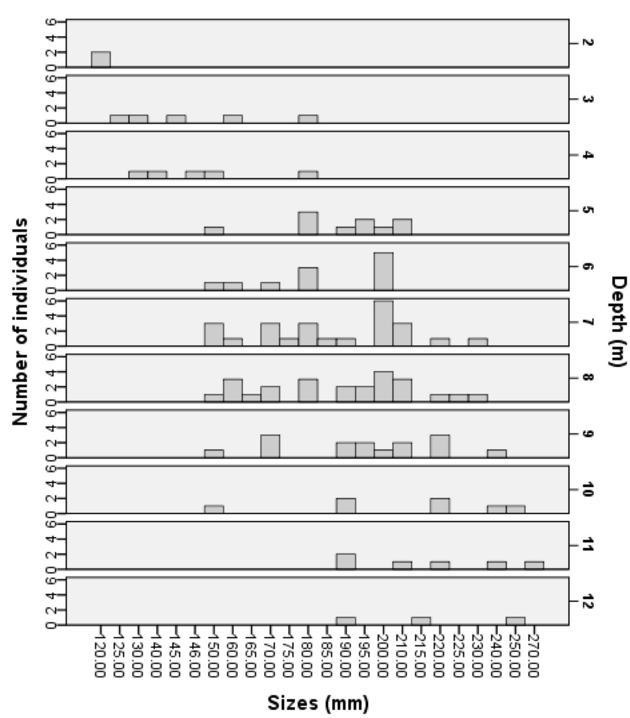

Fig. 3. Depth distribution of the different sizes of *Acanthaster planci* individuals in Lungui Island, Dimataling, Southern Philippines.

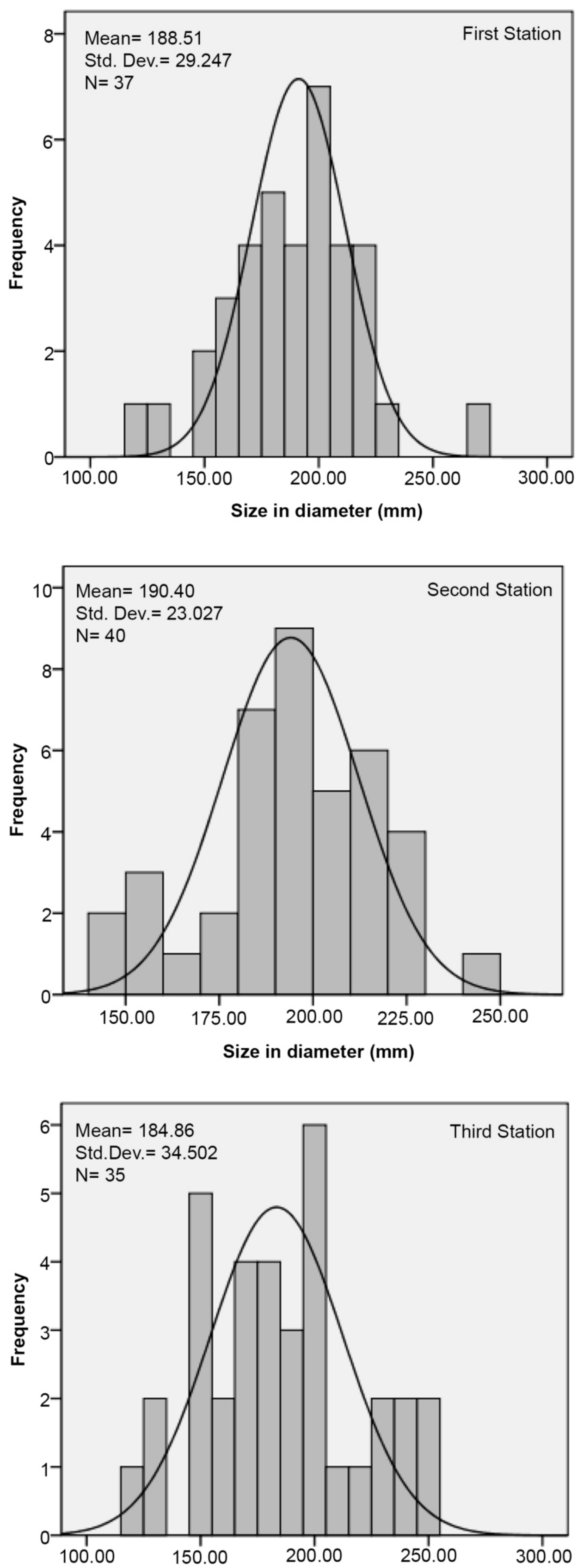

Fig. 4. Diameter frequencies of *Acanthaster planci* measured in the three stations in Lungui Island, Dimataling, Southern Philippines.

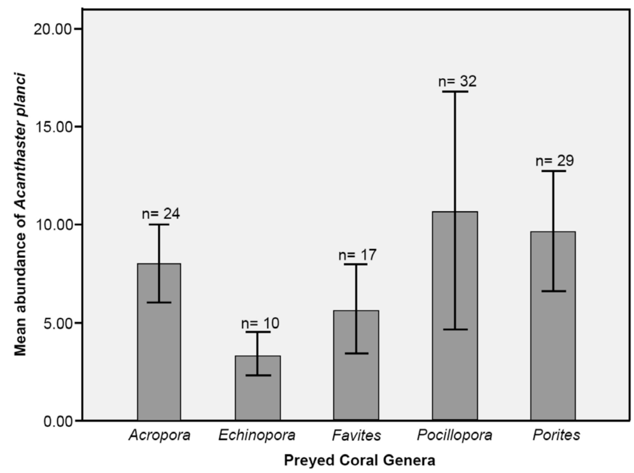

Fig. 5. Preyed coral genera of *Acanthaster planci* in Lungui Island, Dimataling, Southern Philippines.

4). There was slight, but significant variation in the body size of *A. planci* between the three stations (H = 3.401; p = 0.0180 at α = 0.05). Body size of *A. planci* was significantly larger in the second sampling station (mean 190.40 mm, range 140 to 240 mm) compared to other stations. In contrast, the body size of *A. planci* in the third sampling station was significantly smaller (mean 184. 86 mm, range 120 to 250 mm).

Preyed corals

During the course of the study, we observed that all observed *A. planci* (n = 112) were foraging on corals as evidenced by everted and engulfed cardiac stomach around the surface of the corals (Pratchett 2001; Gil, Zaixso 2008; Scheibling, Metaxas 2008). Using morphology based identification, a total of five coral genera were identified (Fig. 5). Among the five preyed coral genera, *Pocillopora* was the most preyed coral genus, foraged by 28.57% of *A. planci* individuals, followed by *Porites* (25.89%) and *Acropora* (21.43%). Few *A. planci* individuals (15.18%) were observed to be foraging on *Favites* corals, whereas only 8.93% of the total *A. planci* individuals were found foraging on *Echinopora* corals, making *Echinopora* as the least preyed coral genus of *A. planci* in Ligui Island.

Discussion

Among the two colour morphs of *A. planci* recorded in Dimataling, Southern Philippines (purple with red spines, and purple with orange spines) (Alibon, Madjos 2019), the island of Lungui hosts the latter. The size of the *A. planci* population recorded in Lungui Island did not exceed the upper threshold level (> 15 *A. planci* individuals per ha) used to characterize outbreaks of *A. planci* (Moran, De'ath 1992; Pratchett 2005), indicating that the *A. planci* population in Lungui Island is at a normal level. The majority of *A. planci* individuals (43%) in Lungui Island were found at depths ranging from 7 to 8 m, possibly because of the considerably abundant corals at this depth range, compared to other depths in Lungui Island.

The *A. planci* population in Lungui Island was comprised of individuals ranging in size from 120 to 270 mm in diameter. The overall size structure of *A. planci* population had a single peak (180 to 210 mm diameter) with the majority of sea stars (87.5%) between 150 and 230 mm in diameter, which is comparable to other areas (Pratchett et al. 2014). *A. planci* individuals with size < 250 mm are approximately considered less than 2 years old, whereas a size of *A. planci* > 260 mm corresponds to age of > 4 years old (Stump 1996). Hence, it is possible that the *A. planci* population in Lungui Island originated as early as 2014.

The preyed corals of *A. planci* are fundamental in determining its effects on coral communities (Pratchett et al. 2009). Low-density infestations of *A. planci*, such as in the case of Lungui Island are likely to lead to localized depletion of only the most highly preyed coral species (Pratchett 2007). The corals foraged on by *A. planci* in Lungui Island include five coral genera: *Pocillopora, Porites, Acropora, Favites*, and *Echinopora*. This might be influenced by several factors, such as the morphological and physiological characteristics of corals including its growth form, skeletal structure and tissue depth (Keesing 1990), the nutritional content of corals, coral defences, host defence by crustacean symbionts, the distribution and abundance of corals, and prior conditioning and learnt behaviour of *A. planci* (Moran 1986; Birkeland, Lucas 1990).

In terms of the morphological characteristics of corals, *Pocillopora* and *Acropora*, the most preyed coral genera of *A. planci* in Lungui Island, are characterized by having branching and tabular structures. Such structures allow *A. planci* to attach firmly on them because of its greater morphological surfaces, which enables *A. planci* to feed more efficiently (Moran, De'ath 1992; Pratchett 2007). Based on the nutritional content of corals, *Acropora* and *Pocillopora* have the highest nutritional contents, ranging 19.3 to 23.7 kJ g^{-1} and 21.6 to 22.7 kJ g^{-1} ash-free dry weight, respectively (Keesing 1990). This may explain the selection of coral genera by *A. planci*.

Interestingly, despite the fact that *Porites* is the least preyed coral genus of *A. planci*, because of its low nutritional value (De'ath, Moran 1998; Pratchett 2007), the high abundance of this coral genus in Dimataling (Alibon, Madjos 2019) might explain why it was the second most preyed coral genus in Lungui Island. This observation is supported by studies showing that coral prey selection of *A. planci* is also dependent on the local composition of coral communities, with the most abundant corals in the local habitat being selected to be foraged (Keesing 1990; Pratchett et al. 2017). Although *A. planci* is well adapted to feed on a wide range of different corals, it often selects a coral as prey from a small suite of available prey species (Keesing 1992; De'ath, Moran 1998; Pratchett 2007). Thus, feeding of *A. planci* on *Echinopora* and *Favites* in Lungui Island might be related to ingestive conditioning of *A. planci* (Ormond et al. 1976), i.e. it accepts normally non-preferred genera after it has been conditioned to forage on these corals in its local habitat (Keesing 1990).

It is still not known how *A. planci* was able to thrive and survive in the coastal waters of Dimataling. Although we had hypothesized previously that this might be due to the normal water conditions and availability of preyed corals in the area (Alibon, Madjos 2019), additional studies are still needed in order to further elucidate and support this hypothesis. In 2018, a massive occurrence of *A. planci* in the Tambunan Marine Protected Area in Tabina, a neighbouring municipality of Dimataling, was reported by local residents to the Philippine Coral Bleaching Watch, an organization that monitors coral reef stressors in the Philippines. Considering that the coastal waters of Dimataling and Tabina are adjacent in terms of geographical location, a hypothesis is now added that the local current pattern likely played an important role in dispersal of *A. planci* larvae to the coastal waters of Dimataling (de Dios et al. 2014). The local currents from Tabina probably initially dispersed *A. planci* larvae to the coastal waters of Dimataling, where they developed, matured, reproduced and afterward, dispersed their larvae to Lungui Island via local currents. The same hypothesis was proposed for Southern Leyte, Philippines (de Dios et al. 2014). Though *A. planci* can only reproduce once a year (March to May in the Philippines) (Bos et al. 2013), female *A. planci* is a highly fecund species (Scheibling 1981; Sanford et al. 2009) and can produce up to 65 million eggs per year, enough to be fertilized and dispersed to other neighbouring areas (Pratchett et al. 2014).

Conclusions

Our study emphasized the importance of preliminary assessment with regards to the management of *A. planci* population in Lungui Island, especially as it was found out that the population is at a normal level. However, its presence in the area should not be overlooked and further monitoring should be done to evaluate if the population remains at a normal level. The results showed that, even with the unavailability of the most preyed corals, *A. planci* could still prey on the available local corals in Lungui Island. This feeding behaviour could be one of the contributing factors to the development and survival of *A. planci* in the island. We recognized that there are caveats to our findings, for example, the coral diversity of the island was not included due to time constrains and available resources. Hence, further studies in the island, which focuses on the impact of *A. planci* population on the local coral assemblages are strongly recommended.

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