Crown of Thorns Seastar (*Acanthaster planci*) Assessment Report:

Napantao, San Francisco, Southern Leyte
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Abstract

Crown-of-Thorn Seastars (*Acanthaster planci*), also known as CoTs, are a major threat to coral reef communities around the Indo-Pacific. At outbreak levels they have the capacity to destroy entire coral reefs and alter the ecological diversity of an ecosystem. In recent years there have been several outbreaks of *A. planci* in Sogod Bay, Southern Leyte, the Philippines and on-going monitoring of their populations is advised. As part of our remit and close ties to the Barangay of Napantao, of the Municipality of San Francisco, Coral Cay Conservation carried out an *A. planci* assessment on the Napantao Marine Protected Area (MPA) in March 2014. The results of the assessment are positive with low overall numbers of *A. planci* being recorded both inside the MPA and the area adjacent to it. However, spatial distribution was not even and small pockets of higher numbers of individuals were noted. An extraction of *A. planci* focused on these specific areas was conducted by the community of Napantao, with CCC's support, following this study.

Acknowledgements

Coral Cay Conservation would like to express our gratitude to the Provincial Government of Southern Leyte (PGSL). Our work would not be possible without the support of the Provincial Environmental and Natural Resource Management Office (PENRMO) and other members of the PGSL. We would also like to thank the Municipality of San Francisco and Barangay of Napantao for supporting this assessment. Finally, we would like to thank our trained volunteers and staff who collected the data during this assessment.

Coral Cay Conservation

Coral Cay Conservation (CCC) is a not for profit organisation, founded in 1986 by a British scientist. CCC's mission is:

> "Providing resources to help sustain livelihoods & alleviate poverty through the protection, restoration and management of coral reefs and tropical forests."

In order to achieve this mission, CCC has carried out conservation projects all over the world, including in the Philippines, Belize, Honduras, Malaysia, Cambodia and Fiji. CCC has successfully set up Marine Protected Areas and provided scientific data that has been used to manage local marine resources. The project in Danjugan Island in the Philippines between the years 1996-1999 was particularly successful and the reefs around the island received the accolade of Best Managed Reef in the Philippines in 2002. Since 1995, CCC has worked with the Philippine Reef and Rainforest Conservation Foundation Inc. (PRRCFI) and local communities to survey and safeguard reef and rainforest areas in the Philippines. To date these have included coastal regions of the Southern Negros Occidental, Anilao, Palawan, Danjugan Island and the forests of North Negros.

At the invitation of the Provincial Government of Southern Leyte, CCC began its survey work in Sogod Bay in September 2002. CCC is conducting a collaborative program to survey the region's coral reefs and provide training and conservation education opportunities for project counterparts. The aim is to develop local capacity and ensure the long-term protection and sustainable use of marine resources throughout Southern Leyte.

1. Introduction

The Crown-of-Thorns Seastar (*Acanthaster planci*, Figure 1) is a voracious predator of Scleractinian corals and poses one of the greatest threats to coral reef ecosystems (Pratchett, 2005). Growing to a size in excess of 50cm, an adult *A. planci* is capable of consuming vast quantities of coral per year. At outbreak levels this can cause significant and lasting damage to reef communities throughout the tropics. While *A. planci* outbreaks are thought to be a natural occurrence, coral communities already stressed by changes in global climate, salinity and outbreaks of disease, struggle to recover from increased levels of predation from *A. planci* (Birkeland, 1990). *A. planci* has a range that covers the tropical waters of the Indo-Pacific and Red Sea, but is not known in the Caribbean.

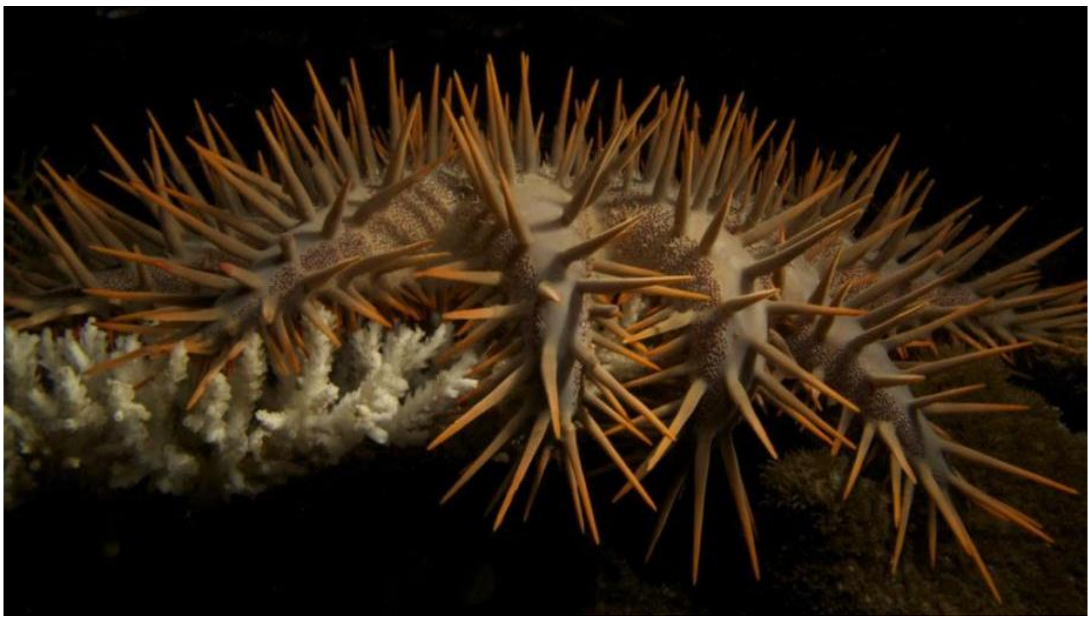

Figure 1 - Crown-of-Thorns Seastar, *Acanthaster planci*, on an Acroporid coral

A. planci reproduce through sexual reproduction during mass spawning events in high summer when males and females release eggs and sperm into the water column. These events are synchronised by changes in light intensity and temperature. The quantity of eggs released depends on the size of the female, with large individuals releasing in the region of 60 million eggs per breeding season (Mundy et al., 1994). During outbreak events when the proximity of males and females is high, fertilisation rates can be as great as 95% (Lucas, 1973). For this reason, populations of *A. planci* can increase by several orders of magnitude in a relatively short period of time.

Within the first 24 hours of fertilization, eggs go through a series of changes and grow into free swimming larvae which disperse in the water column and are transported by prevailing currents. After one month, larvae settle onto the benthos and begin the final metamorphosis into their adult phase. During the early benthic phase juvenile sea stars face a high rate of mortality by predation; however, *A. planci* are able to grow rapidly and will attain a size of 25cm within 2 years (Brodie et al., 2005). The ability of *A. planci* to reach adult size in a short time period mitigates the risk of predation and increases juvenile survivorship.

A. planci tend to feed at night and are frequently observed moving across coral colonies. Like all seastars, they feed by extruding their stomachs which contains digestive enzymes that break down the coral tissue and absorb nutrients. The damage created by this process leaves tell-tale scars of exposed corallite cups devoid of any living tissue.

1.1. Outbreaks

During an outbreak of *A. planci* numbers rise to an unsustainable level and can cause potentially devastating levels of damage to reef corals and the communities that depend on them. Historically, a major outbreaks occurs an average of every 50 years (Fabricius et al., 2010). This lag time between severe events provides the fast growing species of coral, preferentially predated by *A. planci*, sufficient time to re-grow to pre-outbreak levels and offers resilience to lasting ecological damage. In recent decades, the rate of major outbreaks has increased thus reducing recovery time and increasing the pressure on reef communities (Brodie et al., 2005). Typically, outbreaks last 4-5 years although severe events have lasted three times this long. The sudden explosive booms in population are followed by equally rapid declines which are typically due to mass disease outbreak. This classic boom-bust population dynamic is due in large part to the inherent properties of *A. planci* life history, such as high fecundity and rapid growth rates (Pratchett, 2005).

A. planci are capable of causing first-, second- and third-order effects on reef communities. In increasing level of severity, these order effects result in the reduction of surface cover of hard corals, species diversity and colony size distribution. Changes in substrate can lead to a phase shift, away from coral dominated ecosystems to reefs to algae dominated reefs or dominance of other encrusting animals such as soft corals. The loss of hard coral reduces the topographic complexity of the reef and limits the diversity of species it can support.

In 2003 an outbreak of *A. planci* devastated the coral populations around the island Moorea of French Polynesia. *A. planci* predation resulted in a dramatic collapse of coral cover from 40% in 2005 to just 5% in 2010. This coral mass mortality was followed by a decline in coral assemblage diversity and correlated with a significant increase in turf algae, dead coral rubble, and sand. Branching and tabulate *Acropora* species were the most strongly affected. In 2005 the reef was dominated by *Acropora* and *Pocillopora* species whereas massive *Porites* almost exclusively dominated by 2010. A shift in coral cover and coral assemblages led to a community shift and a local collapse of the coral-eating butterflyfish populations. Hunger-driven predation of *A. planci* not only affects coral cover but typically cascades down to many reef communities (Kayal et al., 2012).

During periods between outbreaks, *A. planci* exist on reefs at low background levels. At these densities they are a natural component of reef communities. Indeed fossil records indicate that they have been an active part of reef ecosystems for thousands of years (Walbran et al., 1989). As a natural part of a reef ecosystem, and at the right density, *A. planci* fill an ecological niche and provide a service that benefits the community as a whole. Reports suggest that *A. planci* in low densities help maintain coral diversity by preferentially predating fast growing coral species, including Acroporids. This has a positive effect for slower growing corals such as *Porites* sp., and enhances competition and species diversity on the reef. The carrying capacity of any reef system will determine the optimal number for a healthy population.

1.2. Causes of outbreaks

The direct cause of outbreaks is widely debated. In reality, the cause of any outbreak is likely very complex and will be influenced by a range of factors that determine its severity. Furthermore, the importance of any one causal factor will likely differ from reef to reef. It has been shown that in the last century the frequency and intensity of outbreaks has increased (Fabricus et al., 2010). In the last 100 years direct and indirect anthropogenic impacts on reefs have increased dramatically and are likely contributory factors to the rise in frequency of outbreaks.

Two main hypotheses have been proposed for outbreak frequency increase. Firstly, the larval survival hypothesis suggests that the larval stage is critical in the life-cycle of *A. planci* and will determine potential changes in adult population. Increasing survivorship through this stage will greatly increase the numbers of *A. planci* attaining adult size and sexual maturity. There are a number of possible causes associated with increased larval survivorship including, the increased widespread presence of pesticide residues in marine environment as a factor in limiting predation on *A. planci* by reducing the abundance of predatory invertebrates. Likely more important however, is the increased nutrient supply from terrestrial runoff. New farming methods and destructive deforestation practices on land have led to an increase in nutrient load from freshwater sources into the oceans. Elevated nutrient levels often cause eutrophication episodes and phytoplankton blooms. If an episode occurs concurrently with *A. planci* spawning the result is unusually high survival of larvae. The phytoplankton blooms reduce the morality rate of larvae due to starvation and in addition provide an ample food resource for larvae predators thus both enhancing rates of growth and survivorship (Lucas, 1973). Birkeland (1982) noted that large outbreaks tend to only occur on reefs around high continental land masses and not low coral atolls. Furthermore, outbreaks occur 2-3 years after periods of very high rainfall on land. This spatial pattern is explained by the fact that far greater quantities of nutrients run off high landmasses with deep soils than low-lying coral atolls. The lag time after rainfall events to an outbreak is explained by the development time of juvenile *A. planci* into visible adults.

The second hypothesis suggests that predator removal as a result of increased commercial fishing practices, increases populations of *A. planci*. This hypothesis assumes that the population is controlled by predation and that the removal of predatory fish would allow an ecological release of *A. planci* from predation pressure. However, evidence that predatory fish significantly impact numbers through predation is weak and largely anecdotal. Indeed a study into predation of juvenile *A. planci* found that predation by large fishes was unlikely to be important in population dynamics. (Sweatman, 1995).

Alternatively it has been suggested that overfishing of predatory fish could lead to trophic cascades. With fewer large piscivorous fish there is an ecological release of predation on smaller benthic feeding fish species such as wrasse. With greater numbers of benthic feeders, abundances of benthic inverts decrease. Benthic invertebrates are important natural predators of settlement stage *A. planci*. Therefore a fall in their number would precipitate an expansion in *A. planci* numbers (Sweatman, 2008).

Pratchett (2005) proposed that outbreak events could occur as a result of two conditions; (1) a sudden and large single mass recruitment event or (2) a progressive accumulation of *A. planci* over a number of generations. Many studies focus on outbreaks that have seemingly been triggered by single events that led to the mass recruitment of one cohort of *A. planci*. In the study however Pratchett (2005) showed that the population structure of an outbreak of *A. planci* around Lizard Island on the Great Barrier Reef, Australia, comprised individuals from at least 4 separate cohorts. It is suggested that the outbreak resulted from a prolonged build-up in *A. planci* numbers over multiple recruitment events. This finding shows that in certain cases outbreaks can occur independently of sudden recruitment events and indicates that factors responsible for the onset of outbreaks are likely subtle and difficult to measure.

1.3. Marine Protected Areas

Marine Protected Areas (MPAs) have become an increasingly valuable tool for resource managers to protect and conserve endangered marine ecosystems. They have a range of benefits that not only conserve marine resources for their own intrinsic value, but also for the benefit of human populations that rely on them (World Bank, 2005). Well designed and enforced MPAs have the potential to withstand a wider range of threats than unprotected reefs. Coral reefs within MPAs seem to be better able to withstand *A. planci* outbreaks. Sweatman (2008) reports that reefs on the Great Barrier Reef (GBR), Australia, open to fishing pressure were 3.75 times more likely to have an outbreak than reefs within a no-take MPA. Due to trophic cascades caused by removal of large predatory fish, reefs outside MPAs may lack invertebrates that prey on juvenile *A. planci*. Furthermore MPAs are often located to protect areas that contain a high diversity of habitats and species. Studies suggest that interactions between coral populations can moderate the impact of *A. planci* outbreaks. A high diversity and density of hard coral is characterised by high rugosity that provides refuges for coral away from *A. planci*. As a consequence reefs are better able to recover from predation and are more resilient to outbreaks (Kayal et al., 2011).

1.4. Report Aim

This study was conducted in March 2014, in the coastal waters of Napantao, San Francisco, Southern Leyte, Philippines. The area surveyed is a long term MPA, managed by the Barangay of Napantao

(Figure 2). Using a rapid assessment methodology this study aimed to assess the numbers of *A. planci* inside and outside the MPA.

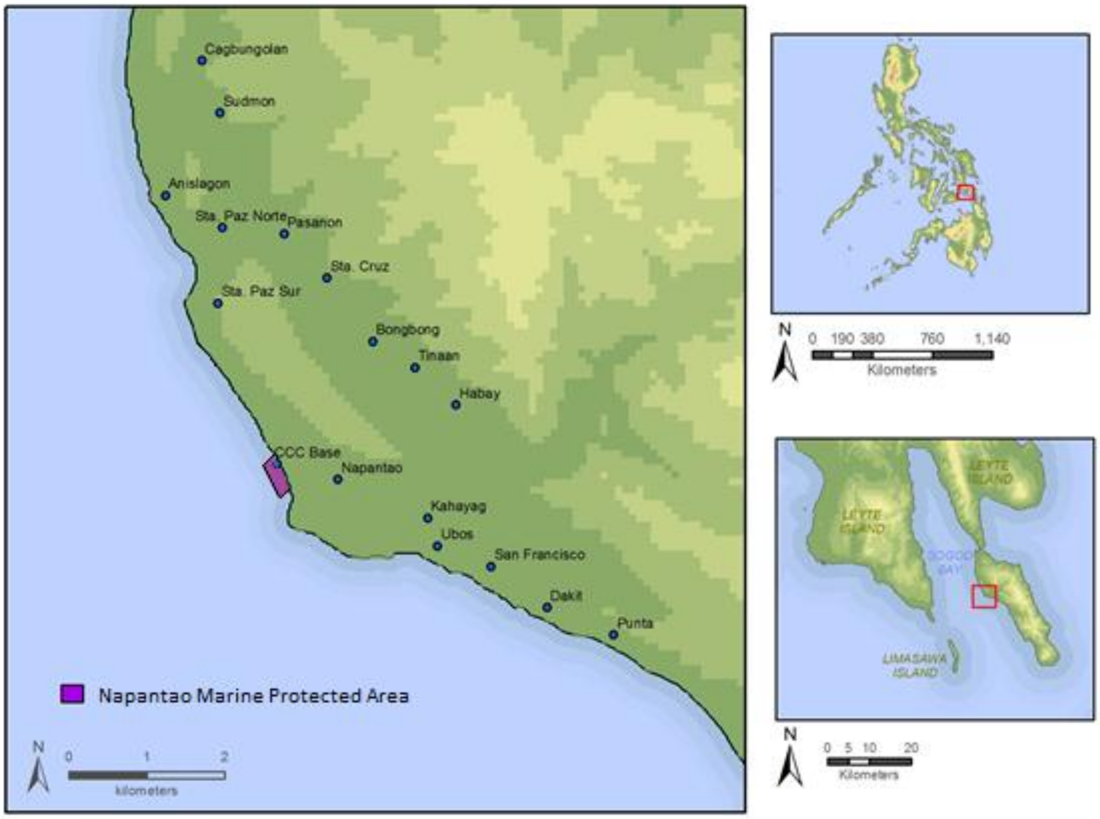

Figure 2 - Map of San Francisco Municipality indicating the boundaries of the Napantao MPA surveyed in this assessment.

2. Methodology

The assessment of the MPA was conducted using a methodology adapted from the Reef Check method for recording reef invertebrates. The Reef Check methodology is widely recognised and is used to survey coral reefs around the world. It was developed in the 1990s with the aim of gathering as much data as possible about the global status of coral reefs (Hodgson et al. 1999). The data from around the world is analysed on a yearly basis and updates about the status of coral reefs are published. Reef Check provides a general picture of the ecological status of a reef and the human impacts affecting it.

Survey transects were conducted at depths of 2 metres, 6 metres, and 12 metres, both inside and outside the MPA (Figure 3). Each transect was 100 metres long and divided into 4 replicates of 20 metres each. Between each replicate there was a 5 metre gap where no data was recorded. This survey set up allows for robust statistical analysis of the collected data.

The assessment at the MPA site in Napantao was conducted in March 2014. It was conducted over 10 dives by trained volunteers from Coral Cay Conservation.

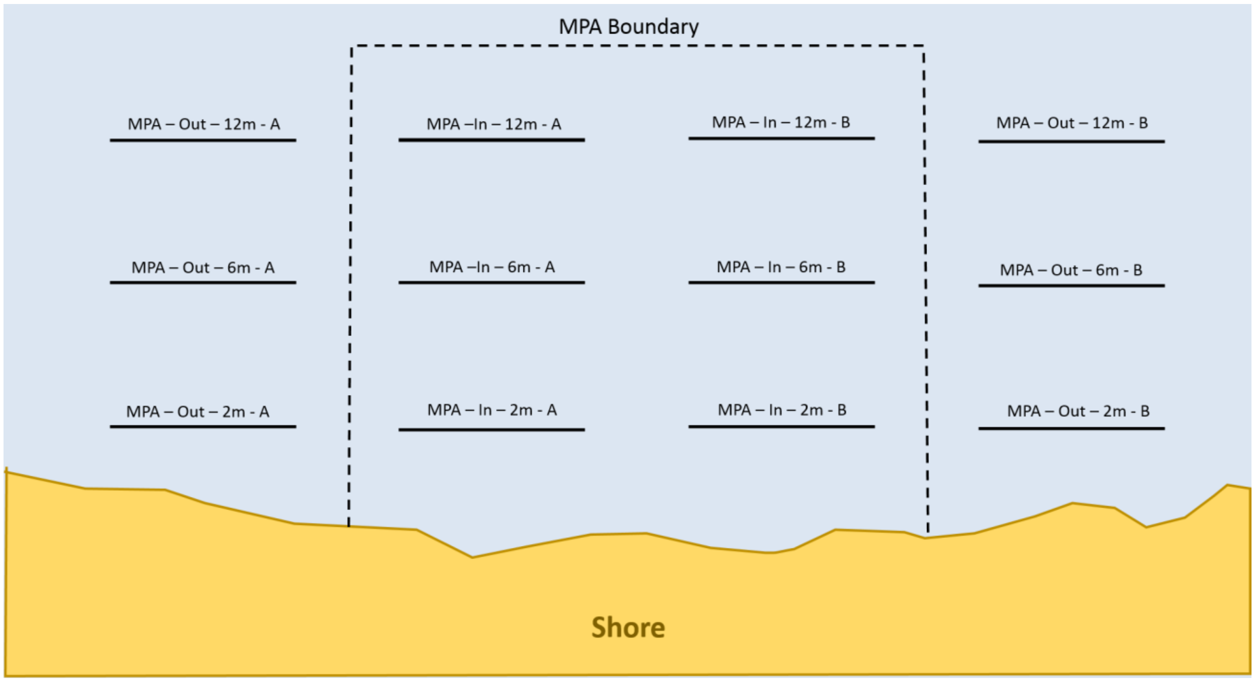

Figure 3 – Schematic plan of the assessment. Each transect was 100 meters long and is divided into 4 replicates.

2.1. Belt Transects

Data was recorded along a belt transect where *A. planci* were counted 2.5m either side of the transect line along the four 20m replicates (Figure 4). Each transect was surveyed by two divers. The first laid out the survey line with the buddy following behind looking for *A. planci* on one side of transect line. On the return leg, one diver counted *A. planci* on the other side of the transect line whilst the buddy reeled in the line. *A. planci* are generally nocturnal and hide from direct sunlight during the day. Divers looked in holes and under overhangs to inspect for *A. planci* that may be hiding.

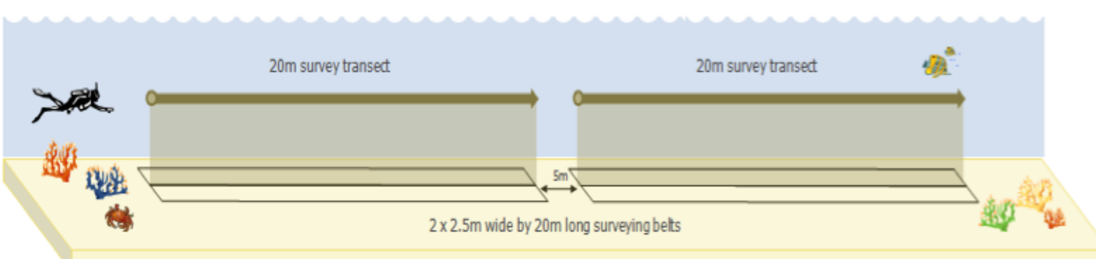

Figure 4 – Survey method for recording *A. planci*. The diagram shows 2 of the 4 replicates in a 100m transect.

2.2 Data Analysis

Each 20m replicate was treated as an independent sample. This produced n=24 inside the MPA and n=24 outside the MPA, when not considering depth. At each of the survey depths, 2m, 6m, and 12m, there were n=16 replicates inside and outside the MPA. To test for statistically significant differences between inside and outside the MPA, Mann-Whitney U tests were used. Preliminary inspection of the data revealed that the variances were not homogeneous and it had a non-normal distribution. Transformations of the data did not sufficiently alter this to warrant using a parametric test.

3. Results

Overall abundance of *A. planci* in the area surveyed was low. Inside the MPA mean abundance was 0.25 ± 0.15 per $100m^2$ (mean ± SE). Outside the MPA the mean abundance of *A. planci* was 0.67 ± 0.27 per $100m^2$ (Figure 5). The difference in abundance between outside and inside the MPA was not significant ($p > 0.05$).

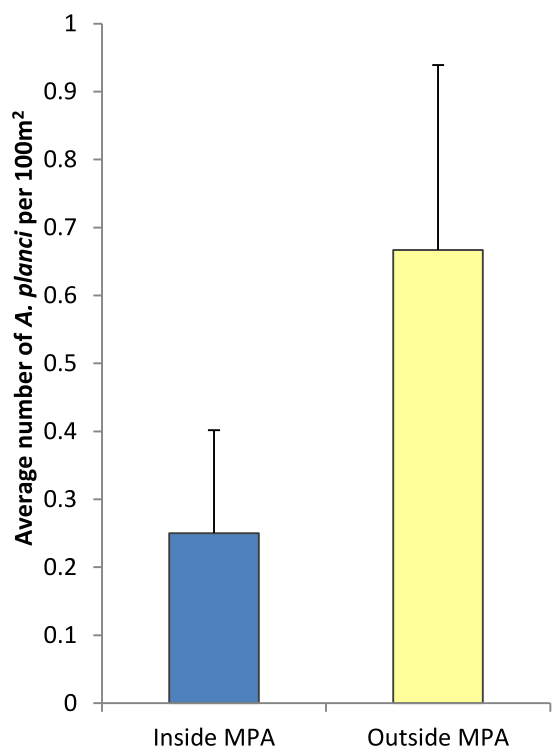

Figure 5 – Average abundance of *Acanthaster planci* per $100m^2$ inside and outside the proposed MPA. Data are mean average per replicate; error bars indicate standard error of the mean.

Across all sites, distribution of *A. planci* appeared not to be even over depth, with the average abundance at 12m being 0.25 ± 0.14 per $100m^2$, at 6m being 0.06 ± 0.06 per $100m^2$ and at 2m being

1.06 ± 0.31 per 100m². There was no statistically significant difference found between 12m and 6m or between 12m and 2m; however, the observed variance in *A. planci* densities between 2m and 6m was found to be significant (p >0.05), (Figure 6).

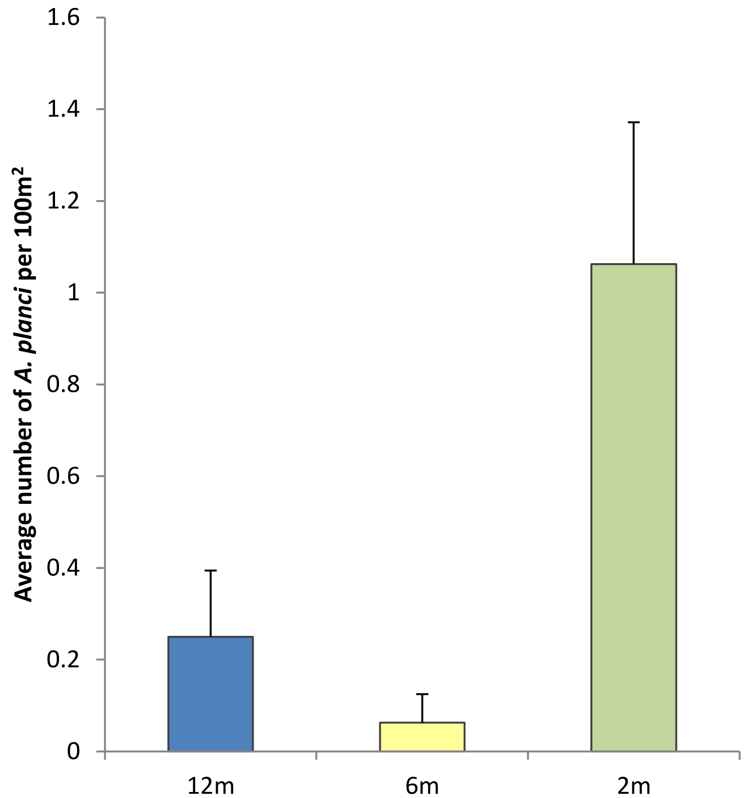

Figure 6 – Average abundance of *Acanthaster planci* per 100m² at 12m, 6m, and 2m. Data are mean average per replicate; error bars indicate standard error of the mean.

4. Discussion

Due to natural variations between populations, it has historically been difficult to define what abundance levels of *A. planci* constitute an outbreak. Definitions for a non-outbreak have ranged from 6 individuals per km² to 14,000 individuals per km² (Moran and De'ath, 1992). This wide degree of variability has led to some difficulty in determining when a reef is threatened by an outbreak and when numbers are within acceptable levels. It is usually necessary to take into account factors such as the relative abundance of live and recently killed coral, in addition to the overall number of individual *A. planci*.

The assessment of the MPA in Napantao reported a relatively low abundance of *A. planci* and is thus unlikely to be below outbreak levels. Hard coral cover recorded during the MPA assessment of Napantao (Longhurst *et al*, 2013) shows healthy cover of hard coral, which improves the reefs ability to cope with larger numbers of *A. planci* (Kayal et al., 2011). There were few examples of recently killed coral colonies, suggesting the coral has had little recent predation. Throughout Napantao reef a high diversity of coral species are found, including slow growing *Porites* sp. and faster growing *Acropora* sp. *A. planci* preferentially predate fast-growing coral species such as *Acropora* (Pratchett, 2007) and therefore a reef containing healthy colonies of these species is a good anecdotal indicator that the *A. planci* population is in healthy balance to the reef.

Although the observed difference between *A. planci* abundance inside the MPA and outside the MPA was not found to be significant, the higher levels of *A. planci* outside the MPA may indicate that the protection afforded by the MPA from fishing activity is mitigating against trophic cascade effects which can lead to outbreaks (Sweatman 2008). The significantly greater abundance of individuals recorded at 2m is likely linked to the spatial distribution and diversity of coral species at this depth. Distributions of *A. planci* on any given reef heavily depend on the specific topography of that area, indeed a recent study of *A. planci* in the Philippines observed 60% of an *A. planci* population in depths of 3 to 4 metres due to the topography and isolation of the study area (Bos *et al*., 2013). Within the study area of this survey, the topographical diversity is high at a shallower depth which creates an abundance of suitable cryptic habitat for small individuals. Juvenile and small *A. planci* are generally nocturnal feeders and seek shelter during the day (Keesing, 1995). Thus a large amount of suitable habitat at this depth would support a greater population than at a greater depth where topographic complexity is less.

In general the relatively low numbers of *A. planci* recorded in the survey is a positive sign for the reefs around Napantao and San Francisco as a whole. However, spatial distribution of individuals recorded was not even, as indicated by the high standard error for all groups. This indicates that individual *A. planci* tend to cluster together on specific areas of reef, most likely in locations where the coral species present offer suitable habitat and food sources.

5. Conclusions

In recent years there have been several outbreaks of *A. planci* within the Sogod Bay area, including at Padre Burgos, Limasawa, and Tabugon. As such, vigilant monitoring and, where necessary, extraction of *A. planci* is a high priority for marine resource management. When managing *A. planci* outbreaks, the target is not complete extraction of the species but to prevent an outbreak. Repeat removal activities appear to be the most effective tactic (Bos *et al.,* 2013). While this study did not find high levels of *A. planci* across the survey area, the variation in spatial distribution recorded and small pockets of high abundance in certain locations does raise some cause for concern.

Following this study and supported by CCC, the Barangay Council of Napantao instigated a pre-emptive removal programme in the shallow waters within the MPA and to the south of the MPA. The aim of this removal was to specifically target those areas where higher numbers of *A. planci* had clustered and were therefore deemed to be reaching a level to warrant concern. Since the results of this study indicate that *A. planci* were more abundant at shallow depths, particularly in the area outside the MPA, individuals were manually removed from shallow areas using snorkelling equipment and tongs. Community members were offered 5 pesos per *A. planci* removed, as an incentive for helping to protect the reef. CCC provided logistical support and also aided in the extraction. In total over 130 individuals were removed from the area south of the MPA.

The findings of this assessment and the small extraction event should be seen as positive indicators that *A. planci* numbers in the Napantao MPA and surrounding area are within an acceptable level and are being effectively managed. However, this study focused on one small area and, since spatial distribution of *A. planci* can vary greatly, should not be taken as a holistic assessment of the region. Instead, the results should stimulate the continued monitoring of the region for evidence of outbreaks and action should be taken when deemed necessary.

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