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An investigation into the impacts of polychaete worm on crown-of-thorn population outbreaks

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Coral reef degradation has occurred at an alarming rate in recent years, with global climate change and ocean acidification being the major causes. Recently, population outbreaks of the corallivorous *Acanthaster planci*, or crown-of-thorns starfish, have been a major cause of coral degradation, due to their ability to consume coral faster than the coral is able to grow and replace the consumed portion. While crown-of-thorns starfish (COTS) have few predators, *Pherecardia striata* are known to prey on injured COTS and increase the mortality rates of these destructive starfish. With lab experiments, we can determine *P. striata* attack rates on *A. planci,* then use field observations to determine the impact of *P.striata* presence on *A. planci* outbreak and coral recovery. Understanding the biology of *P. striata* and its impacts on *A. planci* populations will allow researchers to investigate the possibility of using *P. striata* as a tool to control *A. planci* populations during future outbreaks. Decreasing or preventing *A. planci* outbreaks will allow coral reef recovery in environments heavily populated by these corallivorous starfish, which will be valuable in this period of high coral mortality rates.

Introduction

Coral reefs are one of the most complex ecosystems found on Earth. They are typically found in tropical oceans near the equator, where they thrive in clear waters, warm temperatures, and sunlight (Stehli and Wells 1971, Salvat 1992). Not only do corals species add to the biodiversity of marine life, but they also create habitat that supports other species (Sebens 2015). Coral reefs also act a buffer zone that protects coastal communities from waves and rough waters due to storms, allowing another diverse population to thrive in their environments without the threat of property damage and erosion (Guannel *et al*. 2016). The loss of these crucial organisms will cause large-scale environmental and economic consequences and, with the slow recovery time of coral reefs, will be difficult to overcome if action isn't taken rapidly.

Crown of Thorns starfish (COTS), *Acanthaster planci*, is one of the variety of predators that feed on live coral (Rotjan and Lewis 2008). These organisms are found mostly in tropical Indian and Pacific Oceans and are easily identifiable due to their large body, many arms, and toxic spines (Moran 1988). They feed at night by secreting gastric enzymes that break down the tissues of the coral polyps and then absorb the liquid left after this digestion (Campbell 1970). COTS outbreaks are challenging to predict, and we do not fully understand their causes (Pratchett 2005). These population outbreaks are a major cause of coral reef degradation, with up to 90% loss in coral cover in response to COTS outbreaks (Leray *et al*. 2012). Research that focuses on controlling these outbreaks is important in decreasing coral mortality in tropical areas.

Due to their toxic spines and habit of feeding at night and hiding during the day, COTS have very few predators. Pufferfish, triggerfish, and a gnathophyllid shrimp are their main predators (Endean 1973). Surprisingly, predation on COTS doesn't always end in death, and some can survive after a portion of their body has been fed upon. The presence of *Pherecardia* *striata* is part of what determines whether COTS survive such an incomplete predation event (Glynn 1984).

Pherecardia striata is an amphinomid polychaete worm found only in the marine environment (Fauchald 1979). They are found in reefs where pocilloporid corals are present and form a reef frame (Glynn 1984). They feed mainly on algae, detritus, and crustaceans, but are also known to feed on injured COTS and increase COTS mortality. *P. striata* enter the body cavity of COTS after another predator produces an open wound. They then feed on soft tissues of the sea star such as its gonads, hepatic caeca, and water vascular system, causing further damage that leads to death (Glynn 1984).

Observational motivation

A considerable amount of research addresses mortality rates of coral reefs. The ecological and economic impacts that will follow the loss of reefs will be devastating and, due to coral's slow recovery process, will be impossible to repair (De'ath 2012). In this case, it is important to understand all causes of coral bleaching, not limiting our efforts toward fixing anthropogenic causes.

Crown of Thorns outbreaks have been studied since their first observed occurrence in mid 1900's, but their cause remains unknown (Lucas 2013). Some hypotheses include over-fishing of higher trophic level fish that feed on Crown of Thorns, as well as increased terrestrial runoff that lead to nutrient rich waters allowing COTS larvae to thrive and increase survival rates (Brodie *et al.* 2005, Fabricius *et al*. 2010, Birkeland 1982). COTS population outbreaks have become a major cause of coral degradation because of their ability to consume coral faster than the coral is able to grow.

With high rates of coral mortality currently being observed, it is important to study and understand the range of potential causes of such mortality, and to determine the best way to either resolve or lessen its damage. *Acanthaster planci* population outbreaks are one important source to control. The presence of a predator, such as *Pherecardia striata*, may allow COTS populations to be controlled.

Research Question

The goal of this study is to investigate the ecology and distribution of *P. striata* and how their presence impacts *A. planci* outbreaks. The results of this study will open the possibility of using *P. striata* as a tool to control *A. planci* outbreaks in environments where coral reef populations are declining.

Hypothesis

Studies have shown that *Pherecardia striata* prey on *Acanthaster planci* (crown-of-thorns/COTS) and increase the mortality of COTS when they are present in the same environment (Glynn 1984). With that in mind, it can be predicted that with the presence of *P. striata*, COTS outbreaks will be less intense and allow coral reefs the time to grow and recover. In environments that lack *P. striata*, COTS will be preyed upon but often will be left only injured, allowing them to continue to feed on coral, reproduce, and increase coral mortality. If there is no relationship between *P. striata* and COTS mortality, there will be no observable changes in the mortality of coral reefs with the presence or absence of *P. striata.* With this information, the use of *P. striata* as a tool to control *A. planci* outbreaks can be investigated and understood.

Methods

This study will include a lab experiment and a field experiment. The field experiment will be based on observation and population counts, which will determine the relationship between *Pherecardia striata* presence and *Acanthaster planci* outbreaks and how this impacts coral reef mortality. The lab experiment will provide a more in-depth examination of the effects of *P. striata* presence on *A. planci* populations, by determining the mortality rates of *A. planci* in the presence and absence of *P. striata.*

In the lab, there will be 16 tanks set up: 8 experimental tanks and 8 control tanks. Each tank will be kept at 27^{o}C to mimic sea surface temperature environment with a 12:12H light interval representing day and night (Storlazzi 2013). The 8 experimental tanks will hold injured *Acanthaster planci*, with four of these tanks containing *Pherecardia striata* and the other 4 without *P. striata.* The 8 control tanks will hold uninjured *A. planci*, with four of these tanks containing *P. striata* and 4 tanks without *P. striata*. One *A. planci* will be placed into each tank and acclimatized to the environment for 3 days prior to the start of the experiment. After this acclimatization period, an arm of *A. planci* will be removed from individuals in the experimental tanks. This removal will serve as a model for injured sea stars (Glynn 1984). *P. striata* (3 organisms per tank) will be introduced into 4 tanks of the experimental and 4 tanks of the control. We will leave tanks in these conditions for one week while routinely making detailed observations and taking photos for documentation. Crown of thorns abundance should be calculated once a day at the very least, but preferably at least once in the morning, once midday, and once at night. After one week, determine the state of each *A. planci* and compare with *A. planci* in other experimental environments (Injured/absent *P. striata*, uninjured/present *P. striata*, uninjured/absent *P. striata).* Collect data and create a graph comparing attack rates and health of *A. planci* in all experimental and control variables. Health calculated based on a scale from 0-5: 5-healthy sea star, 4- signs of injury, 3-noticeable decline in health, 2- evident signs of disintegration of body wall, 1-disintegrated into skeletal elements, and 0- virtually no trace of sea star.

Field observations will be conducted in 8 locations, 4 with a known presence of *Pherecardia striata*, the 4 with a known absence of *P. striata.* All locations must be where *Acanthaster planci* populations are known to exist. Counting each *A. planci* individual present in a specific location would be tedious and senseless, thus calculating their coral cover over a 200 sq. m. will allow us to quantify their abundance. Using a 50x4 m belt transect, calculate the number of *A. planci* found within the boundaries of the transect, including the sea stars that are more than half inside. Of these included *A. planci*, determine and note the number of injured, ill, and dead *A. planci* by *P. striata.* This is important in concluding that the deaths were actually caused by *P. striata* rather than another predator. These observations will be done every 3-6 months for the duration of an outbreak. With the data collected, create a graph demonstrating *A. planci* population abundances over the course of the outbreak.

Anticipated Results

In the lab experiments, presence of *Pherecardia striata* in tanks with injured *Acanthaster planci* are expected to show the most decline in health, and presumably death. Injured *A. planci* in tanks without the presence of *P. striata* are expected to show a short decline in health followed by a sign of recovery. Both control variables, the uninjured *A. planci* with *P. striata* present and absent, are expected to show no signs of a decline in health (Fig. 1).

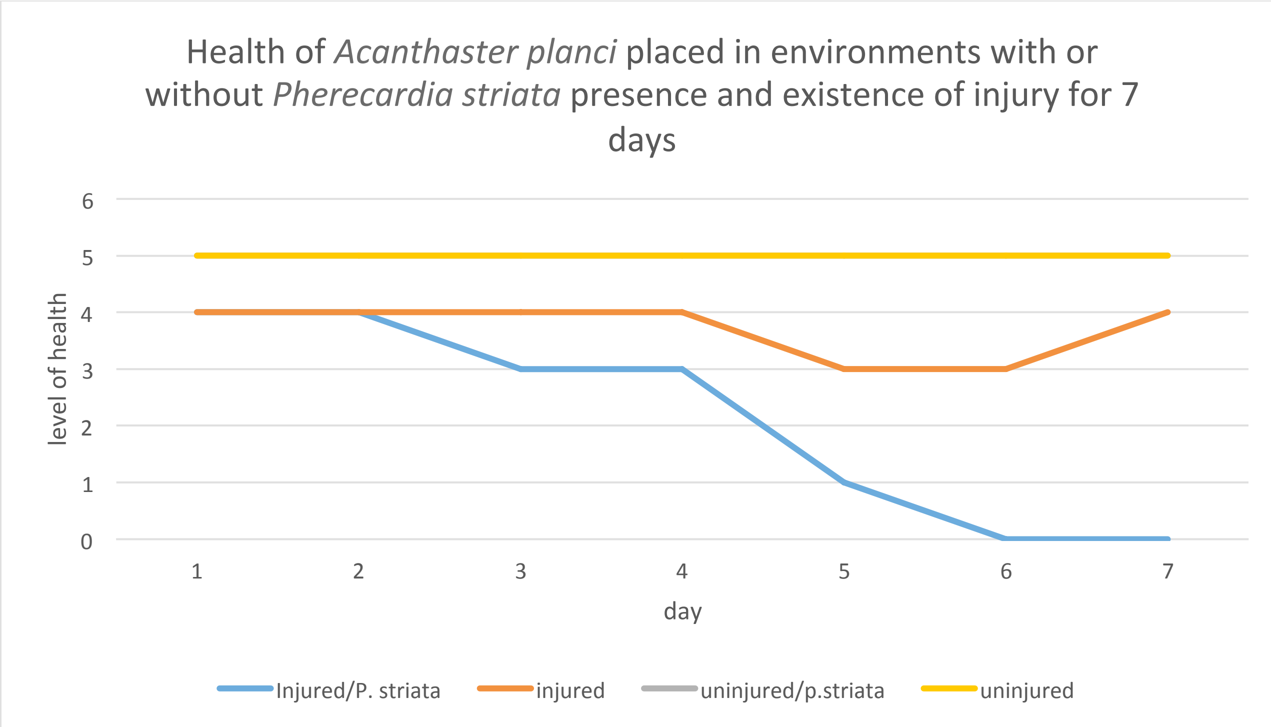

Figure 1. Graph showing the average health of *A. planci* in varying environments over a period of 7 days. Blue represents injured *A. planci* in a tank with *P. striata* present. Orange represents injured *A. planci* in a tank with *P. striata* absent. Grey represents uninjured *A. planci* in a tank with *P. striata* present. Yellow represents uninjured *A. planci* in a tank with *P. striata* absent.

In the case that uninjured *Acanthaster planci* show a decline in health or death, it must be concluded that other factors may have caused an increase in mortality, therefore must discredit *Pherecardia striata* from being the cause of this mortality. If injured *A. planci* exposed to *P. striata* do not show a decline in health, the null hypothesis, which states that there is no relationship between *P. striata* presence and *A. planci* mortality, will be accepted.

The field observations are expected to show the differences in *Acanthaster planci* abundance in locations with *Pherecardia striata* compared to locations without *P. striata.* In locations where *P. striata* are absent, *A. planci* abundances are presumed to be higher with intense population outbreaks. In locations with the presence of *P. striata*, *A. planci* populations will remain steady with less intense outbreaks (Fig. 2).

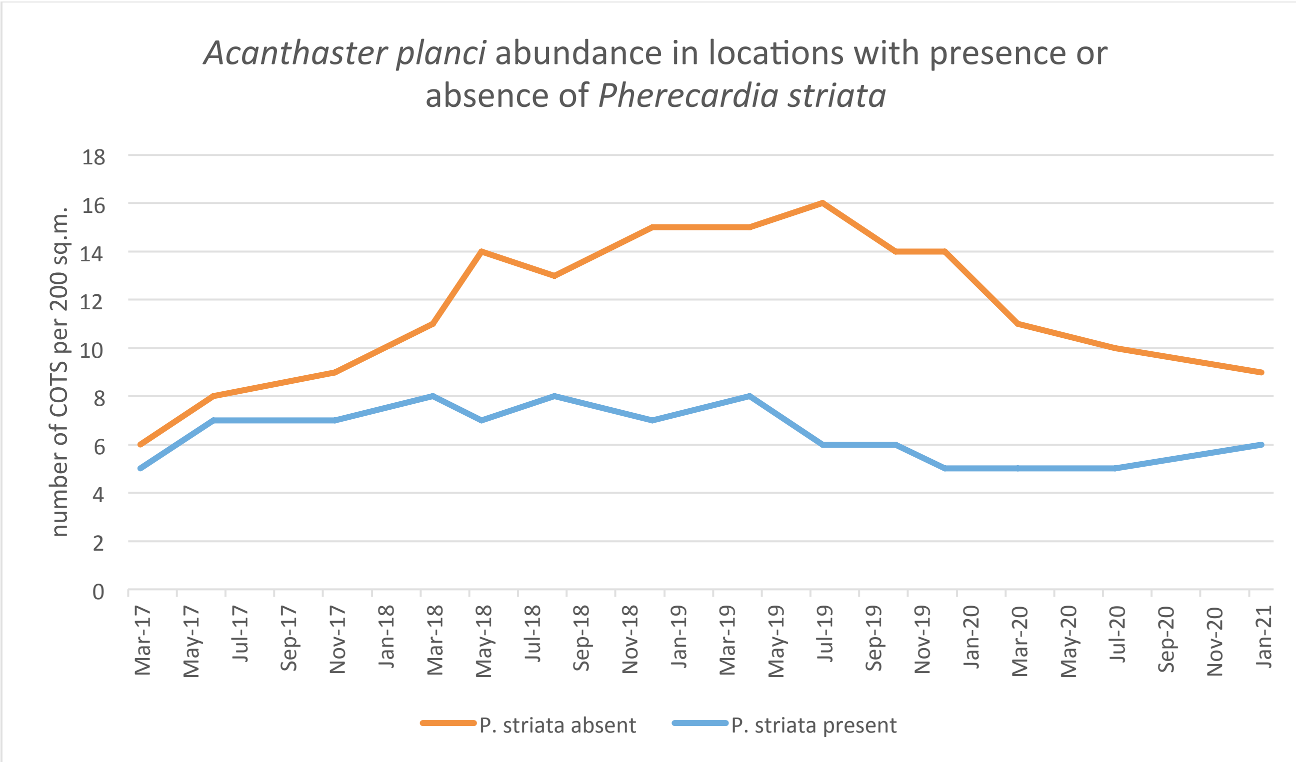

Figure 2. Graph showing average COTS counts within a 200 m^2 transect at locations with *P. striata* (blue) and without *P. striata* (orange) from 2017-2021.

If results show an insignificant difference in abundance between locations where *Pherecardia striata* are present compared to where they are absent, it will be concluded that *P. striata* do not have an impact large enough to affect *Acanthaster planci* populations.

Discussion

Acanthaster planci are a major cause of degradation of coral reefs due to their sudden and unpredictable outbreaks (Nakamura 2014). *Pherecardia striata* are known to prey on injured *Acanthaster planci* by entering through the wound and feeding on their soft tissues. Generally, *A. planci* will survive most predatory attacks being left only injured, but in the presence of *P. striata*, injured *A. planci* are further preyed upon, often leading to death (Glynn 1984). The lab experiments will determine if and to what extent *P. striata* presence impacts *A. planci* health on an individual case. With this, we can conclude whether or not they increase *A. planci* mortality.

This will be the backbone of the study and support the findings of the long-term field observations. In these field experiments, an investigation on the *A. planci* populations will be done in two environments, one with *P. striata* and one without. This will allow a comparison that can determine if *P. striata* presence can influence an entire *A. planci* population in that location. Unfortunately, there may be many factors that influence *A. planci* mortality in the ocean but if many sites are observed, it can possibly reduce the impact of these factors as long as there is a constant variable such as *P. striata* presence or absence.

The presence of *P. striata* is expected to control *A. planci* populations and limit the possibility of an outbreak (Fig. 2). This is beneficial because the high densities of *A. planci* during these outbreaks cause a drastic increase in coral mortality, so being able to control or limit these events is important. Coral reefs offer many services including tourism and recreation, a source of food, and coastal protection that bring in a millions of dollars each year (Moberg 1999). They also not only add to the biodiversity of marine life, but act as a habitat to support it as well covering only 1% of the ocean floor while supporting 25-33% of marine species (Plaisance 2011). Their importance encourages research to be done to investigate different ways to protect coral reefs.

By understanding the dynamics of *P. striata* on *A. planci* populations, there is a possibility to use *P. striata* as a biological tool in preventing future outbreaks. If *P. striata* can control *A. planci* populations and keep densities at a level that allow coral to recover, then further research can be done to closely examine other biological impacts *P. striata* will have if introduced to a new environment. The introduction of *P. striata* into an environment that lack predators who increase *A. planci* mortality can limit population outbreaks. Environments that lack *A. planci* predators are expected to be more susceptible to these population outbreaks, increasing coral mortality. By understanding the significance of *P. striata* presence on *A. planci* populations, further research can be done to possibly use *P. striata* as a biological tool in preventing future outbreaks.

Further research needs to be done to asses any other environmental impacts that the introduction of *P. striata* into new environments will have on other local species. This research will be the first step in using *P. striata* to control or limit *A. planci* outbreaks. It still isn't fully understood what causes these outbreaks but being able to control them will be a big step towards healthier reefs.

Birkeland C. 1982. Terrestrial runoff as a cause of outbreaks of *Acanthaster planci* (Echinodermata: Asteroidea). Marine Biology **69**: 175-185.

Brodie J, K Fabricius, G De'ath, and K Okaji. 2005. Are increased nutrient inputs responsible for more outbreaks of crown-of-thorns starfish? An appraisal of the evidence. Marine Pollution Bulletin **56**: 266-271.

Campbell AC, and R F G Ormond. 1970. The threat of the 'crown-of-thorns' starfish (*Acanthaster planci*) to coral reefs in the Indo-Pacific area: Observations on a normal population in the Red Sea. Biological Conservation **2**: 246-251.

De'ath G, K E Fabricius, H Sweatman, and M Puotinen. 2012. The 27–year decline of coral cover on the Great Barrier Reef and its causes. Proceedings of the National Academy of Sciences of the United States of America **109**: 17995–17999.

Endean R, and W Stablum. 1973. A Study of some Aspects of the Crown-of-Thorns Starfish (*Acanthaster Planci*) Infestations of Reefs of Australia's Great Barrier Reef. Atoll Research Bulletin **167**: 1-62.

Fabricius K E, K Okaji, and G De'ath. 2010. Three lines of evidence to link outbreaks of the crown-of-thorns seastar *Acanthaster planci* to the release of larval food limitation. Coral Reefs **29**: 593-605.

Fauchald K, and P A Jumars. 1979. The diet of worms: A study of polychaete feeding guilds. Oceanography Marine Biology **17**: 193-284.

Glynn P W. 1984. An Amphinomid Worm Predator of the Crown-of-Thorns Sea Star and General Predation on Asteroids in Eastern and Western Pacific Coral Reefs. Bulletin of Marine Science **35**: 54-71.

Guannel G, K Arkema, P Ruggiero, and G Verutes. 2016. The Power of Three: Coral Reefs, Seagrasses and Mangroves Protect Coastal Regions and Increase Their Resilience. PLoS ONE **11**: e0158094

Leray M, M Béraud, A Anker, Y Chancerelle, and SC Mills. 2012. *Acanthaster planci* Outbreak: Decline in Coral Health, Coral Size Structure Modification and Consequences for Obligate Decapod Assemblages. PLoS ONE **7**: e35456.

Lucas J S. 2013. Crown-of-thorns Starfish. Current Biology **23**: R945–R946

Moberg F, and C Folke. 1999. Ecological goods and services of coral reef ecosystems. Ecological Economics **29**: 215-233.

Moran, P.J. 1988. The *Acanthaster* Phenomenon. Townsville, QLD: Australian Institute of Marine Science.

Nakamura M, K Okaji, Y Higa, EYamakawa, and S Mitarai. 2014. Spatial and temporal population dynamics of the crown-of-thorns starfish, *Acanthaster planci*, over a 24-year period along the central west coast of Okinawa Island, Japan. Marine Biology **161**: 2521 2530.

Plaisance L, M J Caley, R E Brainard, and N Knowlton. 2011. The Diversity of Coral Reefs: What Are We Missing?. PLoS ONE.

Pratchett M S. 2005. Dynamics of an outbreak population of *Acanthaster planci* at Lizard Island, northern Great Barrier Reef (1995–1999). Coral Reefs **24**: 453-462.

Rotjan R D, and S M Lewis. 2008. Impact of coral predators on tropical reefs. Marine Ecology Progress Series **367**: 73-91.

Salvat B. 1992. Coral reefs — a challenging ecosystem for human societies. Global Environmental Change **2**: 12-18.

Sebens K. 2015. Biodiversity of Coral Reefs: What are We Losing and Why?. Integrative and Comparative Biology **34**: 115-133.

Stehli F G, and J W Wells. 1971. Diversity and Age Patterns in Hermatypic Corals. Systematic Biology **20**: 115-126.

Storlazzi C D, M E Field, O M Cheriton, M K Presto, and J B Logan. 2013. Rapid fluctuations in flow and water-column properties in Asan Bay, Guam: implications for selective resilience of coral reefs in warming seas. Coral Reefs **32**: 949-961.