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Effects of Coral Stressing on the Feeding Preferences of the Coral Predator, Acanthaster Planci

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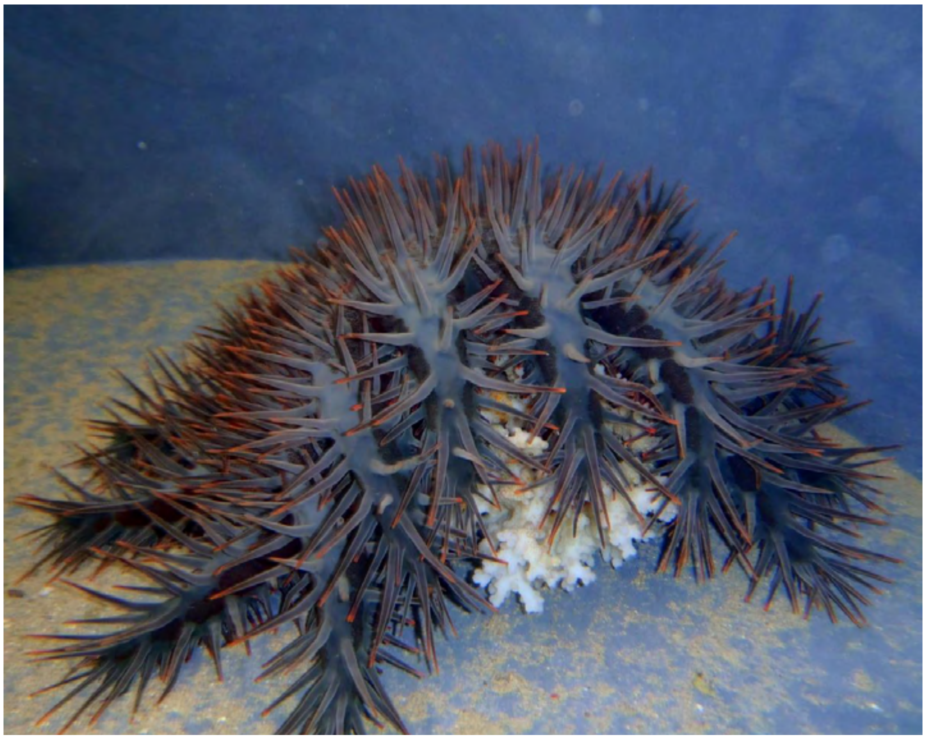
Effects of coral stressing on the feeding preferences of the coral predator, *Acanthaster planci*



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Abstract

Coral predators have always been a natural occurrence on coral reefs, but recent studies have begun to focus on the feeding preferences of these predators in relation to bleached and damaged corals. The recent mass bleaching events, mainly resulting from factors of climate change, have motivated researchers to study the effects of predation on the affected corals to determine the extent of harm these large-scale disturbances may be causing to reefs. This study examined how coral stressing affects the feeding preferences of *Acanthaster planci*, a coral-feeding starfish that has been known to cause widespread damage to coral reefs, especially during periods of outbreaks. By determining whether *A. planci* prefers to prey on stressed or healthy coral colonies in a controlled aquarium setting, we can apply these findings to situations in the wild, relating them to the vulnerability of coral reefs after stressing events.

This study was set up as a simple, two-choice, observational experiment, where an *A. planci* specimen was placed in a tank with a healthy colony of *Pocillopora damicornis* and a similar colony that had been submerged in freshwater several times. Out of 32 nights of trials, 1 trial resulted in *A. planci* choosing the healthy coral, 14 trials resulted in the starfish choosing the stressed coral, and no choice was made in 17 trials. Significant differences were found between the average proportion of trials resulting in the choice of healthy coral and those resulting in the choice of stressed coral (T-test for Independent Samples: $p = 0.016$; Chi-square test: $p = 0.0011$). This shows that *A. planci* selectively preys on stressed coral over healthy coral, opening up numerous questions as to what kind of motivations may be driving this preference, and how these findings will affect the persistence of coral reefs during increasingly frequent bleaching events.

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Acknowledgements

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1.0 Introduction

1.1 Coral Reefs

Corals reefs have always been recognized as an ecosystem characterized by a remarkably high amount of biodiversity. The Great Barrier Reef alone has been estimated to support approximately 1500 species of fish, 350 species of hard coral, 4000 species of mollusk, 500 species of algae, along with 6 of the world's 7 species of marine turtle (Wachenfeld, 2007). In addition to their vast ecological value, coral reefs play a crucial role in the social and economic scenes of coastal areas; an estimated 500 million people depend on tropical coral reefs as a source of food and income, and the overall value of the industry has been estimated at $375 billion annually (Reid, 2009). These ecosystems are crucial to the persistence of high levels of biodiversity in the ocean and the success of many economies on land.

1.2 Climate Change and Coral Stressing

Because of their incredible value in a broad range of areas, coral reefs have been studied extensively in relation to possible threats, specifically climate change. The change in global temperatures, mainly resulting from anthropogenic factors, can directly influence the conditions of the ocean and thus the status of coral reefs. Influences such as carbon dioxide and temperature increases can affect the health and composition of coral reefs, changing what species can survive and persist in the new conditions (Hughes et al, 2003). Coral bleaching, one of the main results of climate change on the reef has been a focus of reef research, especially after the mass bleaching events of 1998 and 2002 on the Great Barrier Reef (Berkelmans, 2004). Coral bleaching is a process where the symbiotic dinoflagellates, known as zooxanthellae that live within the coral tissue are expelled. These organisms live in a symbiotic relationship with the coral, where they provide nutrients through photosynthesis, as well as give the coral its color. When environmental changes cause zooxanthellae to be expelled to a low enough density, the coral loses its color, revealing its white skeleton. This kind of stressing event can occur from factors of climate change, such as temperature and acidity increases, as well as salinity and water chemistry changes.

1.3 Predation of Corals

While coral bleaching as a result of climate change poses one of the main threats to the persistence of coral reefs, other factors have a huge influence as well. Coral predation by corallivorous fishes and other organisms is a natural occurrence, but occasionally can become devastating for coral reefs. Crown of Thorns starfish, *Acanthaster planci*, is a sea star that feeds on many different species of coral and has been known to eat as much as a square meter of coral per month (Davis, 2008). Generally, *A. planci* are found in fairly low densities on the reef, but outbreaks have been known to occur, which can result in complete devastation of the coral community (Pratchett, 2001). Previous studies have shown that these starfish prefer to prey on certain species of coral over others, tending to target corals in the family Acroporidae and Pocilloporidae (Pratchett, 2001).

While they appear to display these feeding preferences and to consume prey that maximizes their net intake of energy, they have also been observed to prey on almost every species of corals when food is limited during outbreaks, giving them their reputation as voracious coral predators. Other factors seem to play a large role in the feeding choices of *A. planci* as well; these include the nutritional content of corals, distribution and abundance, previously learned feeding behavior of the starfish, and coral defense mechanisms (nematocysts, mesenterial filaments, antagonistic behavior of symbiotic coral crustaceans) (Pratchett, 2001).

Despite reports that *A. planci* have significantly negative impacts on the coral reef ecosystem, a previous study claimed that the feeding activity of *A. planci* can benefit coral reefs because it prevents the dominance of one species of coral, thus increasing the coral biodiversity in a given area (Porter, 1972). Porter's research shows that there was significantly higher coral biodiversity in a given area visited by the starfish then in areas without them; each location had the same number of species, but the different species were more evenly distributed in the area with *A. planci*. While having a small number of *A. planci* specimens on a reef may not be detrimental to the coral cover, and may even be beneficial in some situations, numerous studies have shown that these animals cause a great deal of harm to coral reefs, especially when present in large numbers.

1.4 Effects of Coral Health on Predation

Bleaching is one example of the kind of stress that can be placed on corals, jeopardizing their chances of survival in the wild. Other examples include coral disease and environmental factors such as temperature and salinity changes that place a large amount of stress on the corals and, if continued, often lead to bleaching. While there has been limited research conducted on the feeding preferences of *A. planci* in relation to healthy and stressed coral, some studies have looked at the response of other corallivorous organisms to stressed coral. From the limited observations that have been made, it has been noticed that some animals are strongly attracted to damaged, diseased, or bleached coral. A study conducted on the prey selection of obligate coral-feeding wrasse in response to small-scale disturbance revealed that adult male *Labrichthys unilineatus* consumed a larger amount of damaged coral tissue than healthy tissue, despite its small abundance (McIlwain, 1997). Coral colonies with damaged tissue were strongly selected for and feeding rates dramatically increased in areas that showed significant physical disturbance (McIlwain, 1997). This is one example of coral predators selectively feeding on stressed coral tissue even when healthy coral tissue is more abundant.

Another study showed that corallivorous reef fishes, specifically in the Chaetodontidae (butterflyfish) family, selectively feed on coral lesions associated with black band and brown band disease (Chong-Seng, 2011). Despite the tiny percentage of areas that were affected by these diseases, the fish chose to feed on the lesions over the much more abundant and accessible healthy coral tissue (Chong-Seng, 2011). Finally, one of the few studies that have been conducted involving *A. planci* and its preference for healthy or stressed coral showed that this predator survived on bleached coral just as well as healthy coral. After a bleaching event, Glynn (1985) showed that other coral predators declined in population density after a bleaching event, but the relative effect of predation by *A. planci* intensified.

Other studies have shown that the symbiotic crustaceans that live on the corals migrate off coral colonies that have been bleached or stressed in some way; this could justify the reason why a predator that is strongly deterred by these coral associates, like *A. planci*, may strongly select stressed coral as prey (Stella, 2011; Tsuchiya, 1999). Other reasons for this feeding preference have been suggested, including the loss of nematocysts on stressed or damaged coral, or the release of mucous or some other chemical signal that is an attractant to predators (McIlwain, 1997).

1.5 Justifications and Aims of Study

In this study, we examined how coral stressing plays a role in the feeding preferences of *A. planci*. This is an important area of study because of the recent bleaching events that have been occurring on reefs worldwide, leading to massive amounts of stressed coral. By determining the extent to which predators prefer stressed or healthy coral, we can then examine possible reasons behind these preferences, and analyze ways to deter predators from devastating coral reefs when in a weakened state. The null hypothesis for this study would be that *A. planci* chooses to prey on the healthy and stressed coral an equal number of times. While many previous studies have examined general effects of coral bleaching and coral predator feeding patterns, there has been limited research conducted on *A. planci* and its predation habits on stressed coral. Since *A. planci* can have such devastating effects on coral reefs, however, they are a key organism to study. Their abundance makes them a feasible study species and results from the study can help answer the question of how the feeding preferences of coral predators may be influenced by the level of stress or health of their prey. This, in turn, can provide useful information from which we can make predictions of the future health and status of coral reefs.

2.0 Materials and Methods

2.1 Study Site

All research was conducted at the Lizard Island Research Station between November 1st and November 16th, 2011. Lizard Island (14"42'S; 145"30'E) is a granitic island on the Great Barrier Reef, located roughly 30km from the coast of North Queensland, Australia and 18km from the Outer Barrier reef. Over the course of the study, eight *Acanthaster planci* specimens were collected from Big Vicki's reef, a large patch reef with an average depth of about 5 meters. All starfish were collected by retrieving the animal with tongs and placing it in a bucket with a secure lid. Coral colonies were collected from several reefs in the Lagoon, including the reef crest near Bird Islet (approximate average depth of 2 meters). These were either picked up off the reef if already loose or chiseled off and placed in a plastic bag for transport back to the research station. After the initial collection, specimens were transferred to large holding tanks in the outdoor aquarium of the research station, where they were kept when not involved in feeding trials. All the individual feeding trials were conducted in five large, circular tanks with running saltwater and oxygen sources. Carrying out each feeding trial in individual tanks allowed us to control for all factors in the experiment and also allowed us to conduct separate and simultaneous trials in each of the tanks.

2.2 Study Species

This study examined the feeding preferences of the species of sea star, *Acanthaster planci* between healthy and stressed specimens of *Pocillopora damicornis*. *A. planci* are coral predators that feed on many different corals in the wild, but studies have shown that *P. damicornis* is one of their preferred species of prey (Pratchett, 2001). Because of their destructive effects on coral reefs, we chose to study *A. planci* in order to analyze what conditions corals are most likely to be fed upon and what reasons may be influencing the coral predators to target them. There is a large amount of *A. planci* on the reefs around Lizard Island and they have a profound effect on the coral cover when not kept in check, so their abundance allowed us to collect them easily and conduct a feasible study. The specimens of *A. planci* ranged in size from 24 cm to 45 cm, but were chosen because they were all visibly mature and healthy.

In total we collected 21 heads of *P. damicornis*, each with an average diameter of 20cm. Each colony was chosen for its relative size and health conditions. Even though some of the colonies would become stressed and potentially bleached, the initial status of the coral was mainly standardized so as to attain comparative levels of stress.

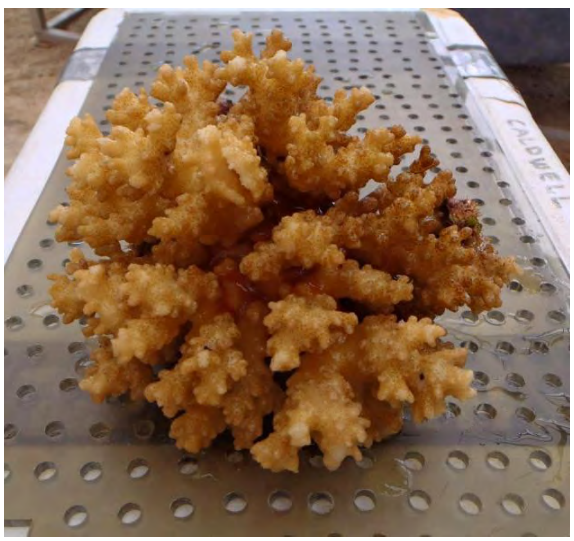

Figure 1: Healthy *P. damicornis*

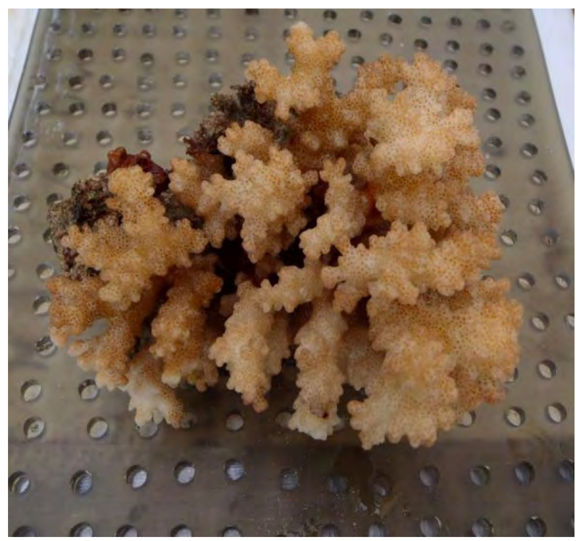

Figure 2: Stressed *P. damicornis*

During collection, the invertebrates in the coral colonies were kept in the coral, and then removed once the corals were placed in the holding tanks. Mating pairs of the coral crabs, *Trapezia cymodoce,* were kept in a separate tank on unused coral heads. These organisms live in a symbiotic relationship with many corals and are a strong deterrent against coral predators like *A. planci*. Previous studies have shown that coral predators strongly favor corals without these coral crabs and will often avoid colonies with the antagonistic symbionts (Pratchett, 2001). As a minor part of the study, we looked at whether the crabs' ability to deter the starfish changed depending on whether they were living on healthy or stressed coral. This allowed a comparison to be made between the results from the trials without the crabs. In the single trial we conducted with crabs, a mating pair of *T. cymodoce* that had been kept on a healthy coral colony was placed on the healthy coral specimen, and a mating pair that had been kept on a stressed colony was placed on the stressed coral. All animals used were removed from the coral, even if they would be placed back on it, so as to control for the amount of stress the crabs were experiencing. This allowed us to look at how their behavior was affected solely by the status of their coral hosts.

2.3 Data Collection

Approximately 24 hours before the start of a trial, the coral heads that were to be stressed were submerged in a bucket of freshwater for two intervals of duration two minutes. Between the first and second freshwater submergence, the corals were returned to the saltwater holding tanks for at least 12 hours. We experimented on the appropriate length of time to submerge the corals, deciding that two intervals of two minutes stressed the coral an appropriate amount, but allowed the coral to recover after the study. These stressing events often lead to the bleaching of the coral heads, but the extent of bleaching varied across individuals and their responses to the stressing event. However, whether fully bleached or not, all the corals were appropriately stressed after their exposure to freshwater. Freshwater bleaching has been a prominent issue in places such as the Keppel Islands located in the southern Great Barrier Reef. The reefs around these islands have been inundated with freshwater from flooding events, resulting in a large amount of bleaching on the shallow coral reefs (Woesik, 1991). As a justified method of bleaching, freshwater stressing was an efficient and reliable technique to prepare the experimental coral colonies.

The experimental design was a simple two-choice set-up. After the second submergence in freshwater, the stressed coral was placed on one side of a tank and a healthy coral was placed on the opposite side. A single starfish was randomly selected and placed in the center of the tank.

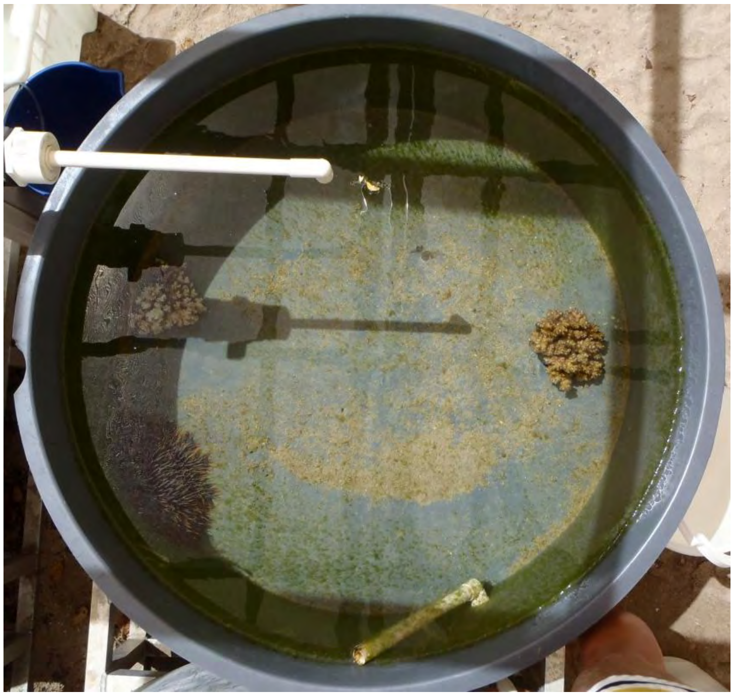

Figure 3: An experiment in progress; a healthy *P. damicornis* (right) and a stressed *P. damicornis* (left), with an *A. planci* specimen resting on the near side of the tank.

Observations were made every hour throughout the day, until approximately 11:00pm at night. Observation times were determined because of noted behavior of *A. planci*; while they are generally nocturnal animals, they have often been observed to feed during the daylight hours

(Davis, 2008). Trials were ended as soon as an animal chose a coral and began feeding on it. The starfish was then moved back to the holding tank. Five feeding trials were conducted at once and they were timed so that new trials could be initiated as soon as others were completed.

2.4 Data Analysis

All data was compiled and graphs were completed in Microsoft Excel. After determining the total number of trials for each specimen, the proportion of trials that resulted in the choice of healthy coral, the choice of stressed coral, and the proportion of trials that ended in no choice were determined. The average proportion of trials resulting in bleached and healthy corals eaten was graphed, while the no choice category was also analyzed. We determined the total number of healthy and stressed coral heads used over the course of the study, and then found the proportion of corals in each category that were eaten by *A. planci*. We then analyzed the feeding trials of each individual starfish, looking at the individual preferences and how many corals each animal preyed upon. Finally, we measured the diameter of all the *A. planci* specimens to see if there was a correlation between the animals' size and feeding frequency. The data was then exported to Statistica 10 where a T-test for Independent Samples was run, analyzing the average proportions of trials resulting in bleached and healthy corals eaten. A Chi-square test was also run, pooling all the data and using all three possible end-results of the trials (healthy, stressed, and no choice) to see whether the trends in the data were significant.

3.0 Results

3.1 Feeding Trials

A total of 32 trials were completed, each consisting of one night, with 7 *A. planci* specimens used during the experiment. The average proportion of trials that resulted in *A. planci* feeding on the stressed corals was significantly higher than the average proportion of trials that resulted in the healthy corals being chosen first. There was no significant difference between the average proportion of trials resulting in no choice made and the average proportion of trials resulting in the choice of stressed coral. However, there was a significant difference between the average proportions of trials that ended in the choice of healthy coral versus no choice. The average proportion of times a starfish chose to feed on the healthy colony before the stressed colony was only 0.05 (± 0.048 SE). Out of the 32 trials, only one ended in a healthy coral preyed upon instead of a stressed coral. The average proportion of trials that ended in the stressed coral heads preyed upon was 0.46 (± 0.079 SE). This is approximately 9 times higher than the proportion of healthy corals chosen, and almost 50% of the total number of trials. 14 out of the 32 trials resulted in the stressed corals being preyed upon by *A. planci*.

The final category consisted of the average proportion of trials that resulted in the starfish making no choice to feed upon either coral head. This was the highest proportion (0.49 ± 0.11 SE) of trials, but only slightly higher than the proportion of trials that resulted in the starfish feeding on stressed coral. There were relatively small standard errors for the stressed and healthy coral categories, but the larger standard error in the no choice category is a result of more variation in the observed numbers of trials ending with no choice (Fig. 4).

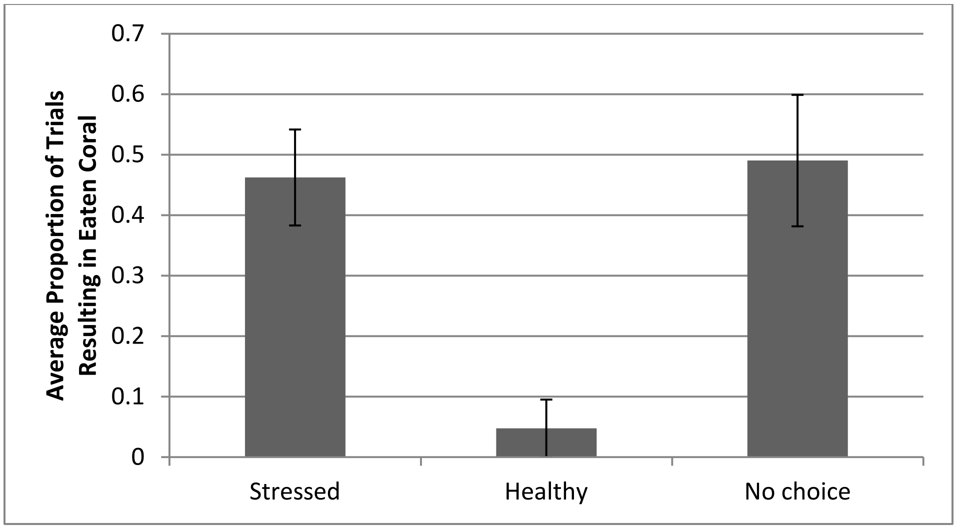

Figure 4: Average proportion of trials resulting in the *A. planci* choosing to prey upon stressed coral, healthy coral, or no coral at all.

3.2 Total *P. damicornis* Used and Eaten

Over the 32 trials, a total of 6 healthy coral heads were used and a total of 15 stressed corals heads were used. The discrepancy between the numbers of corals used and the number of trials is a result of the large number of trials where neither coral was preyed on. Out of the 6 healthy corals used, only 1 of them was fed on by *A. planci*. 14 of the 15 stressed coral heads were preyed on by the starfish. The total number of stressed corals used in the trials was more than double the total number of healthy corals used, while the number of stressed corals eaten was 14 times larger than the number of healthy colonies consumed. A significantly larger proportion of stressed corals were eaten than the proportion of healthy corals chosen. The total number of corals that were used in each category depended on how often the starfish fed on them (Fig. 5).

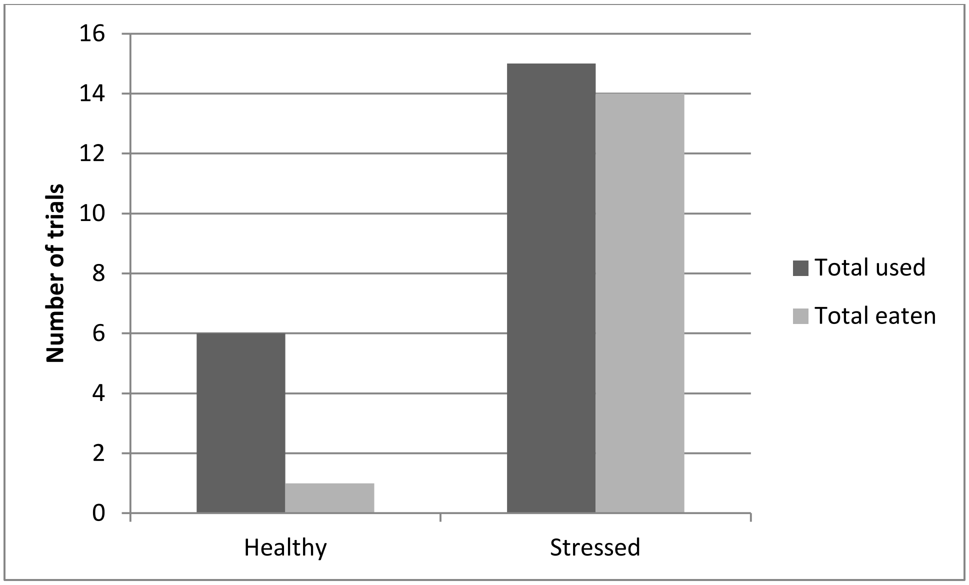

Figure 5: Total number of healthy and stressed corals used in all trials and the total number of healthy and stressed corals consumed by *A. planci*.

3.3 Feeding Choices of Individual *A. planci*

A total of 7 starfish fed on corals, each having a number of replicates ranging from one to three trials, depending on the length of time each starfish took to complete a trial (the faster the animal made the choice of prey, the easier it was to complete the goal of three replicates). Only one *A. planci* (#2) chose to feed on healthy *P. damicornis*, while all the other specimens either chose to prey on the stressed coral, or did not feed at all some nights. Starfish #5 had the greatest number of trials without choosing either coral head (5 trials), while starfish #2 had the least number of trials resulting in no choice between the corals (0 trials). This starfish fed on a coral in every one of its trials: once on the healthy coral and twice on the stressed coral. Starfish #4 had the largest proportion of trials resulting in a choice of stressed coral. Out of 4 trials, 3 of these resulted in the choice of stressed coral. The smallest proportion of trials resulting in a choice of stressed coral was that with starfish #7; out of 5 trials, the starfish chose to feed upon the stressed coral only once.

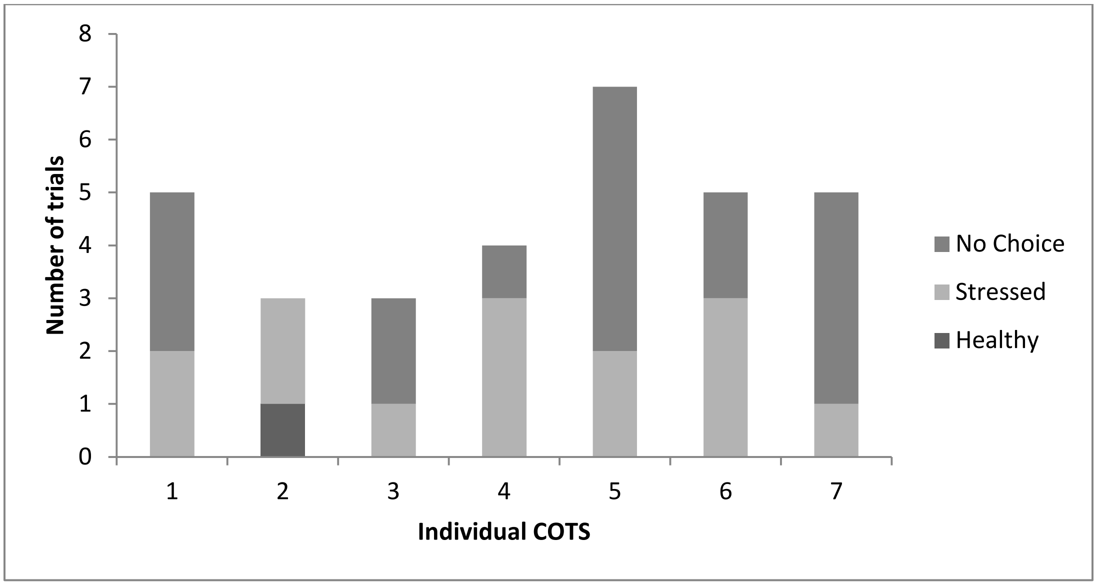

Figure 6: Number of trials for each individual *A. planci* specimen, divided into the number of trials resulting in a feeding choice of stressed coral, healthy coral, or no choice.

3.4 Size Range of *A. planci*

The size of the *A. planci* study organisms ranged from 24 cm in diameter to 45 cm in diameter. The diameter of the animals was measured in order to determine whether there existed any correlation between the size of the starfish and its feeding frequency and preferences of the coral. While there were significant differences in the size of the starfish, a maximum variation of 21 cm in diameter, there was no direct correlation with the feeding habits of the animals. The largest starfish (#2) fed the most frequently (0 trials resulting in no choice), while the smallest starfish fed the second most frequently (3 choices out of 4 trials). The other larger starfish (#1, #6, #7) had the same number of trials, but varied greatly in the length of time they chose to feed on the coral and the number of choices they made. There was no correlation between the size of the predator and its preference between healthy and stressed coral. There was only one instance of healthy coral chosen over the stressed coral, and this occurred only once by the largest starfish (#2). After this initial event, the healthy *P. damicornis* was never again chosen over the stressed coral by any of the study organisms (Fig. 7).

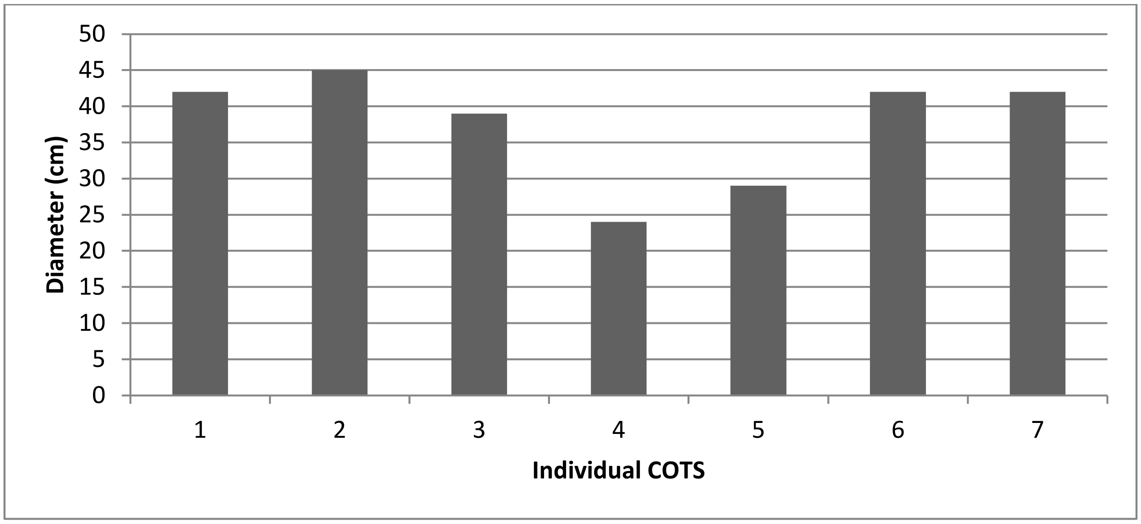

Figure 7: Diameter (cm) of each individual *A. planci* specimen used in the feeding trials.

3.5 Statistical Results

The results of the T-test for Independent Samples showed the difference between the average proportions of trials that resulted in each choice. The difference between the average proportion of trials resulting in the choice of stressed coral and those resulting in the choice of healthy coral was significant (T-value = $2.77_{df\ 12}$, p = 0.016). The results of the frequency distribution test (Chi-square test) test were also significant ($\chi = 13.574_{df\ 2}$, p = 0.0011).

4.0 Discussion

4.1 Feeding Trials

The significant differences found between the average proportion of feeding trials that resulted in the *A. planci* specimen choosing the stressed coral and the average proportion of trials the starfish chose the healthy coral could be due to a number of factors (Fig. 4, Fig. 5). Pratchett (2007) conducted a study on the feeding preferences of *A. planci* between different species of coral, and found that the animals showed a significant order of preference. He suggests a variety of reasons that may be driving these choices: nutritional content of the corals, coral growth forms, coral defenses, or previously learned feeding behavior of the starfish (Pratchett, 2007). While some of these possible explanations for the starfish' coral prey choices may be similar to the reasons behind their preference for stressed coral over healthy coral, several of them do not seem applicable.

There has been very limited research conducted on the nutritional content of different coral species; however it seems reasonable to assume that healthy coral would have greater nutritional value than stressed or damaged coral tissue. If this were true and *A. planci* consistently followed the optimal diet theory, where the animal chooses prey that would give it the maximum net amount of energy (Ormond et al., 1976), then the prediction would be that *A. planci* would consistently choose to prey on the healthy coral. However, the predator only chose to prey on the healthy coral once during the entire experiment, and consistently chose the stressed coral the remainder of the time. It seems unlikely that the growth form of the coral would be a preferable factor either because the corals used in the experiment were the same species and size, thus very similar in form. It is possible that there could be some previously learned behavior of these creatures, where they choose to prey on stressed corals when available in the wild. However, even this learned behavior must derive from some appealing factors of the stressed coral that influences the preference over the healthy coral.

One of the other factors that Pratchett (2007) mentioned may have influenced the order that *A. planci* ate the different species of coral was differences in the coral's defenses (nematocysts, mesenterial filaments, and host symbionts). If a coral is stressed or damaged, their nematocysts (a venomous cell structure that fires a toxin in order to catch prey and ward off predators) may be less effective, thus allowing a predator to prey on them without harm. The mesenterial filaments, extending structures that contain nematocysts, may also be weakened or damaged in a stressed coral, resulting in an easier meal for a predator. These factors could both contribute to the reason *A. planci* consistently preferred to prey on stressed coral over healthy coral when given the chance.

Several studies have been conducted that examine the role of the coral symbionts in the deterrence of coral predators and how coral bleaching affects their behavior. Pratchett (2001) found that *A. planci* have very specific feeding preferences over 6 different corals when coral symbionts were present. However, after removing the coral associates, the starfish readily consumed all 6 species of coral (Pratchett, 2001) This leads to the conclusion that any influence on the feeding preference by nematocysts, mesenterial filaments, nutritional content, or growth form must be quite insignificant, at least compared to the influence of the coral symbionts (Pratchett, 2001). Pratchett found that the *Trapezia* and *Tetralia* coral crabs were the most effective at deterring *A. planci*; one could then conclude that corals without these associates would be the most vulnerable.

These species of coral crabs, especially the *Trapezia*, are found much less commonly on bleached or stressed coral colonies, and have been observed to migrate off these unhealthy colonies if given the chance (Tsuchiya, 1999; Stella, 2011) Stella (2011) also found that the bleaching of a host-colony coral leads to reduced fecundity in the associated *Trapezia* crabs. As studies have shown that these crabs play a major role in the protection and maintenance of their host corals, any detrimental effect on the crabs from a stressing event could lead to further predation on the coral.

In this study, all the recorded feeding trials were conducted without any coral symbionts on the corals; we were simply looking at the preference of *A. planci* to healthy or stressed coral. However, during the study, we ran an additional feeding trial where we placed a healthy mating pair of *Trapezia cymodoce* on the healthy coral, and on the stressed coral, we placed a mating pair of *T. cymodoce* that had been kept on bleached coral. The *A. planci* in this trial chose to feed on the stressed coral during the first night. At the end of the trial, the stressed crabs had relocated to the healthy colony; this migration could have occurred because the crabs preferred to live on the healthy coral, or they may have been forced to move off the stressed colony when the starfish began to feed. While the results of this trial were purely observational, they were still relevant and interesting to think about; the starfish' preference for stressed coral may be so strong that it overrides any of the above-mentioned factors, or the crabs that had been living on the stressed coral were indeed weaker defenders than those living on the healthy coral. Perhaps *A. planci* has learned that the coral crabs are found less often on stressed corals, thus they choose to feed on these corals first as an easier option.

Besides differences in coral nutritional content, growth forms, and defense mechanisms, studies have found that damaged or diseased coral may send out stress signals or chemical cues that are an attractant for coral predators (McIlwain, 1997). As observed in our study and in previous studies, corals that are under a significant amount of stress release a noticeable amount of mucous that may notify predators of the coral's vulnerable state. Studies have shown that diseased corals are voraciously preyed upon by corallivorous fishes; the diseased colonies may be releasing some sort of stress signal that these fish receive and use to target the weakened coral. While any of these factors could be potentially influencing the feeding preference of *A. planci* for stressed coral, it seems likely that it is a combination of several of them. It has been shown that the presence and health of the coral symbionts play a significant role, and it also seems feasible that other defenses such as nematocysts and mesenterial filaments would be less potent in weakened coral. Finally, given the numerous observations of corallivorous fishes attacking diseased and damaged coral, it seems likely that the mucous of stressed colonies and possible other chemical signals attract the predators and influence them to prey on the stressed coral. In relation to climate change and mass bleaching events in the wild, these results could mean that coral predators would benefit from large areas of stressed coral reef. While the predators would have their preferable prey however, it means that the weakened coral would have an even more difficult time recovering to full health.

Other studies have shown that anthropogenic influences may not only be a main cause of climate change and coral bleaching, but they may also be responsible for the increasingly frequent outbreaks of *A. planci* in the wild. While the primary causes of *A. planci* outbreaks have been under great scientific debate, one of the suggestions is that these events are linked to terrestrial run-off and increased nutrients in the water that feed *A. planci* larvae (Brodie, 2004). Brodie (2004) conducted a study that focused on the Great Barrier Reef, and examined how nutrient run-off from rivers results in roughly double the concentration of large phyto-plankton in the waters of the reef. His study shows that *A. planci* larval development, growth, and survival increases almost ten-fold when large phyto-plankton concentrations are doubled in the area (Brodie, 2004). This means that not only are humans responsible for the environmental changes that result in mass events of coral bleaching, but anthropogenic factors, such as pollution and the use of pesticides on land, may be causing the outbreaks of *A. planci* that are so devastating to already weakened and threatened coral reefs.

4.2 Individual *A. planci* Data

The results that display the preferences of each individual *A. planci* reflect some of the behavioral differences between the starfish. Various eating frequencies between the starfish resulted in the wide range of values in the no choice category of the trials. These discrepancies with feeding frequencies could have been due to the adaptability of the animal to adjust to the situation and the amount of stress it was feeling. All individuals were observed to feed at night, which reflects the nocturnal nature of the animals, but disagrees with observations that have been made in the wild where smaller *A. planci* specimens feed only at night, when they have a decreased chance of predation, but larger starfish have been observed to feed frequently during the daylight hours as well (Davis, 2008)

Because of the broad range of sizes of the *A. planci* specimens used in the study, we examined whether there was any size correlation with feeding frequency or preference. By comparing the range of sizes (Figure 7) to the results of each starfish' feeding trials, one can see that there is no obvious trend or correlation. While the largest *A. planci* specimen ate the most coral in the least number of trials, there was no further pattern of larger *A. planci* consuming coral at a faster rate or having a different preference to smaller *A. planci* specimens. Since this was the only factor that was not standardized in the experiment, we can conclude that the reason for these specific feeding preferences stems from features of the coral itself or previously learned behavior of the predator.

4.3 Improvements and Future Research

While numerous studies have looked at how climate change and other anthropogenic influences affect coral reefs, there has been limited research on how coral predators respond to affected areas of the reef. By studying the feeding preferences of *A. planci* on stressed and healthy corals, we obtained significant and interesting results, but this study could be improved by having a larger sample size and a longer period of time to collect data. A larger sample size of *A. planci* would allow one to confirm that any trend or tendencies observed reflects the preferences of the entire species, and not just those of several individuals. It would also be beneficial to have a longer sampling period so as to run more trials and obtain more data to analyze. If we had more time, we could also look at different methods of stressing the corals, besides freshwater bleaching, to make sure predation responses are consistent towards any stressed coral.

A longer study period would also allow one to look at the question of how stressed corals may affect the ability of the coral symbionts to deter *A. planci*. We only had time to run one trial because we needed to gather data on the main feeding trials, but this could be a valuable area for further research. Previous studies have shown that bleached host corals have a detrimental effect on the fecundity and health of the coral crabs, but it would be worthwhile to find out whether their defensive behavior would be affected as well. If crabs living on stressed corals were unable to deter *A. planci* as well as those living on healthy coral, it would provide a possible explanation to the findings that *A. planci* selectively prey on stressed coral. Other future studies could look at whether other coral symbionts (e.g. snapping shrimp or other species of crabs) have any effect on the feeding preferences of coral predators. This has been mentioned as a possibility, but there have been limited studies conducted in the area. Further research could also look into the specific factors that influence the feeding preferences of *A. planci* and how these predators may be able to sense and seek out stressed or weakened coral in the wild.

5.0 Conclusion

Based on our results, *A. planci* displays a strong preference for stressed coral, even when healthy coral is abundant and available. The significant findings obtained from the feeding trials disproved the hypothesis that *A. planci* would consume both corals equally; of the trials where feeding was observed, the preference for stressed coral was much higher than expected (50-50). Because of this clear trend, one can conclude that the reasons behind this preference must consist of more than a preference for the nutritional content or growth form of the coral. All corals were standardized in the experiment, leading one to the conclusion that *A. planci* prefer the stressed coral because of its weakened defenses and relations to its coral associates or because the starfish have some previously learned behavior that influences the choice. Also, when the results of this study are placed in conjunction with the results of other studies involving corallivores preying on diseased or damaged corals, it seems very feasible that stressed corals release some sort of chemical attractant and mucous that predators use to target the weakened prey.

The findings that *A. planci* have an apparent preference for stressed coral could have significant effects on the status of coral reefs in the wild. Even after a mass bleaching event, much of the coral community can recover and thrive once again. However, if an outbreak of *A. planci* happened to occur in the same area as a large stressing event, the predators could devastate the entire reef, preventing any chance of recovery within the coral community. Because so little research has been conducted in this particular area, it is hard to say what kind of impacts these results may have in the wild. However, the fact that *A. planci* displays such a significant preference for stressed coral opens the door for further studies on the predation habits of coral predators and what kind of impacts their activity may have on areas of threatened coral reef.

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