Sanctuary zones: Do they provide refuge and safety for *Tridacna maxima*?

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INTRODUCTION

Protecting small habitat areas using sanctuary zones is “One of the oldest and most versatile tools used across the ocean for the conservation of reef resources, in particular for invertebrates” (Dumas 2013). Inside the Ningaloo Marine Park are certain areas called sanctuary zones. A sanctuary zone is an area of the ocean set aside for conservation. The sanctuary zones protect the habitat and natural beauty of the reef from human intrusion. The Ningaloo reef as a whole is a marine park that is run and taken care off by the government of Western Australia’s Department of Parks and Wildlife (DPaW). While humans are allowed to go and explore these sanctuary zones, they are not allowed to remove or destroy any animals or the habitat. The Ningaloo Marine Park has a total of twenty-one sanctuary zones, each measuring 50 meters by 15 meters (DPaW 2014). Each sanctuary zone contains a species or number of species that are endangered, threatened, or unique to the Ningaloo Reef. Each site’s name came from the area in which they are located. Since 2014, only thirteen of the twenty-one sanctuary zones were sampled for clams by CIEE-Perth, the academic program that started and continues the governmental study, while six sites were outside the sanctuary zones. These six sites allow for fishing and are more susceptible to human intrusion and damage, despite being protected by the marine park boundaries.

A variety of organisms such as corals, blue swimmer crabs, and the small giant clam, *Tridacna maxima*, are vital to the ecosystem of the reef. *T. maxima* lives along the Ningaloo reef and plays diverse ecological roles for coral reefs (Neo 2014). The tissue of the clams provide a source of food for scavengers and predators. Clams and zooxanthellae, single-cell protozoans that live in the cytoplasm of marine invertebrates, have a mutualistic relationship, in which the clams provide the zooxanthellae a home and protection from predators while the zooxanthellae provide the clams with energy through the process of photosynthesis. Clams produce calcium carbonate, the backbone for reef framework. While obtaining energy through the zooxanthellae, the excessive richness of nutrients causes a boom in algae growth.

In addition to direct benefits to the reef ecosystem, *T. maxima* is a great indicator of determining the reef’s overall health. This study was performed to determine if sanctuary zones are beneficial in protecting the giant clam population in the Ningaloo Reef. Previous studies (Black 2011) have researched the population density at twenty sites in the marine park, thus discovering that abundance varied among the sites. Few sites contained large numbers of clams, however most sites contained average or below average number of clams. While Black (2011) looked at abundance and mortality at twenty random sites within the Ningaloo Marine Park, the results in the context of sanctuary zones were not examined. This study is an expansion of the previous study by examining the significance of sanctuary zones on *T. maxima* abundance.

The *T. maxima* clams sampled at Ningaloo were observed for their abundance and size, as well as the habitat in the surrounding area. This study focuses on the abundance of clams from inside and outside sanctuary zones. It was hypothesized that the abundance of clams will have greater numbers inside the sanctuary zones. This hypothesis stems from the fact that clams are better protected inside the sanctuary zones from disturbances in their habitat. The regions outside of the sanctuary zones have more fishing and human activities. The final results of this study are to determine if sanctuary zones are ultimately better habitats and ecosystems for the *Tridacna maxima* when compared to non-sanctuary zones.

Methods

In order to record the abundance of clams present in a given area, a square quadrant of 15 by 50 meters was plotted. Whether the quadrant contained the presence of a clam was unknown at the time of plotting. This semi-haphazard method was chosen in order to limit the potential for human bias. The sites were predetermined by Dr. Kate Sprogis and the

government of Western Australia. The sites sampled were the same sites sampled in previous years by the Marine ecology program through CIEE-Perth. Of the nineteen surveyed sites, thirteen were in sanctuary zones and six were outside the sanctuary zones. Twenty-five separate quadrants were sampled at each site, totaling to twenty-five square meters of area sampled. Each quadrant was one square meter. In order to determine if a clam was present in the given quadrant, a bathyscope was utilized to examine the ocean floor if the water was clear. Snorkeling to look for clams in a quadrant was necessary if the water was too deep or gave rise to poor visibility. The data was recorded on waterproof sheets labeled with each site, date, and time in which the session began and ended. The data was then recorded in a HyperSQL database using LibreOffice Base. The database was used for the statistical analysis, as well as for the use of future researchers.

Using the statistical program RStudio, two two-sample t-tests of unequal variances were conducted, comparing data inside sanctuary zones to data outside sanctuary zones. This was completed for the 2014 data and the 2016 data. The two-sample t-test of unequal variances compared two sets of data with unknown or unequal variances. Next, a linear regression was completed, comparing the sanctuary zones between 2014 and 2016. The resulting data points were graphed with a regression line. The linear regression was completed in order to predict the next year's data. This process was repeated for sites outside of the sanctuary zones as well. The data collected in 2014 was led by CIEE-Perth, along with the students involved with the summer study abroad Marine Ecology program at Murdoch University, WA.

A total of sixty-nine clams were counted in 2014, with fifty-two residing in sanctuary zones and seventeen residing outside of sanctuary zones. In 2016, thirty-nine clams were counted, with twenty-six clams being in sanctuary zones and thirteen clams being outside of sanctuary zones. More clams were counted inside sanctuary zones than were counted in non-sanctuary zones. The average number of clams per site was fairly even in 2016, but favored sanctuary zones in 2014. The variance had a wider range in 2014 than 2016.

	Clam 2014 In Sanctuary Zone	Clam 2014 Out Sanctuary Zone	Clam 2016 In Sanctuary Zone	Clam 2016 Out Sanctuary Zone
Mean	4 clams	2.8 clams	2 clams	2.2 clams
Median	1 clams	0.5 clams	1 clams	0 clams
Mode	0 clams	0 clams	0 clams	0 clams
Variance	87	26.2	5.7	12.2
Standard Deviation	9.3	5.1	2.4	3.5

For the two-sample t-test of unequal variances comparing the abundance of clams in 2014, the p-value was 0.730. For the 2016 data, the p-value was .918. The linear regression comparing the two years in versus the two years out also showed no significance. For data inside sanctuary zones, the r-squared value was 0.152, with an equation of Y=X0.09962+1.60153. For data outside sanctuary zones, the r-squared value was 0.164, with the equation Y=X0.2764+1.3834.

Table 1: Summary Statisitcs from the four sets of data

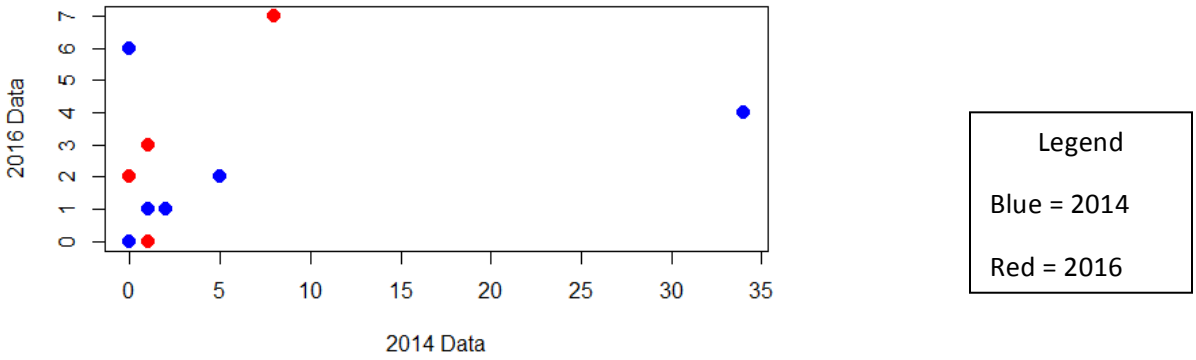

Figure 1: The graph compares the abundance of clams inside sanctuary zones between 2014 and 2016. No significance was found according to the r-squared value; therefore, no regression line was needed.

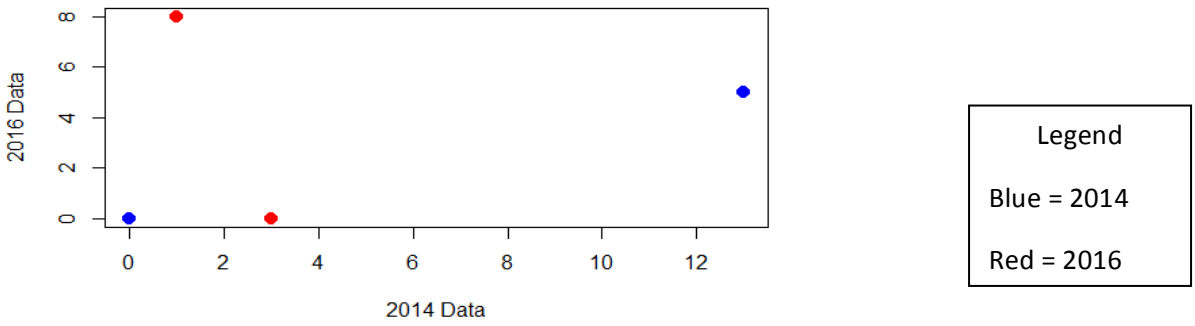

Figure 2: The graph compares the abundance of clams outside sanctuary zones between 2014 and 2016. No significance was found according to the r-squared value; therefore, no regression line was needed.

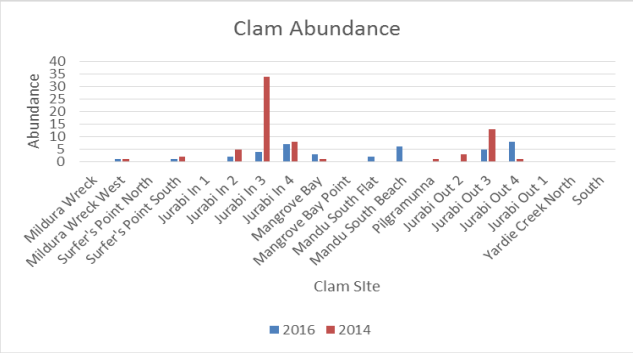

Figure 3: The graph displays a comparison in clam abundance between 2014 and 2016. At certain sites such as Jurabi In 3 and Jurabi Out 3, clams abundance decreased from 2014 to 2016, while at other sites such as Mandu South Beach and Jurabi Out 4, clam abundance increased from 2014 to 2016.

DISCUSSION/ CONCLUSION

The main finding from the sampling was there was no significant difference between the abundance of the clams with respect to whether or not they live in sanctuary zones. The two separate years sampled were 2014 and 2016. 2014 was sampled due to a major flood in the southern region of the marine park, destroying many suitable habitats for the *Tridacna maxima* to thrive. However, even in 2014 there was no significance in the abundance of clams when comparing sanctuary populations to non-sanctuary populations. In 2014, the mean for the amount of clams was larger in sanctuary zones, but in 2016, clam populations were more abundant outside of sanctuary zones.

The p-values for the t-test were 0.730 for 2014, and 0.918 for 2016. Neither of these values showed any significance when comparing inside and outside of sanctuary zones. Then, linear regressions were run to determine if 2014 was able to predict 2016, also proving insignificant. The r-squared values were 0.152 for inside, and 0.164 for outside sites. Due to no significant data, a regression line was not plotted on the first two graphs. Figure 3 shows the comparison of abundance between 2014 and 2016. Other than “Jurabi In 3”, “Jurabi Out 3”, and “Jurabi Out 4”, there was not much variation in clam abundance. Jurabi is at the northern tip of the reef and has a turtle sanctuary. The increase in tourism due to the turtles might have played a role in the decrease of clam abundance. The Jurabi sites indicate that precise location within the park makes a difference and should be further investigated to determine if location plays a factor in clam abundance. Black (2011), showed that most of their sites contained low numbers of clam abundance. However, “low” for the Black paper averaged to about 110 clams. The highest clam total that was found in a site this year was 8 was at “Jurabi Out 4”, a non-sanctuary zone. Black’s paper looked at a much larger amount of area, while this study was limited to 25 square meters using quadrants. With no significant difference for clam abundance when comparing sanctuary and non-sanctuary zones, the zones appear to be ineffective in protecting the clam population. The entire Ningaloo Reef is protected by the Ningaloo Marine Park, thus making the sanctuary zones not as effective as if the reef was not a marine

park. The non-sanctuary zones are still protected by the marine park, just not to the same degree as the sanctuary zones. Sanctuary zones inside a marine park may be redundant, however an interesting further research topic would be to test abundance in sanctuary zones that are not located inside a marine park.

Potential errors or biases that occurred are: whether a clam might have been buried under the sand, not enough area of the sites being surveyed, human bias, and skewed data due to the 2014 flood. Human bias included throwing the quadrant in an area where a clam was previously seen. The haphazard method involves throwing the quadrat randomly. If the quadrat was thrown towards a previously seen clam, then human bias comes into effect. Dr. Sprogis wanted the data to have as little human bias as possible, thus requiring that the quadrat be thrown haphazardly. The flood from 2014 wiped out most, if not all, of the clam population in the southern sites. Those sites included Mandu South Beach, Mandu South Flat, Pilgramunna, South site, and Yardie Creek North. While both Mandu sites increased in clam abundance, the other sites did not.

In order to get concrete results on whether or not *Tridacna maxima* help scientists determine the health of the reef, the study should continue for twenty or more years. It takes *Tridacna maxima* about thirteen years to reach maturity and spawn. If clams are given the time to grow, spawn, and repopulate sites along the reef, one might be able to determine the health of the reef, as well as if sanctuary zones help the abundance of the clams. However, another study should be conducted to determine if clam abundance in a marine park is different to or the same as clam abundance outside of a marine park. Since Ningaloo Marine Park protects the entire Ningaloo reef, the question can be asked; is there a significant difference in clam population size when looking at habitats inside and outside of marine parks? In the paper by Hart, 1998, it was discovered that clams growing near the Solomon Islands were able to grow and survive with the right nutrients and protection. While the clams were not grown in a marine park, the survival rate hovered around 40%. A future research possibility would be to compare clam growth and survival in the Ningaloo Marine Park to the results in Hart's experiment.

The aim of the study was to determine if there was a significant difference in clam abundance between sanctuary zones and non-sanctuary zones, with inside sanctuary zones containing the greater population size. The study determined that were was no significant difference between clam abundance inside and outside sanctuary zones at Ningaloo Reef. The study also discovered that there was no correlation between clam populations in 2014 and 2016. As Cassata said in 2008, sanctuary zones provide biodiversity and protection from human intrusion. While the Ningaloo Marine Park protects the entire reef, the sanctuary zones go a step further by preserving the natural beauty of the reef. The *Tridacna maxima* help indicate the health and biodiversity of the reef, thus leading to further research studies along the Ningaloo Reef. With the results discovered in this project, the sanctuary zones offer little to no more protection to the clams than in non-sanctuary zones. However, because the clam abundance is very similar inside of sanctuary zones and outside of sanctuary zones, the reef can be deemed healthy and diverse throughout.

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