

The Effects of human activities on the reef diversity

“A comparison between different sites”

On behalf of:

Has Hogeschool

Written by:

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1. Introduction

1.1 The Philippines as a part of the coral triangle

The Philippines is a republic in South East Asia and contains an archipelago comprising of more than 7,100 islands.

It's part of an area better known as the coral triangle, which expands over an area of approximately 6 million km² containing parts of Indonesia, Malaysia, The Solomon islands, Timor-Leste and Papua New Guinea.

Many researchers in the past have been discussing the actual boundaries of the coral triangle. It was not until the global distribution of marine data at species level was introduced by Veron (1995) that the actual area was defined. It changed the focus of marine protection that was mainly aimed at the Great Barrier reef to the Indonesian-Philippines archipelago.

In addition to the high number of coral diversity which includes 75% of all coral species, it also contains more than 3,000 species of reef fishes, whale sharks, and over 27 species of marine mammals. The high diversity of marine life can be attributed to important geological factors. These factors can include currents, plate tectonics, and ocean temperatures.



1.2 Purpose of research

The goal of this research is to identify the human activities and influences--both negative and positive--on the Sogod Bay coral reefs. In addition to these direct effects, the indirect effects of these human impacts will also be observed. Finally, a comparison will be made between different sites to obtain accurate information on how these human impacts effect the reefs from Napantao and Santa Paz.

1.2 Research question

The main question that will be answered is the following:

Is there a relationship between certain human activities and reef diversity and which of these activities have the greatest effect on the reef diversity?

1.4 Acknowledgments

I would like to thank the Coral Cay Conservation staff members who made this research possible, and give a special thanks to supervisor Kate Longhurst for providing me with the data and her suggestions in my research proposal. Furthermore, I would like to thank all the staff members that made my stay in the Philippines so much more valuable.

I would also like to thank: Rob King and Claire Ogg for keeping the place up and running. The science staff, Tom Appleyard, Alex Ferguson, Sophie England and Thomas Fey for giving the Skills development program and helping out with collecting all the data. Education officer Sammie Euridge for putting all her efforts in teaching all the locals about the beauty and importance of the reef. And all the local staff, for making my stay in the Philippines an experience I will never forget. Without them it wouldn't be possible to keep surveying and to keep the boat running.

Finally, I would like to thank all the volunteers that helped with the surveys and who were always in for a good laugh.

The province in which I have completed this research was hit by typhoon Haiyan just two months after my stay. My thoughts and prayers go out to all the people in the Philippines who have lost their homes and families due to typhoon Haiyan.

2. Background on coral reefs

2.1 What are coral reefs

Coral reefs are large structures formed by the growth of coral, coralline algae, and other organisms that build calcium carbonate skeletons. This complex ecosystem often referred to as "rainforests of the ocean," contains a large diversity of marine species which range from sharks to a wide variety of invertebrate species that live in the shades of the corals. Warm shallow waters, currents and low dissolved nutrient levels are conditions for a coral reef to thrive well.

2.2 Different kinds of coral reefs.

Darwin was the first to distinguish different kinds of coral reefs. In his publication of "The structure and distribution of coral reefs" he explained his "subsidence theory" on how the reefs convert due to geological changes and the accumulation of the calcium carbonate skeletons of the growing corals over thousands of years (Darwin, 1842). The report stated that fringing reefs, barrier reefs and atolls are the three major reef formations (figure 2). His theory was proven to be right due to drillings in Eniwetok Atoll. At approximately one mile the first volcanic rock was found under the coral lime stone (H.S. Ladd et al, 1953).

When a new island rises from the water due to volcanic activities, fringing reefs will form. Along the shoreline of these tropical islands, the water is clear, warm, and low in nutrients. These are ideal conditions for corals to grow.

A barrier reef is created when, over time, the island begins to sink due to erosion and the lack of volcanic activity. Corals tend to grow towards the surface. Over thousands of years as the island sinks, corals, to remain in the clear warm waters, grow on top of the old calcium carbonate skeletons. A lagoon between the island and the barrier reef will gradually form.

As the island sinks further, the corals continue to grow upwards to remain in the photic zone. The coral reef surrounds the lagoon and an easily recognizable, distinct circular shape can be seen. This is known as an atoll.

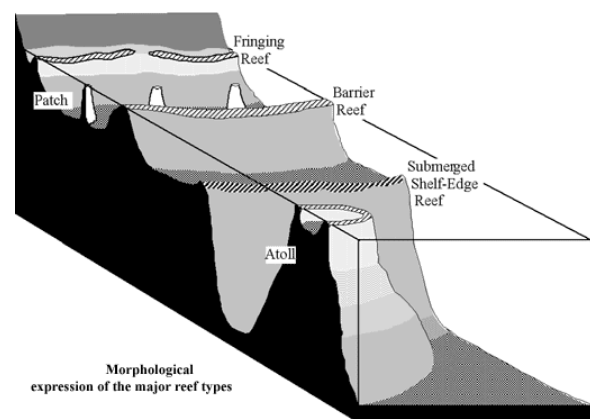
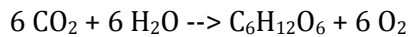


Figure 2. Differences between reef types.
Reprinted from Geological Oceanography
Program (2005) by Morelock J. et al.

2.3 Basic needs for reef building corals

Corals build the reef. In order to do this they need to obtain nutrients to build tissue and to create a calcium skeleton. This skeleton is used for protection and for attachment to the substrate. Corals thrive in waters with low nutrients, they are provided with nutrients by a symbiotic relationship with Zooxanthellae. Zooxanthellae are single-celled plants that use sunlight to provide energy and fix carbon, not only for themselves, but also for the corals they live in. This process is called photosynthesis.

The following reaction occurs during the photosynthesis:

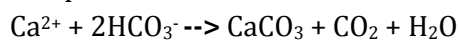


Inorganic carbon (CO_2) is converted to organic carbohydrates which are then used by the corals. Corals can not live only off of these organic carbohydrates. In order to build tissue and the calcium carbonate skeleton, they need nitrogen (N), phosphorus (P) and certain macro elements such as calcium.

In addition to the symbiotic relationship with zooxanthellae, corals have another method to gain nutrients. They extend tentacles, mainly during the night, to feed on organic matter such as plankton and detritus.

Calcium carbonate is produced by corals in order to protect the polyps from predators. Calcium is gained from the water by diffusion and in the calcicoblastic ectoderm (layer between tissue and skeleton) of the coral, "aragonite" a form of calcium carbonate is formed.

This process is called calcification and the following reaction occurs:



Coral reefs can have very high densities of coral, constantly fighting for space on the reef they can harm each other with stinging tentacles.

Most corals can reproduce both asexually and sexually. The sexual reproduction of most corals takes place at a certain time in the year. It is believed that this is triggered by temperature change and lunar cycles.. When the conditions are right a mass spawning event will take place and eggs and sperm are released into the water. Free floating in the planktonic layer and taken away by the current, the larvae will settle on both new reefs and old reefs.

2.4 The coral reef food pyramid

Each ecosystem has a complex food web. Different organisms consume others to grow and reproduce. In the trophic pyramid (figure 3), we can distinguish different trophic levels. Each level of the pyramid has its role in this ecosystem and the higher up in the pyramid the more loss of energy has taken place.

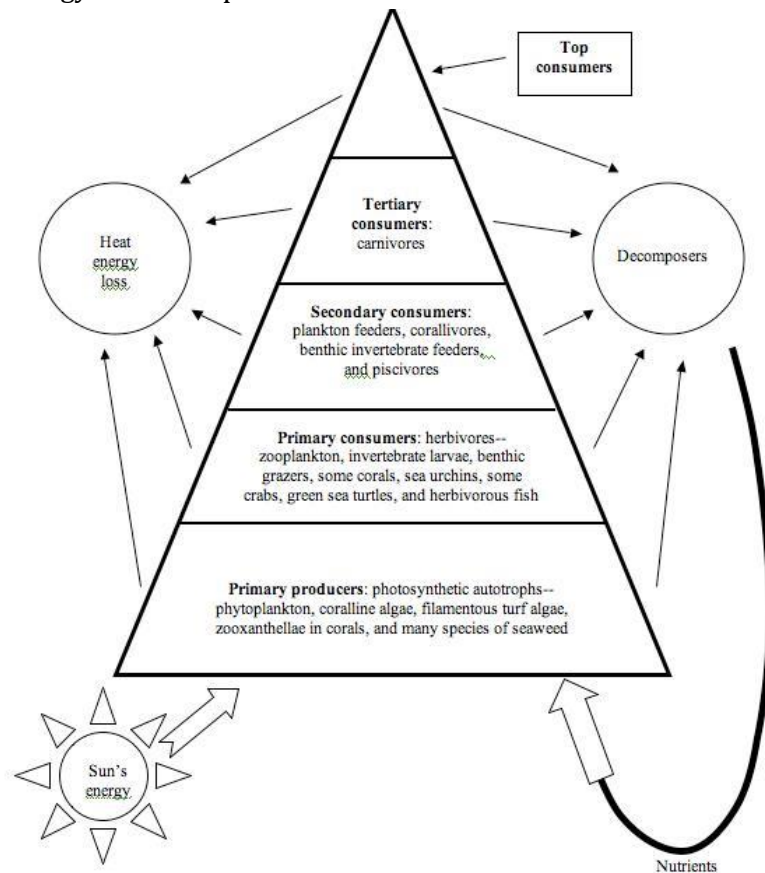


Figure 3. Trophic pyramid of the coral reef ecosystem. Reprinted from coral science (2008) by Rose, A.

The bottom part of this pyramid exists out of primary producers. Primary producers use photosynthesis to gain valuable energy to grow. With sunlight and nutrients they produce sugars and oxygen. In some cases primary producers can be chemosynthetic this means they can get energy without the use of sunlight.

The algae, plankton, and other single-celled primary producers are consumed by the primary consumers. These primary consumers are herbivorous and can include herbivorous fish, urchins, filter feeding invertebrates, and the most abundant group, zooplankton. Secondary consumers are carnivorous, and consist of plankton feeders, corallivores, and piscivores which receive energy from predating on primary consumers. Plankton feeders exist from a wide range of animals such a coral, mantas, and whale sharks. Corallivores, such as Crown of Thorns sea stars or butterfly fishes, predate on coral tissue. Piscivores are carnivores that mainly eat fish.

On the top of the trophic pyramid are the larger marine mammals and fish species. Some examples can include sharks, dolphins, groupers, and tuna.

In reality, this system is more of a complex food web than a pyramid. The result of this is that the removal of species from different trophic levels can result in the phase shift of the reef ecosystem.

3. Human impacts on the reef

Human activities have a major role in the decline of the biodiversity of the coral reefs. Though such activities effect the whole ecosystem directly, most effects are indirect, suggesting a domino effect.

3.1.1 Overfishing

Overfishing occurs when fish are caught in numbers that the population can't reproduce fast enough to replace them. The main cause of overfishing is the demand for food for the growing human population and the demand for live marine fish for the growing aquarium trade.

It disturbs the ecological food chain in many ways because species at different trophic levels are caught.

Large predatory fish such as groupers, snappers, and sharks have been caught extensively over the years, and the amount of sexually reproductive individuals has dropped down significantly. Groupers are predators high up in the food chain. As larger predators, they show slow growth rate and late sexual maturity. Groupers are sex-changers with just a small amount of young males. They reach sexual maturity within 2-6 years (Tupper et al. 2008). This makes them vulnerable for overfishing because male specimens, already in shortage, are caught from the reef. With this shortage of males and larger spawning fish, only small fish can spawn, releasing less eggs than a larger grouper would.

In a study conducted by Ruppert et al. in 2013, it was observed that the removal of sharks resulted in an increase in secondary consumers such as snappers and a consequential decrease in herbivores such as parrotfishes. Herbivorous fish, like these parrotfish, are very important to the reef because they graze on the algae and dead corals. Without these herbivores, the algae would cover new colonies of coral. This can also be described as fishing down food webs. Fishing down food webs may lead to increasing catches in the beginning and then lead to a phase transition associated with declining catches.

When large, highly priced predatory fish decline in numbers, other large fish will be caught. One of these large fish can include the herbivorous parrotfish that lives from the turf algae growing on the reef. Without those herbivorous fish, algae would have the advantage and out-compete corals for space (Munro, 1983).

The Triton's trumpet is a large snail that mainly predaes on Crown of Thorn sea stars that preys on corals. These shells have been heavily collected for decorative purposes. The lack of predation on these Crown of Thorns sea stars would increase their abundance, killing more corals.

For the same reason, giant clams have been removed from the reefs. Giant clams are a biologically important species because of their capability to reduce nutrients by filtering the water.

Even some invertebrates are indicator species for overfishing. Lobsters are valuable species and caught for human consumption.

It's not just the reduced abundance of fish that affects the reef. When fish abundance is reduced, dynamite may be used to increase fish catches. Dynamite fishing is very common in the indo-pacific region. It not only kills fish, but it can blast off large pieces of the reef structure, killing everything near it.

Fish are not only caught for consumption and decoration, but also for the growing trade in marine ornamental fish. Many different species are targetted for this trade, and there are various techniques for catching those fish. A method used quite often is cyanide. Cyanide stuns the fish but it will target invertebrates and corals and most likely kill them (Wabnitz et al. 2003). The other side effect of fishing is the reduction of certain herbivorous species of the reef, and, in some instances, single-sex reduction of fish species. This could result in algae dominating the reef and the reduction of fish reproduction.

3.2 Eutrophication and river runoffs

Coral reefs thrive in waters with extremely low nutrient levels. Nutrients are essential elements for growth of all life. The most important limiting nutrients on coral reefs are nitrogen and phosphorus (Dubinsky et. al 2011). Due to this limitation, opportunist species such as algae are limited in growth while corals benefit from the nutrients provided from their symbiotic relationship with zooxanthellae. Research has shown that the critical level of phosphorus and nitrogen is respectively 0.003 ppm and 0.014 ppm (Lapointe et al., 1992, 1993, in press; Bell, 1992). Those levels are so low that they are almost undetectable and minor changes in these nutrient levels can cause a phase shift of the reef. An increase in nutrient levels will affect the primary productivity and certain species will dominate.

Over the past years, human activities on land have increased quite significantly. Rivers flowing to the reefs carry high nitrogen and phosphorus levels. This is caused by inadequate or non-treated sewage, livestock manures, agricultural fertilizers and soil erosion due to deforestation, all of which provide rivers with these nutrients. In addition to these nutrients, rivers can contribute to a high level of silt in the water. Silt has the ability to stay easily suspended in fast flowing waters. It will block sunlight and once it reaches the slower moving waters of the estuary and coastal waters it will settle, creating a thin layer over the substrates and corals.

As mentioned above eutrophication will benefit the growth of algae. These algae will outcompete corals in the fight for space on the reef. While growing rapidly, they will cover the coral and reduce or even completely stop the photosyntheses in the

zooxanthellae. Due to the lack of nutrients the coral will die (Dubinsky 2010). The nutrients in the water also create higher densities of phytoplankton. This can, in certain circumstances, decrease the amount of sunlight which reaches the corals. This is especially so deep under water.

3.3 Trash

Trash in the water doesn't effect the water parameters, but it can harm the reef in several different ways. Trash can cover the surface of the water or the coral itself, blocking the sunlight and disabling photosynthesis. Often, fish, turtles or other marine life will mistake trash for edible things such as jellyfish. The trash will block their digestive system, causing the animal to starve. In addition to this, nets and fishing lines left by fishermen may strangle fish and marine mammals.

3.4 Coral reef degradation and phase shifts as result of human activities

3.4.1 Algae outbreaks, the relative dominance model

Algae outbreaks are the result of physiological stress, factors that limit metabolic production, and physical disturbance which removes biomass (Littler et. al 2009). Triggered by eutrophication and overfishing, reefs can shift from being healthy, diverse reefs to an algae dominated reef.

Coral reefs contain four major groups of photosynthetic organisms: microalgal turfs, macro algae, coralline algae, and reef building corals (Littler et. al 2006). The coralline algae and reef building corals are important groups for the structure of the reef due to their ability of building calcium carbonate skeletons.

These four groups are covered in the Relative Dominance Model (figure 4)

A healthy reef with massive forms of corals has high grazing activity and low nutrient levels. Reducing herbivorous fish such as parrotfish by overfishing will cause a shift to a turf algae dominated area. Turf algae form a thin layer (>5cm) over the substrate. In combination with high nutrient levels due to eutrophication it will cause a shift to a macro algae dominated area.

When nutrient levels rise in a reef that hasn't been overfished, coralline algae will be dominant.

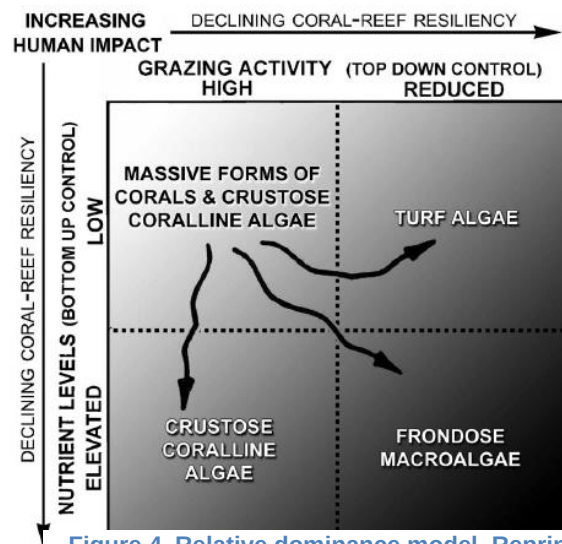


Figure 4. Relative dominance model. Reprinted from Harmful algae on tropical reefs(2006) by Littler et al.

3.4.2 Crown of Thorns (COTs)

Crown of thorns (*Acanthaster planci*) is a sea star that predares on corals. Usually present in low numbers, they have an important niche in the ecosystem. Crown of thorns sea stars feed mainly on fast-growing corals, giving slow-growing corals the opportunity to form colonies (GBRMPA 1995, 2011).

Normal abundance of Crown of thorns can vary anywhere between 1-15 per hectare depending on the coral coverage of the area. There is strong evidence that outbreaks occur when nutrient levels are elevated in the spawning season of the starfish. These elevated nutrient levels are discharged in rivers by monsoons and cyclone driven floods causing phytoplankton blooms. The COT larvae feed on phytoplankton and more larvae survive and reach maturity. This survival rate is even higher in highly fished areas, where fish that predate on the larvae are overfished (Brodie et al. 2005).

3.4.3 Urchins

Urchins can be highly destructive to the reef when found in excessive numbers. Urchins mainly feed on turf algae and coralline algae. Coralline algae is a calcium carbonate building algae and forms a good substrate for new coral colonies to settle. By feeding on coralline algae, it will stimulate bio-erosion and slowly breakdown the structure of the reef. The decline in natural predators is often enhanced with phase shifts from a coral dominated reef to an algae dominated reef, increasing the number of urchins (Bak R.P.M. 1994).

4. Methods

4.1 Reef check

The reef check methodology was used to collect data in Napantao and Santa Paz. The reef check method was developed in the late 1990's and is a method that is recognized worldwide to collect data on coral reefs all over the world. Coral Cay Conservation has added several additional target species to the reef check method to get more information about the health of the coral reef. One of those are butterfly fish species, butterfly fish are good indicators for coral reef diversity. Different species have a specialized diet in certain coral polyps and sponges, a wide variety of species can indicate to a healthy reef.

To reassure the accuracy of all the collected data all surveys are conducted by trained volunteers. These volunteers were only allowed to go on surveys once they have passed the following computer tests;

- Hard coral
- Invertebrates
- Substrates
- Fish
- Butterfly fish

Pass marks for these test are 90% and after the computer test in water validations for all the above had to be successfully completed. The trainee was validated by an experienced surveyor with a pass mark of 80%. Once passed all the validations a couple of practice surveys are done with experienced surveyors to get used to the methodology.

4.2 Survey methodology and different roles within the survey team

The data is collected at a depth of 12 meter over 95 meter transects, each transect exists out of four individual replicates of 20 meter with 5meter gaps after each 20 meter (figure 5). Each survey team exist out of four surveyors with each different roles within the team.

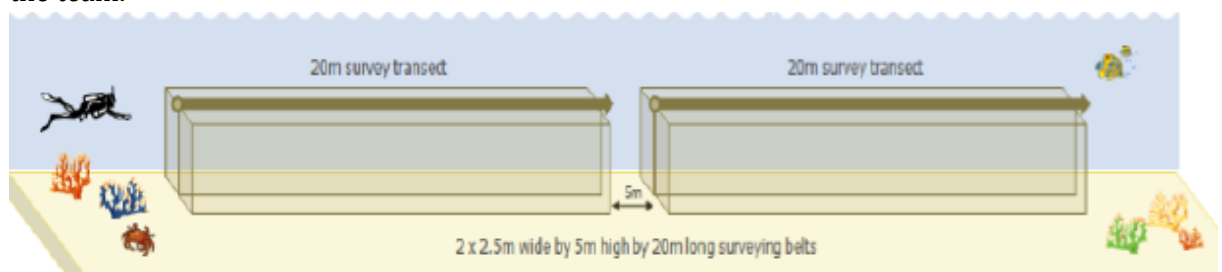


Figure 5. Survey transects. Retrieved from Coral Cay Conservation

Physical:

Makes sure that the team follows the contour of the reef and stays at depth, besides physical will gather data such as temperature, visibility and invertebrates and impacts. Invertebrates and impacts are recorded while swimming in an s pattern within 2.5m on each side of the line. Giant clams are sized and impacts such as trash, coral damage and diseases are recorded.

Line:

Rolls out a line for each 20 meter replicate and attaches it closely to the substrate on to dead coral or rocks and surveys Invertebrates and impacts.

Fish 1 and 2 :

Record all target species and abundance of fish within a box of 2.5m on each side. Every 5 minutes a 1 min pause is carried out to make sure that target species that are hidden can come out of the reef. Parrotfish, groupers and snappers are sized.

Fish 1 will record substrates this means that every 50 cm on the line all benthic life will be recorded including life form. Fish 2 is the last person to go back the transect and will role in the line.

Photos and a list of all target species can be found in appendix 2 and 3.

4.3 Shannon-wiener diversity index

The Shannon- wiener diversity index is used to calculate the diversity index. The index accounts for species richness and the proportional distribution among the species and is based on measuring uncertainty. (Khan 2006).

Shannon- wiener index values are calculated in excel with the following equation:

$$H' = - \sum_{i=1}^R P_i \ln P_i$$

In this equation R is the species richness and Pi the proportion of individuals belonging to the species.

The index value H' is an absolute number without value and can only be compared to other areas. The higher the number the higher the diversity is.

4.4 Pielou's evenness index

Species evenness is calculated by the Pielou's evenness index. This index refers to how close in abundance different species in an certain area are. The closer the value is to 1 the more equal species are present.

The following equations are used to calculate the evenness in excel:

$$J' = \frac{H'}{H'_{max}}$$

With H' the value calculated with the shannon-wiener index. And H'_{max} equal to:

$$H'_{max} = - \sum_{i=1}^S \frac{1}{S} \ln \frac{1}{S} = \ln S$$

With S the total number of species present in the data set .

4.5 Mann Whitney U-test

A Mann Whitney u-test is used to compare samples from both areas and to tell if there is a significant difference between them. The U-test is a nonparametric statistical test to determine the difference between 2 samples without a normal distribution.

5. Discription of research sites

Napantao and Santa Paz are small barangays located on the west side of Panoan Island, Southern Leyte, the Philippines. West from both villages lies Sogod Bay. The reefs of Sogod bay are one of the least disturbed areas and are home to a wide variety of fish species and marine mammals such as whale sharks and manta rays. The people on Panoan Island mainly live from coconut plantations and fishing activities. Appendix 2. Shows satellite pictures including the position of the survey replicates.

5.1 Napantao MPA

The Napantao MPA was established by the provincial government in 1996 to protect natural resources. The MPA covers 5 hectares and no fishing is allowed at all times. It's a typical fringing reef starting at the coast from the island. Geological the reef has a large wall going down to 50 meters on south side and a smaller wall on the north side approximately 10-11 meters deep.



5.2 Santa Paz

Santa Paz is a small barangay about 3 km up north from Napantao. A small river runs next to the village and into the bay. Just outside the estuary large boulders of coral are present raising up to 4 meter of the seabed. In line with the river about 200 meter offshore a steep wall going down to about 35 meters. Following the coastline up north the reef starts to look more like a fringing reef. As result of the river there is a lot of silt found on the reef.



6. Results

The following section outlines the results gained from the data collected in Napantao and Santa Paz.

6.1 Fish general

The overall mean number of fish recorded at the time of the surveys is higher in Santa Paz (figure 6). The difference between the fish abundance in Santa Paz and the Napantao transects is found not to be significant. A higher abundance doesn't mean that there is a higher biodiversity in fish and therefore a Shannon wiener diversity index is calculated.(figure 7) The higher the number of the index the higher the biodiversity, the difference in diversity In and Outside the MPA is found not to be significant. However the diversity between the MPA and Santa Paz is significantly higher ($P=0.018$).

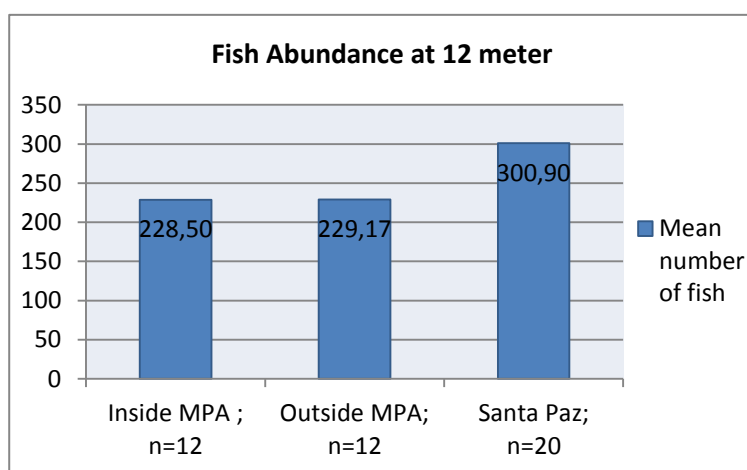


Figure 6. Average fish abundance per transect.

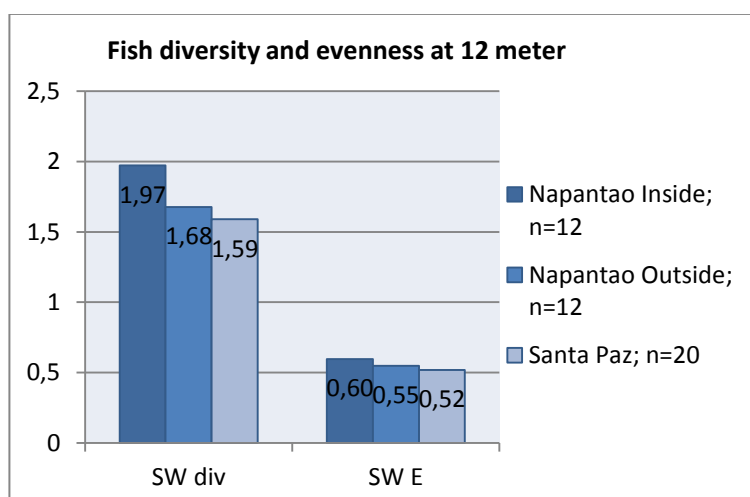


Figure 7. Average fish diversity and evenness per transect, Shannon- diversity index and Pielou's evenness index.

6.2 Indicator fish

Parrotfish were recorded in relatively normal numbers (figure 8). But most individuals are small in size and mainly found in the Napantao replicates. The largest individuals sized, measured 41-50 cm but only 2 fish with this size are recorded. The abundance of parrotfish was not significant larger inside the MPA compared to outside the MPA and Santa Paz. Abundance of groupers and snappers are not found to be significant more abundant inside the MPA. The groupers and snappers found on all replicates are relatively small and categorized within the size range of 11-20cm, the largest individuals are sized between 31-40cm (figure 9,10).

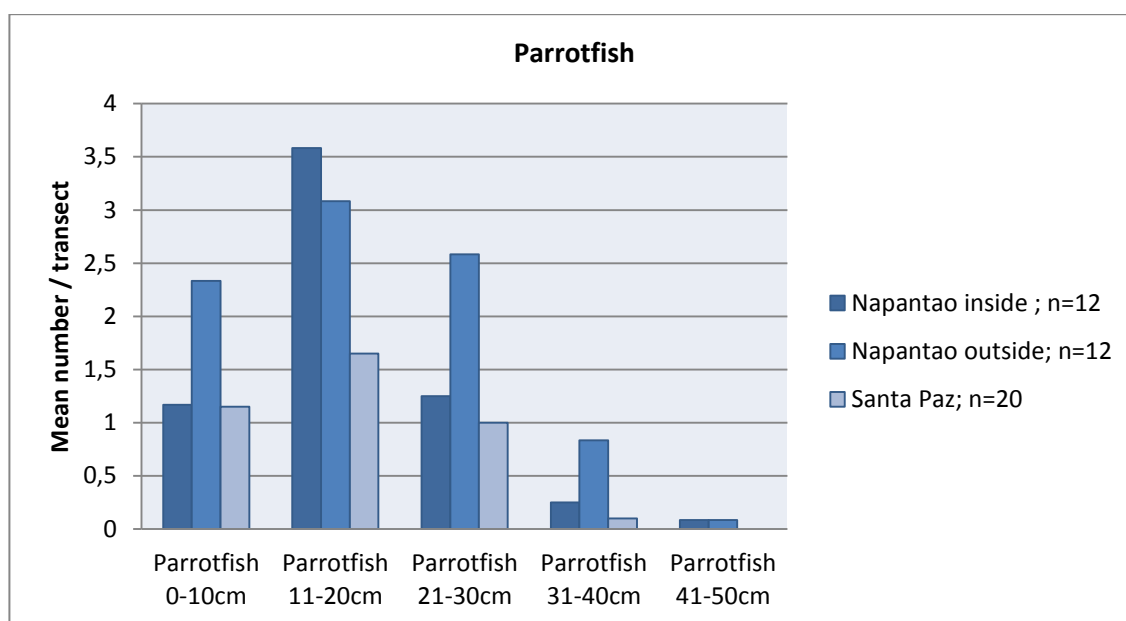


Figure 8. Average number of parrotfish per transect.

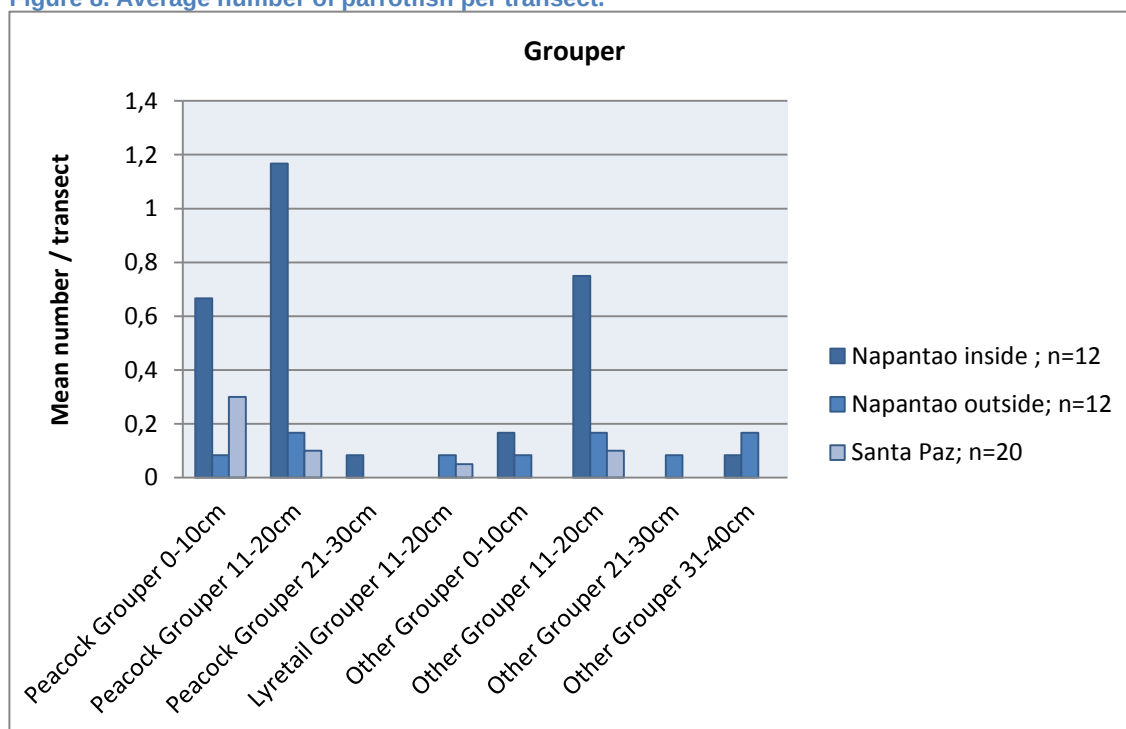


Figure 9. Average number of grouper per transect.

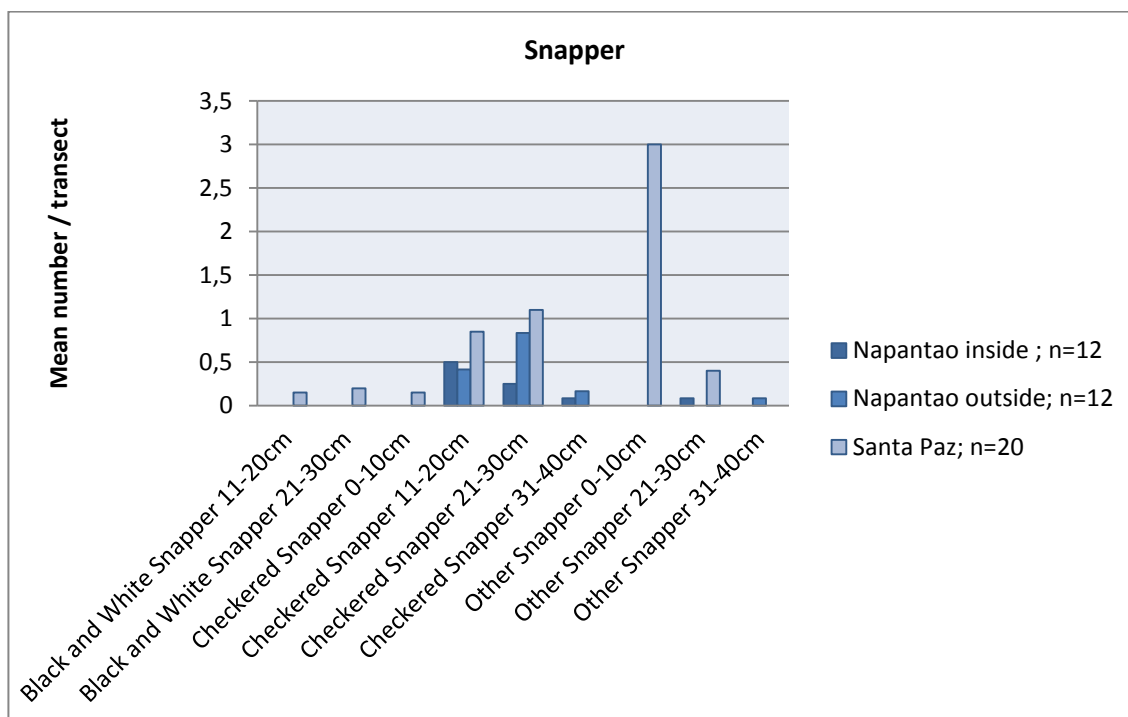


Figure 10. Average number of snapper per transect.

The abundance of Butterfly fish inside the MPA is significantly higher than the numbers recorded in Santa Paz ($P=0.001$). In addition butterfly fish species were also significant more diverse inside the MPA ($P=0.01$) (figure 11).

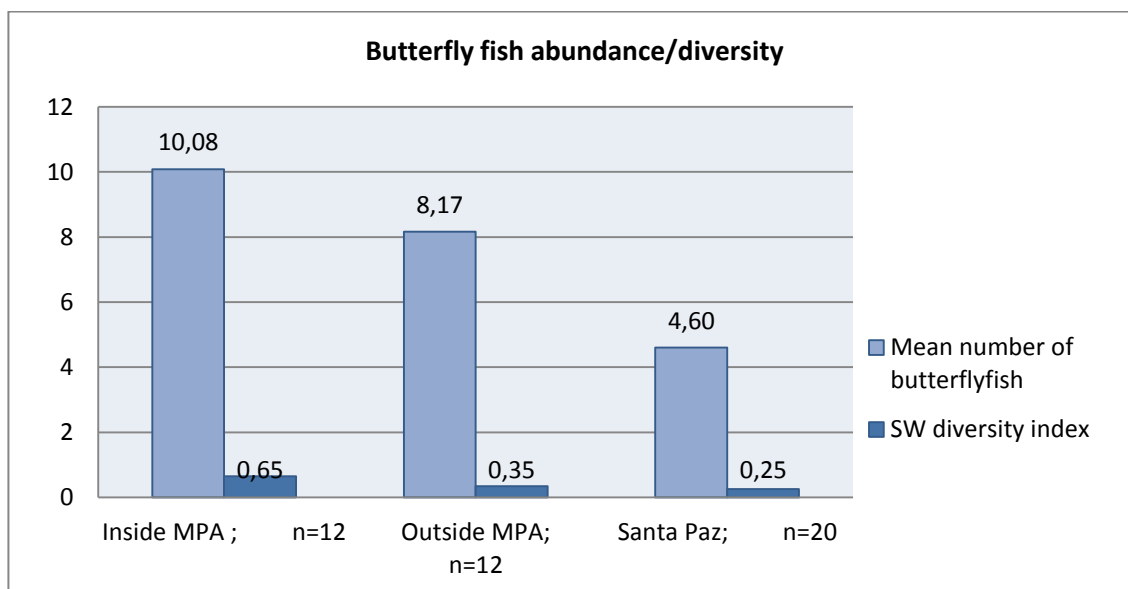


Figure 11. Average abundance and diversity of butterfly fish per transect.

6.3. Substrates

Hard coral is the most abundant substrate inside the MPA (figure 12). The hard coral coverage inside the mpa is found not to be significant more than outside the MPA. However comparing the MPA data with the Santa Paz data the difference is found to be significant ($p=0.024$). And covers respectively 47.50%, 29.48% and 25.65% of all substrates. The most abundant substrate in Santa Paz is rock, rock is present in significantly higher amounts than in the Napantao MPA ($P=0.0026$) and outside MPA ($P=0.013$) replicates.

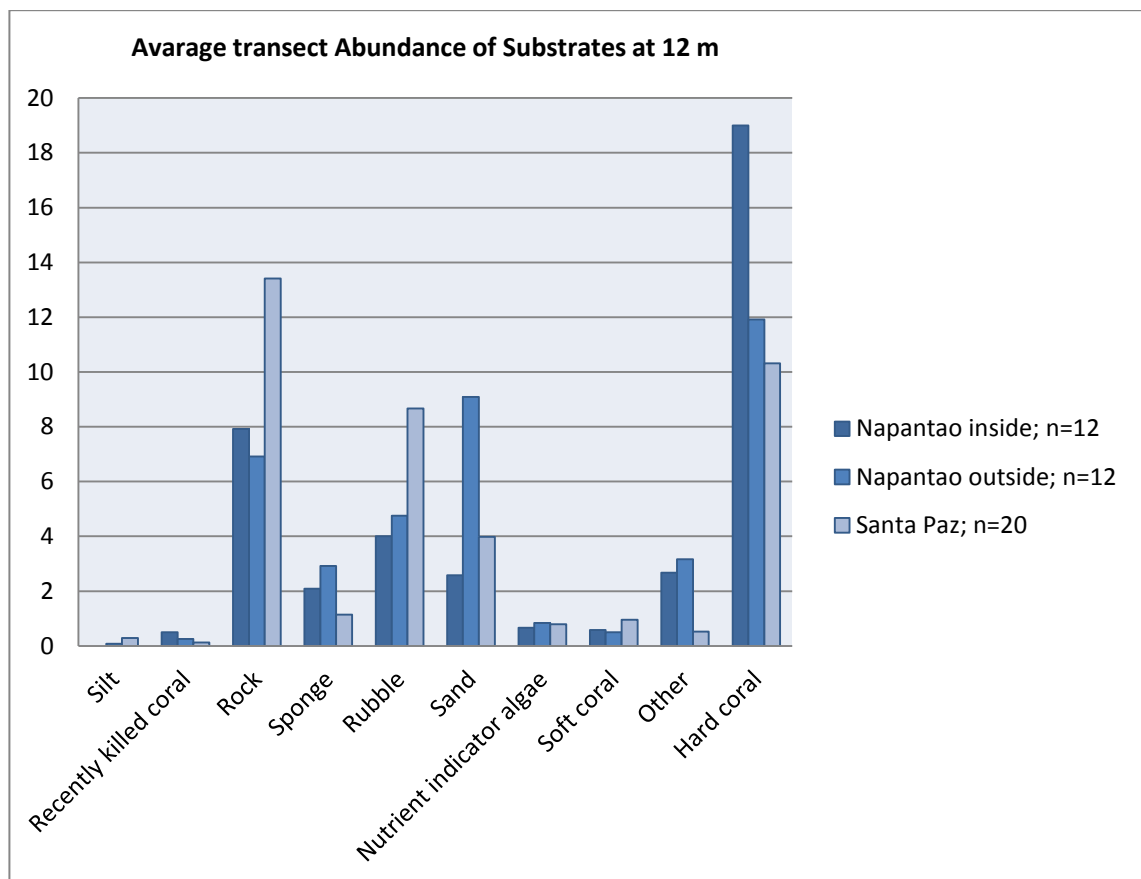


Figure 12. Average abundance of substrates per transect.

6.4 Invertebrates

Invertebrates are significantly more abundant in Santa Paz compared to inside the Napantao MPA ($P=0.000217$) (figure 13). Diversity and evenness of the invertebrates in Santa Paz is slightly less and not found to be significant (figure 14). The lower evenness value indicates some species are more dominant than others. High numbers of Feather stars and urchins are present in Santa Paz. Feather stars are present with an average of 72.6 individuals per transect this is significantly higher than in the Napantao MPA with an average of 20.6. ($P=0.00007$).

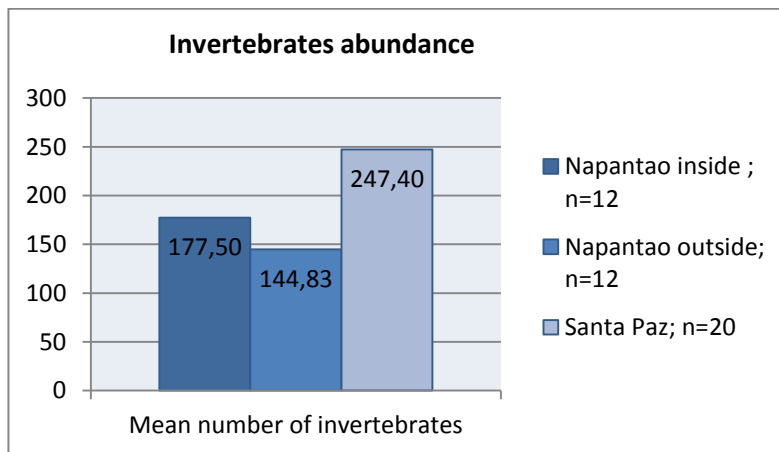


Figure 13. Average invertebrate abundance per transect

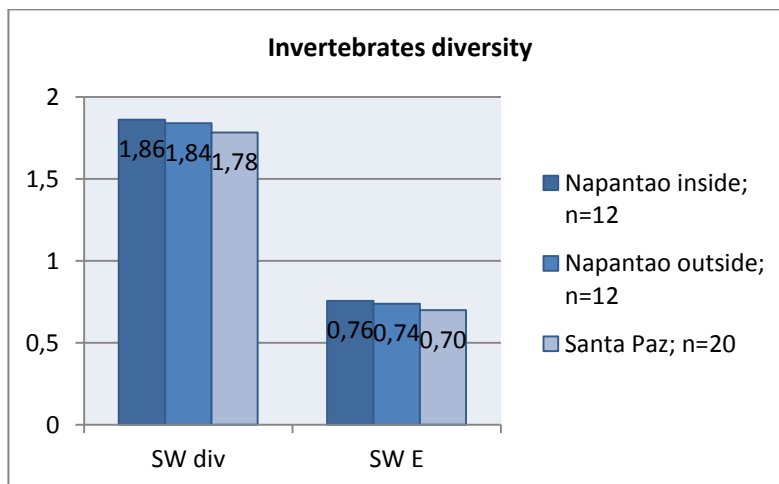


Figure 14. Average invertebrate diversity per transect

Giant clam were found in relatively low numbers, 5 inside the MPA, 1 outside the MPA and 5 in Santa Paz. The sizes of these giant clam ranged from >10cm – 41-50cm for the biggest individual. With 64% smaller than 30cm. Tritons trumpet have not been recorded at all.

Numbers of Crown of thorn starfish (*Acanthaster planci*) are as low as 2 individuals inside the MPA, 2 outside the MPA and 11 in Santa Paz.

Long spine urchins are significantly more abundant in Santa Paz ($P=0.00086$). Their mean abundance is more than 3 times as high than in Napantao with almost 500 individuals recorded. (figure 15.)

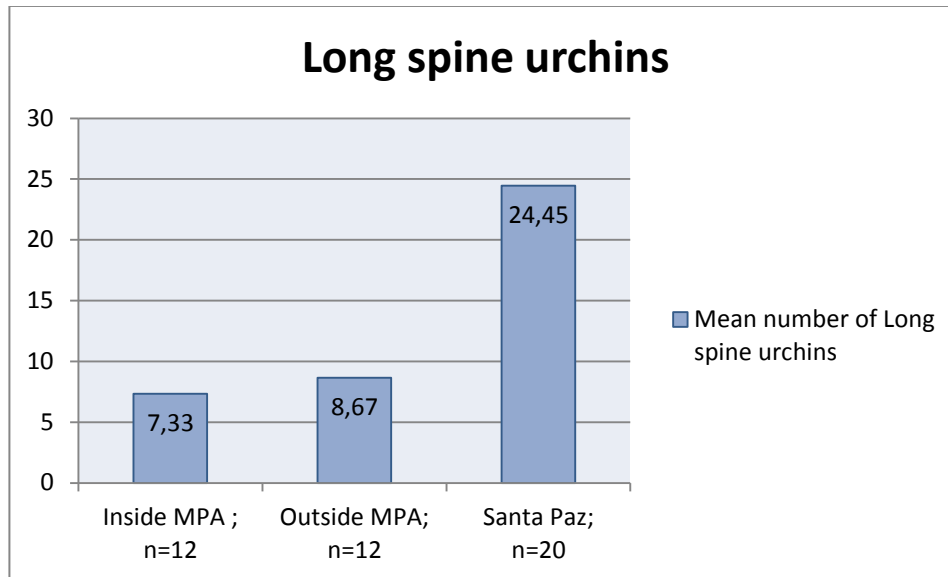


Figure 15. Abundance of urchins on total replicate and average number on transect.

6.5 Anthropogenic impacts, disease and bleaching

During the surveys instances of fishing lines, nets and other forms of trash were recorded. In the Napantao MPA, 5 pieces of fishing lines/nets were recorded, 8 outside the MPA and 9 in Santa Paz. In Santa Paz one piece of dynamite was recorded. Other trash not contributed by fishing activities were recorded in number of 10 inside the MPA, 14 outside the MPA and 37 in Santa Paz. The river is probably the cause of this higher number of trash on the reef.

One instance of white band disease was recorded in Santa Paz affecting less than 1% of the colony. Bleaching occurred on several individual corals but far less than 1% of the whole transect. In Napantao MPA just one colony was bleached by 20%, outside the MPA 4 colonies with an average of 40% of the colonies bleached. In Santa Paz 3 instances of bleaching were recorded with an average of 41% of the colonies bleached.

7. Discussion

7.1 Fish

Fish diversity is found to be significantly higher in Napantao. Looking at the evenness index, the higher abundance of fish can be explained by dominant fish species. The closer to one, the more fish species are present in equal numbers. Santa Paz has high numbers of fish but a low number of evenness. Looking at the data, high numbers of gobies have been recorded in Santa Paz. Gobies are most commonly found on rubble and sandy bottoms. This could indicate coral coverage is low and sand or rubble are present in large amounts. Parrotfish are present in a large amount of small sized individuals. Lower numbers of parrotfish have been found in Santa Paz, but no statistical difference was found. In addition to parrotfish, groupers and snappers are other important indicator species to overfishing. Both species are only found in low numbers of small sized fish. On one of the surveys on the Santa Paz transect 001, 60 snappers with the size of 0-10cm were recorded.

The data collected on the fish indicates that all areas have been exposed to high fishing pressure indicated by the absence of larger fish such as sharks, parrotfish, groupers and snappers.

7.2 Substrates

High hard coral coverage is recorded in the Napantao MPA. With 47.50% of all substrates being hard coral. The difference in hard coral coverage is significantly higher than in Santa Paz with 25.65% coral coverage. The most abundant substrate in Santa Paz is rock with a significant difference to the Napantao MPA. Furthermore, rubble was recorded in high amounts in Santa Paz. The reason that low coral coverage in Santa Paz is present could be the fact that corals have died of either by algae or river sediment blocking sunlight.

In all areas, low numbers of nutrient indicator algae were present. This could indicate that the areas are low nutrient waters. Hard coral coverage outside the MPA was 29.48% and sand was present in high levels. A large sand patch is the cause of this.

7.3 Invertebrates

The difference in the abundance of invertebrates was found to be significantly higher in Santa Paz than the Napantao MPA. There is no significant difference in diversity values. The evenness however, is lower for the Santa Paz transects which indicates that certain species are present in higher dominant numbers. High numbers of feather stars and urchins are found in Santa Paz.

Feather stars mainly feed on plankton and therefore, they are often found in areas with strong currents which provide them with food. This difference is found to be significant. Urchins are also present in significantly higher numbers. The high number of urchins indicates a lower coral abundance and higher algae coverage.

Target species such as the giant clam and Triton's trumpet were present in low numbers or completely absent. The largest individuals of giant clams were recorded inside the MPA but abundance was similar in Santa Paz.

Crown of thorns sea stars indicates stress levels on the reef. Outbreaks of crown of thorns are thought to be caused by elevated nutrient levels due to river runoff. Healthy numbers were present in Napantao with 2 individuals inside and 2 outside the MPA. 11 individuals were present in Santa Paz.

7.4 Anthropogenic impacts, disease and bleaching

Bleaching and disease only occurred on several individual colonies. Current fishing is larger in Santa Paz with more fishing lines and nets found on the reef. Even one piece of dynamite was found here. High numbers of trash such as plastics were found on the reef in Santa Paz. The river was suspected to be the source of this.

8. Conclusion

All three areas surveyed were different from each other geologically and ecologically, but they are all situated relatively close to each other. The data shows that the area has been overfished in the past. Therefore, a total absence or low numbers of large groupers, parrotfish, snappers and sharks was recorded. Invertebrates like the Triton's trumpet were completely absent and only small individuals of giant clams were present in the area. Since the establishment of the MPA in 1996 it's not legal to fish inside the MPA, but reefs recover slowly and the MPA is small (5ha). Fish that grow up inside the MPA will get caught once they swim out the MPA. Due to the fishing pressure, abundance of sexually mature adults are extremely low. All surveyed areas are affected by this and therefore no hard conclusion can be drawn out of the data from these areas in reference to how much diversity decreases by overfishing.

The area surveyed in Santa Paz is characterized by the river that enters on the reef. The data gathered from this site shows that the reef is partially showing signs of degradation to an algae dominated reef as a possible result of the river outflow. The reef is, or has been, under stressful conditions which can be seen by the low coral coverage and high numbers of long spine urchins that have been recorded. It can be said that the river decreases the coral abundance, which, as a result, decreases fish diversity. Because no data was gathered on the nutrient levels in the areas, it's not possible to draw hard conclusions on the actual amount of eutrophication due to human activities. But, taking the remoteness of the area and it's land use in consideration, it's most likely the cause of natural influences that increase the sediment and possibly nutrient levels in Santa Paz.

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Figure 1:

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Figure 2:

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Figure 3:

Rose A. (2008), *trophic pyramid*, retrieved from <http://www.coralscience.org/main/articles/climate-a-ecology-16/coral-reef-ecology>

Figure 4 :Littler M.M.; Littler D.S.; Brooks B.L. (2006) *Harmful algae on tropical coral reefs: bottom-up eutrophication and top-down herbivory*

Appendix 1. Location of research site with replicates



Figure 16. The Philippines

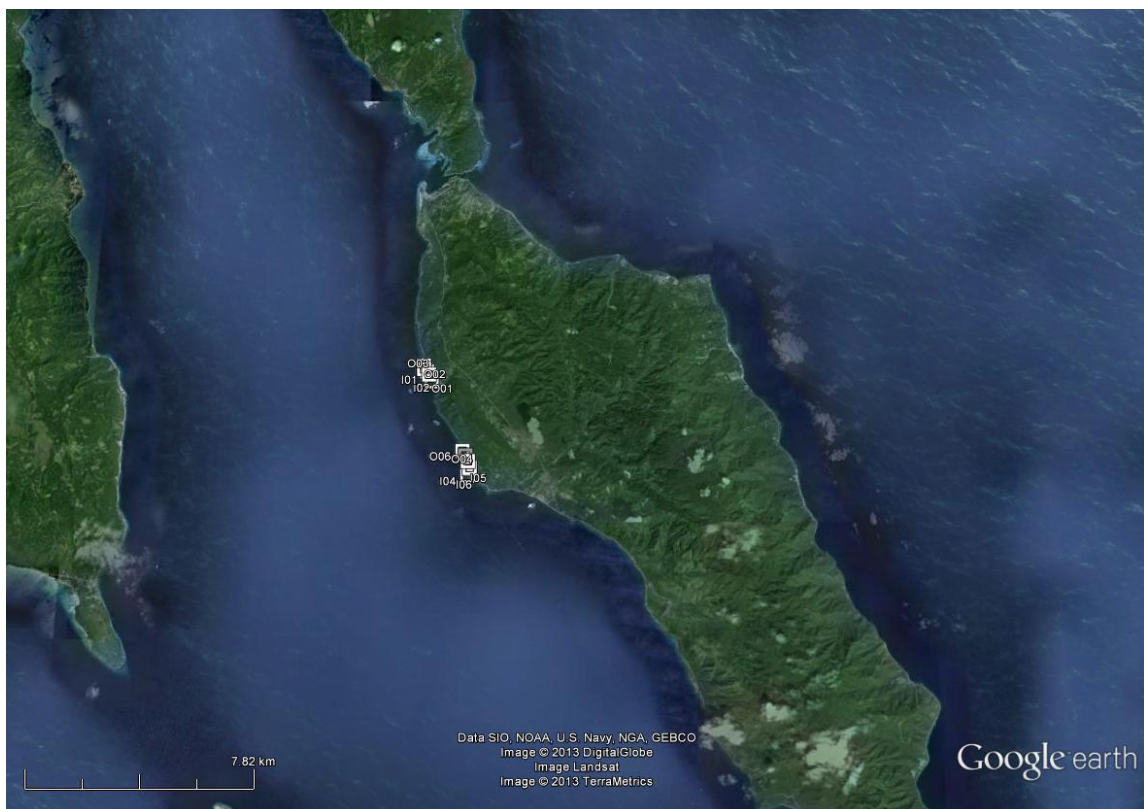


Figure 17. Panoan Island, Southern Leyte

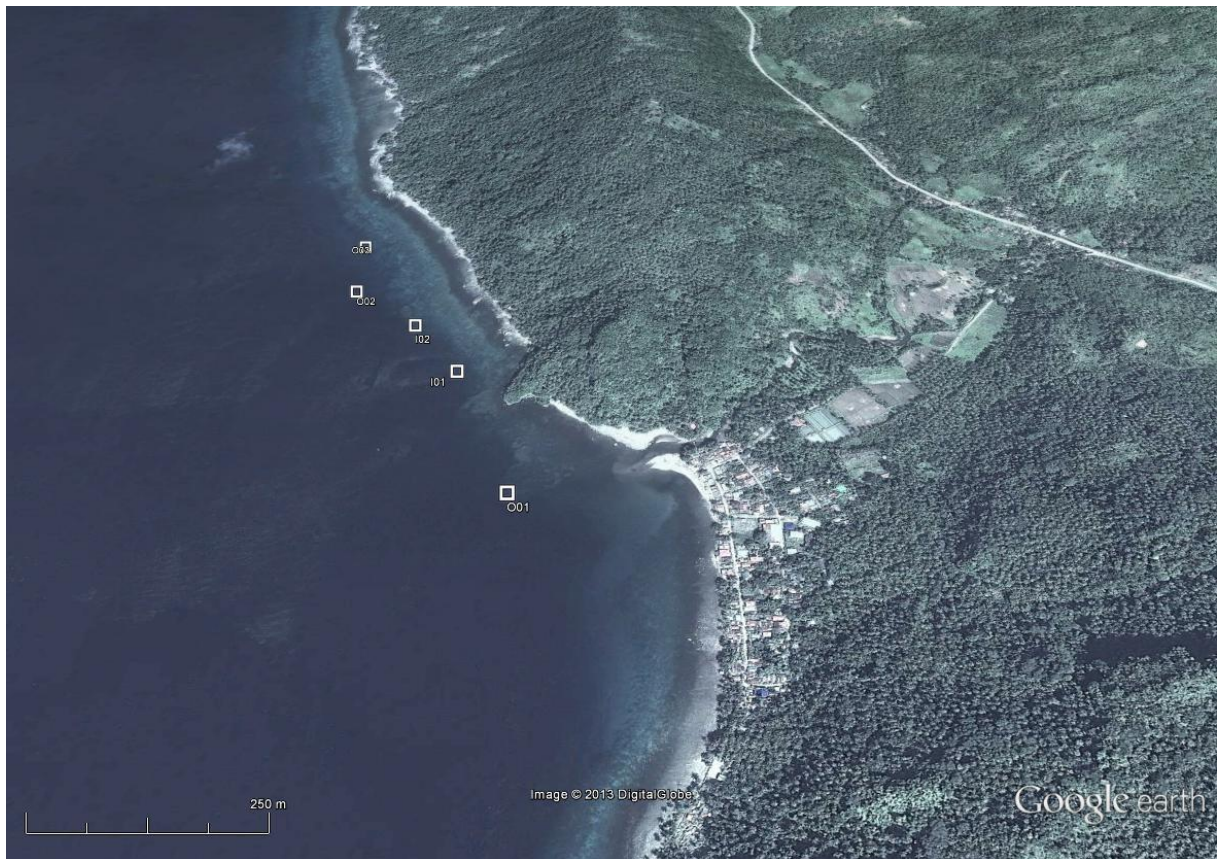


Figure 18. Santa Paz, including replicates



Figure 19. Napantao, including replicates

Appendix 2. Survey



Figure 20. Part of the survey team recording substrates. Photo taken by Tom Sparke (2013)



Figure 21. Recording substrates. Photo taken by Tom Sparke (2013)

Appendix 3. Target species list

SUBSTRATES		
Soft Coral	Sponge	Recently killed coral
Rock	Silt/mud	Rubble
Sand	Nutrient indicator algae	Other*
Hard Coral Lifeforms**:		
<i>Acropora</i> branching	<i>Acropora</i> encrusting	<i>Acropora</i> submassive
<i>Acropora</i> digitate	<i>Acropora</i> tabulate	Non- <i>Acropora</i> branching
Non- <i>Acropora</i> encrusting	Non- <i>Acropora</i> foliose	Non- <i>Acropora</i> submassive
Non- <i>Acropora</i> mushroom	<i>Heliopora</i> (blue coral)	<i>Millepora</i> (fire coral)
<i>Tubipora</i> (organ-pipe coral)		
*Other:		
Anemone	Corallimorph	Halimeda
Tunicate	Zoanthid	Gorgonian
Hydroids		

** If hard coral, also record target species

TARGET HARD CORALS		
Brain small	Brain medium	Brain large
<i>Ctenactis echinata</i>	<i>Diploastrea heliopora</i>	<i>Echinopora</i>
<i>Euphyllia</i>	<i>Favia</i>	<i>Favites</i>
Foliose <i>Montipora</i>	<i>Galaxea</i>	<i>Goniopora/Alveopora</i>
<i>Herpolitha limax</i>	<i>Hydnophora</i>	<i>Lobophyllia</i>
Massive <i>Porites</i>	<i>Montipora digitata</i>	<i>Mycedium elephantotus</i>
<i>Pachyseris rugosa</i>	<i>Pachyseris speciosa</i>	<i>Pavona clavus</i>
<i>Pectinia lactuca</i>	<i>Plerogyra</i>	<i>Pocillopora</i> small
<i>Pocillopora</i> medium	<i>Pocillopora</i> large	<i>Polyphyllia talpina</i>
<i>Porites cylindrica</i>	<i>Porites nigrescens</i>	<i>Porites rus</i>
<i>Seriopora hystrix</i>	<i>Tubastrea micrantha</i>	<i>Turbinaria</i>
Upside-down Bowl		

Target Invertebrates		
Feather duster worms	Christmas tree worms	Flatworms
Crabs	Shrimps	Banded coral shrimp
Lobsters	Nudibranch	Abalone
Conch	Cowrie	Triton's trumpet
Cone shell	<i>Drupella</i>	Top shell
Other gastropod	Giant clam	Octopus
Cuttlefish	Squid	<i>Acanthaster planci</i>
<i>Linkia laevigata</i>	<i>Culcita novaeguineae</i>	<i>Protoreaster nodosus</i>
<i>Choriaster granulatus</i>	Feather star	Brittle star
Long spine sea urchin	Pencil urchin	Collector urchin
Prickly redfish	Pinkfish	Greenfish
Other sea cucumber	Giant Clam	

Target Fish

Common Name	Latin Name	Visayan Name
Angelfish	Pomacanthidae	Adlo
Barracuda	Sphyraenidae	
Blenny	Blenniidae	
Butterflyfish*	Chaetodontidae	Alibangbang
Cardinalfish	Apogonidae	
(Damselfish)	(Pomacentridae)	
Anemonefish	<i>Amphiprion</i> sp.	
Sergeant Damselfish	Pomacentridae	
Emperor	Lethrinidae	Katambak
Filefish	Monacanthidae	Ilak
Fusilier	Caesionidae	Dalagang bukid
Goatfish	Mullidae	Timbongan
Goby	Gobiidae	
Groupers	Serranidae	Lapu-lapu
Flagtail Grouper	<i>Cephalopholis uroeta</i>	
Honeycomb Grouper	<i>Epinephelus</i> sp.	
Humpback Grouper	<i>Cromileptes altivelis</i>	
Lyretail Grouper	<i>Variola louti</i>	
Peacock Grouper	<i>Cephalopholis argus</i>	
Jack/Trevally	Carangidae	Talakitok
Lionfish	Scorpaenidae	
Lizardfish	Synodontidae	
Moorish Idol	<i>Zanclus cornutus</i>	Sanggowanding
Moral Eel	Muraenidae	
Parrotfish	Scaridae	Mulmul
Pipefish	Syngnathidae	
Porcupinefish	Diodontidae	
Pufferfish	Tetraodontidae	
Rabbitfish	Siganidae	Kitong
Virgate rabbitfish	<i>Siganus virgatus</i>	
Ray	Rajiformes	
Sandperch	Pinguipedidae	
Scorpionfish/Stonefish	Scorpaenidae	
Snapper	Lutjanidae	Maya-maya
Black and White Snapper	<i>Macolor macularis</i>	
Checkered Snapper	<i>Lutjanus decussatus</i>	
Two Spot Snapper	<i>Lutjanus biguttatus</i>	
Spade/Batfish	Ephippidae	
Spinecheeks	Nemipteridae	Silay
Twoline Spinecheek	<i>Scolopsis bilineatus</i>	
Squirrelfish/Soldierfish	Holocentridae	
Surgeonfish	Acanthuridae	Indangan
Unicornfish	<i>Naso</i> sp.	
Sweeper	Pempheridae	
Sweetlips	Haemulidae	Lipti
Toby	Tetraodontidae	
Triggerfish	Balistidae	Pakol
Trunk/Box/Cowfish	Ostraciidae	
(Wrasse)	(Labridae)	
Crescent Wrasse	<i>Thalassoma lunare</i>	
Humphead Wrasse	<i>Cheilinus undulatus</i>	
Red Breasted Wrasse	<i>Cheilinus fasciatus</i>	

*Target Butterflyfish

Vagabond Butterflyfish	Spot-Banded Butterflyfish	Merten's Butterflyfish
Klein's Butterflyfish	Dot and Dash Butterflyfish	Chevroned Butterflyfish
Latticed butterflyfish	Singular Bannerfish	Threadfin Butterflyfish
Eastern Triangle Butterflyfish	Longfin Bannerfish	Teardrop Butterflyfish
Redfin Butterflyfish	Masked Bannerfish	Spot-Nape Butterflyfish
Pyramid Butterflyfish	Pennant Bannerfish	Lined Butterflyfish
(Big) Long-Nosed Butterflyfish	Raccoon Butterflyfish	Yellow-Dotted Butterflyfish
Copper-Banded Butterflyfish	Dotted Butterflyfish	Black-Backed Butterflyfish
Orange-Banded Butterflyfish	Ovalspot/Mirror Butterflyfish	Spot-Tail Butterflyfish
Humphead Bannerfish	Bennett's/Eclipse Butterflyfish	Panda Butterflyfish
Asian Butterflyfish	Bluespot Butterflyfish	Eight-Banded Butterflyfish
Burgess' Butterflyfish	Highfin Coralfish	Reticulated Butterflyfish
Ornate Butterflyfish	Two-Eyed Coralfish	Saddled Butterflyfish
Meyer's Butterflyfish	Brown Banded Butterflyfish	Spotted Butterflyfish
Speckled Butterflyfish	Ocellate Coralfish	Yellowtail Butterflyfish
Pacific Double-Saddle Butterflyfish		

Appendix 4. Overview collected date