

Coral Cay Conservation Marine Protected Area Assessment Report

Tabugon MPA



Tabugon
Lilo-an, Southern Leyte, the Philippines

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EXECUTIVE SUMMARY

- Coral Cay Conservation conducted an assessment of the reef fish, invertebrates, substrate and anthropogenic impacts in and around the Tabugon MPA, between February and March 2014.
- A modified Reef Check protocol was used to survey 12 transects, each containing four 20m replicates. Four transects were placed inside the MPA at a depth of 6m and 8 outside the MPA divided evenly between 12m and 6m depths.
- Overall, fish abundance was significantly higher outside the MPA. Fusilier, Angelfish, and Parrotfish were also significantly more abundant outside the MPA.
- Overall abundance of invertebrates was not significantly different between inside and outside the MPA or at different depths.
- Crown of thorns seastars (*Acanthaster planci*) were observed in low numbers across the entire survey area.
- Sand and Rock were the most abundant substrates within the MPA and hard coral only contributed to 15% of the substrate within the MPA.
- Commercially important species, such as Groupers, Sweetlips, Giant Clams, Tritons Trumpet, were observed in low abundances or were absent wholly from the entire area that was assessed. Non-target Sea Cucumbers were more abundant outside the MPA although commercially important species were wholly absent from the survey area.
- Damaging impacts such as discarded fishing gear and household trash were observed in high frequency inside and outside the MPA.
- Low abundances of commercially important species both in- and outside the MPA is indicative of unsustainable fishing pressure and of poaching inside the MPA.
- Much of the MPA is sand and unsuitable for coral growth. Re-zoning the MPA or extending the MPA to a greater depth will allow the MPA to be more productive to the area.
- The Tabugon MPA appears to be in poor health with relatively low numbers of commercially important fish and invertebrates. With proper management and enforcement , along with a possible extension, the MPA will begin to recover and work to sustain fish populations for ours and future generations.

ACKNOWLEDGEMENTS

Coral Cay Conservation would like to express our gratitude to the Provincial Government of Southern Leyte (PGSL). Our work would not be possible without the support of the Provincial Environmental and Natural Resource Management Office (PENRMO) and other members of the PGSL. We would also like to thank the Barangay Council of Tabugon and the Municipality of Liloan for facilitating the MPA assessment. In particular we would like to acknowledge the cooperation of Sir Terance Dipay, Liloan Municipal Agriculturalist and Ma'am Beney Dipay, Liloan Municipal Agricultural Technician. . Finally, we would like to thank our trained volunteers and staff who collected the data during this MPA assessment.

LIST OF ACRONYMS AND ABBREVIATIONS

CCC	: Coral Cay Conservation
CoTs	: Crown of Thorns Seastars (<i>Acanthaster planci</i>)
GPS	: Global Positioning System
IEC	: Information, Education, Communication
LGU	: Local Government Unit
MPA	: Marine Protected Area
MPA MEAT	: MPA Management Effectiveness Assessment Tool
MWU	: Mann-Whitney U test
NIA	: Nutrient Indicator Algae
NIPAS	: National Integrated Protected Area System
PRRCFI	: Philippines Reef and Rainforest Conservation Foundation Inc.
RKC	: Recently Killed Coral
SE	: Standard Error

CORAL CAY CONSERVATION

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

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

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

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

1. INTRODUCTION

1.1 Marine Protected Areas

Marine resources have come under increasing pressure from an ever growing world population (Jackson *et al.* 2001). Strong declines in catch from fisheries worldwide, such as the North Atlantic Cod (Myers 1997) and reef fisheries in the Caribbean (Hardt 2009), have illustrated that biological marine resources are limited (Jackson *et al.* 2001; Pauly *et al.* 2002). Additional pressures such as pollution, coastal development and the effects of climate change contribute to the stress the marine environment is under. This has given rise to the increased drive for conservation efforts and resource management in the marine environment (Wood *et al.* 2008; CBD 2010). Marine protected areas (MPAs) can achieve conservation and resource management targets simultaneously and are therefore considered instrumental to sustainable ocean utilization (Pauly *et al.* 2002). The International Union for the Conservation of Nature (IUCN) defines a MPA as:

“A clearly defined geographical space, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with the associated ecosystem services and cultural values.”

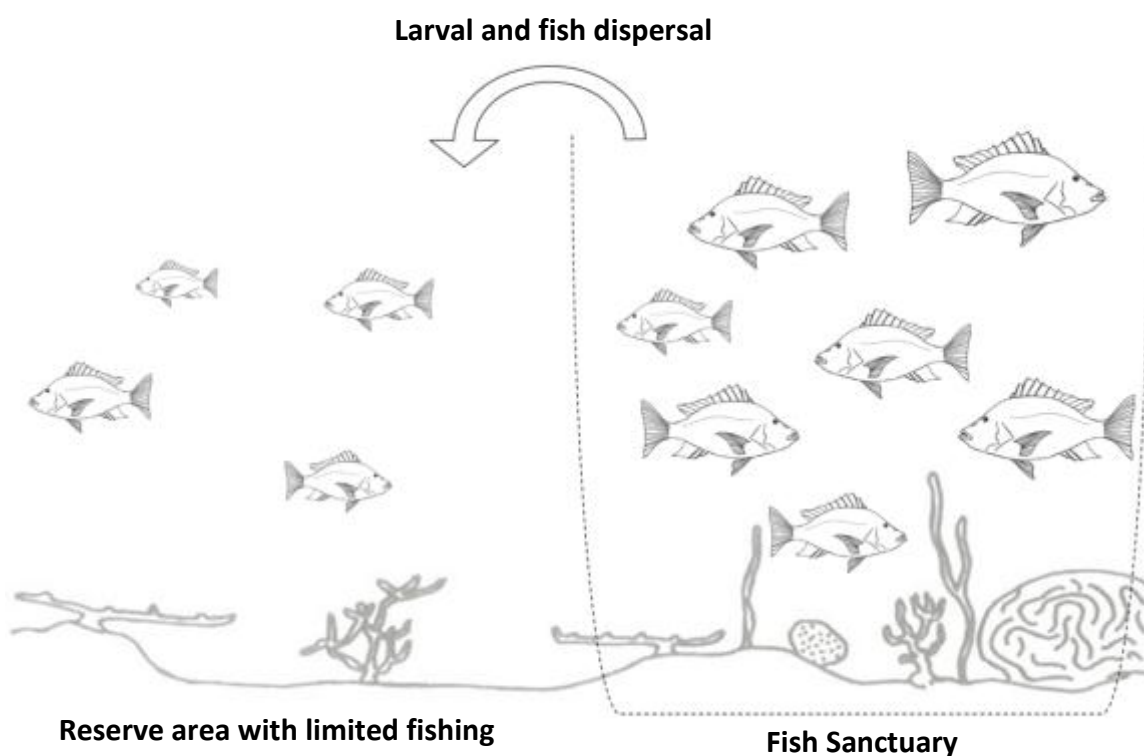


Figure 1 – Schematic diagram of MPA functioning. Protected fish in the MPA grow larger and produce more offspring, this leads to ‘overspill’, increasing fish numbers outside the MPA. In addition, the corals inside the MPA are not disturbed by direct human impacts.

MPAs have become vital tools in conserving marine resources; not only for their own intrinsic value but also for the services they can provide humanity. The ecosystem within the MPA, if left undisturbed for an extended amount of time, has the potential to provide a

sustainable supply of goods - such as fish, algae and salt - and services - such as shoreline protection, maintaining water quality and recreation (World Bank 2005). Increased fish catch is perhaps the most sought after potential benefit of MPAs. There are two ways that this can happen; through spillover and larval export (Figure 1).

However, the success of MPAs is for a large part dependent on the willingness of local people to adhere to the rules. Experience from around the world has shown that closely involving local people in the planning, implementation and management of their own MPA can increase their sense of ownership and pride. Only when the local stakeholders feel their concerns are taken seriously and they are consulted on management of the MPA regularly, will it be possible for the full beneficial potential of the MPA to be attained (Green *et al.* 2009, Human and Davies 2010).

1.2 Coral Reefs & Marine Conservation in the Philippines

The Philippines lies within a region known as the Coral Triangle. The Coral Triangle, which includes Indonesia, Malaysia, Papua New Guinea, Timor-Leste and the Solomon Islands, is recognized as the global centre of marine biodiversity (Roberts *et al.* 2002). It is home to the oldest coral reefs in the world and the largest expanses of mangrove forest. More than 75% of the known coral species and over 30% of all the coral reefs in the world are found in the Coral Triangle (Veron *et al.* 2009). The same extraordinary diversity is found in the other types of marine creatures; with over 3,000 species of fish recorded, even higher figures for molluscs and new species are still being discovered regularly (Allen 2008).

The waters of the Philippines contain roughly 25,000 km² of coral reefs. An estimated 60% of the country's 92 million citizens live in coastal regions, i.e. in close proximity to coral reefs, and over half of the consumed animal protein comes from marine sources (CTI 2012). This heavy reliance on marine resources has caused large areas of coral reef ecosystems to become threatened. In 1980 33% of coral reefs were characterized as being in poor condition, in 2008 this figure had increased to 40% (Wilkinson 2008). These figures make a strong case for increased marine conservation efforts. Legislation concerning marine conservation in the Philippines is probably one of the most advanced within the Coral Triangle (Jacinto *et al.* 2000). Some important laws include:

- 1998 Fisheries Code (Republic Act 8550): 15% of municipal water should be within a MPA
- Marine and Coastal Resource Protection Act: Each municipality should have at least one MPA that is bigger than 10 hectares (if the total municipal waters are larger than 15 hectares)
- The Philippine Marine Sanctuary Strategy (2002): By 2020, 10% of all the Philippine marine waters will be fully protected

Currently there are about 1,640 MPAs in the Philippines. Of these MPAs, 33 have been declared at national level as NIPAS sites and the remainder is managed by Local Government Units (LGU) (DENR-CMMO presentation, March 19 2013). Box 1 highlights a case study of successful MPAs in the Philippines.

Box 1 - Case study of successful MPAs in the Philippines: Apo Island & Sumilon Island

The MPAs at Apo Island and Sumilon Island are some of the best-known examples of successful tropical marine conservation efforts in the world. Years of monitoring have provided accurate data that shows what can be achieved if the coral reef inside a MPA is given the chance to recover (Figure 2). These figures also show that although an increase of biomass was observed in the first years of reserve protection, the biggest increase in biomass took several years to become evident (5-10 years). Unequivocal evidence of spillover from these MPAs remains elusive but the increased number and size of fish within the reserve make it likely that the MPA is a source for net larval export, which can aid recovery of fish stocks in the area. Indirect positive effects of the effective management of these MPAs include increased tourism income and elimination of unsustainable fishing practices such as dynamite fishing (Russ and Alcala 2004).

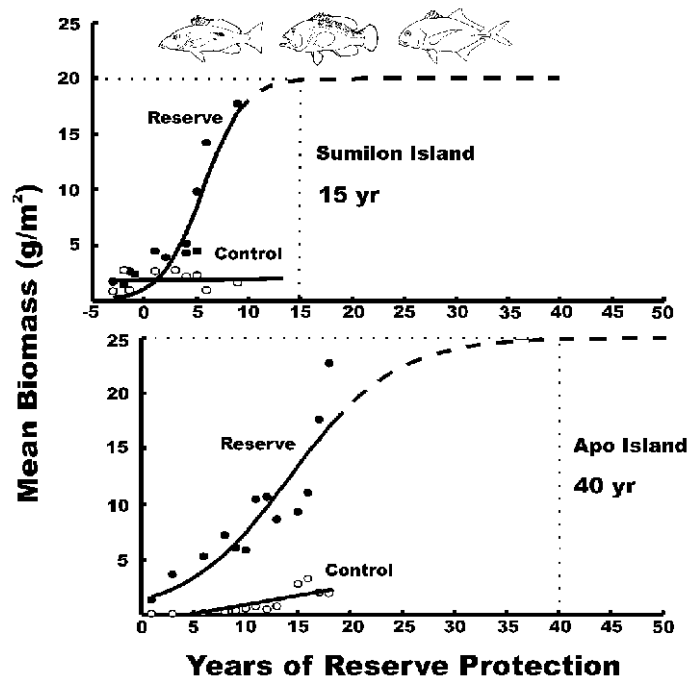


Figure 2 - observed and projected increase in mean biomass of commercially important species of fish inside the MPAs at Apo Island and Sumilon Island.
Figure from: Russ and Alcala (2004).

1.3 - Characterization of Study Region

1.3.1 - Sogod Bay

The coral reefs of Southern Leyte remain some of the least disturbed habitats in the Philippines. Sogod Bay is an important fishing ground and the area is rich in tuna, flying fish, herrings, anchovies, shell-fish and Spanish mackerel. The bay has been targeted by the Fisheries Sector Program of the Department of Agriculture as one of the country's ten largest bays in need of assessment and management (Calumpong *et al.* 1994). Sogod Bay is also a feeding ground for attractive mega-fauna such as pilot whales, melon-headed whales,

dolphins, manta rays and whale sharks. The bay is characterised by naturally limited mangrove areas, narrow fringing coral reefs, limited seagrass beds and narrow intertidal areas and beaches (Calumpang *et al.* 1994). Depths in the bay reach a maximum of approximately 1,400 metres in the central channel.

Currently there are 23 established MPAs within Sogod Bay covering an estimated 170 hectares. These figures will increase in the coming years as more MPAs are currently being set up. The size of the MPAs ranges from 2 hectares (Maujon/Juangon Fish Sanctuary) to 45 hectares (Limasawa Fish Sanctuary), with a mean average size of 8.7 hectares (± 2.1 SE) and a median average of 5 hectares. The sizes for several MPAs are not known, as accurate GPS coordinates are not available.

1.3.2 – Tabugon MPA (Tabugon Fish Sanctuary)

The Tabugon MPA, was established in 1993 and covers 19.6 hectares. It is located in the Municipality of Lilo-an, in the waters of the barangay Tabugon. The MPA is to the south-east of the village (Figure 3). The MPA has trained Bantay Dagats and a guardhouse, although it is not always manned and is often absent (Table 1). Fishing takes place in the area surrounding the MPA and on one occasion the CCC survey team witnessed poaching inside the MPA.

Table 1 – Summary of MPA infrastructure at Tabugon MPA

MPA Infrastructure	Present?
Trained Bantay Dagats	√
Permanent Bantay Dagat presence	X
MPA guardhouse	√
Demarkation buoys	√
Patrol boat	√
Bantay Dagat gear (flashlight, fins, mask, etc.)	X
User fees collected	X

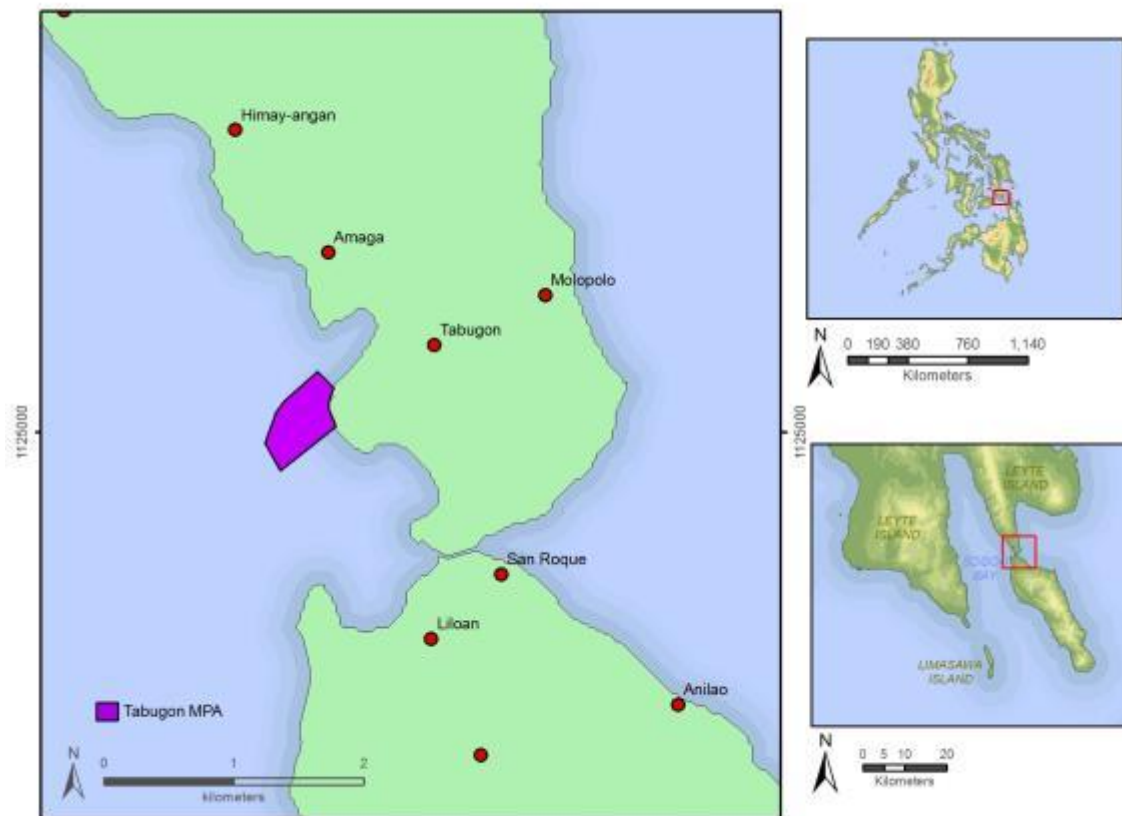


Figure 3 – Map showing the location of the Tabugon Marine Protected Area

2. METHODS

2.1 Biophysical Survey

The assessment of the MPA was conducted using an enhanced Reef Check method. The Reef Check methodology is widely recognised and is used to survey coral reefs around the world. It was developed in the 1990s with the aim of gathering as much data as possible about the global status of coral reefs (Hodgson 1999). The data from around the world is analysed on a yearly basis and updates about the status of coral reefs are published. Reef Check provides a general picture of the ecological status of a reef and the human impacts affecting it. CCC has augmented the methodology by adding additional target species of fish, coral and other invertebrates to better reflect the high biodiversity of the area (see Appendix A for target species).

Typical CCC MPA survey transects are conducted at depths of 6 metres and 12 metres, however the maximum depth within most of the Tabugon MPA was less than 12m. Therefore, 6m transects were conducted both inside and outside the MPA, while 12m transects were only conducted outside the MPA (Figure 4). Each transect was 100 metres long and divided into 4 replicates of 20 metres each. Between each replicate there was a 5 metre gap where no data was recorded. This survey set up allows for robust statistical analysis of the collected data. GPS points for each transect can be found below (Table and Figure 5).

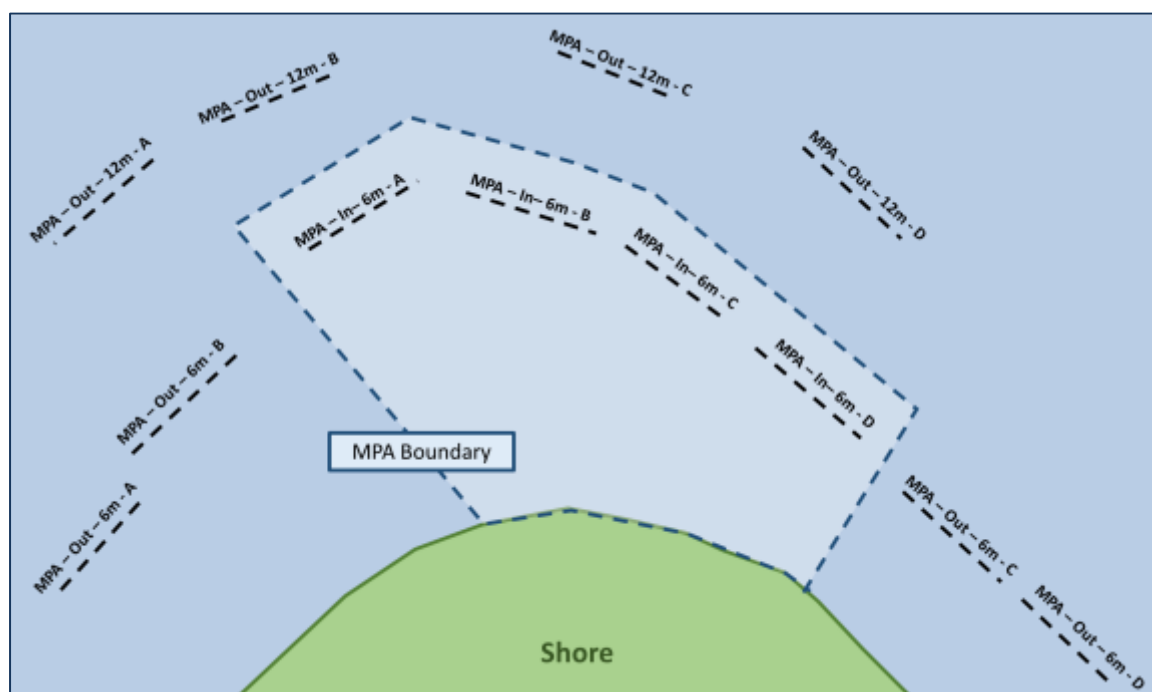


Figure 4 – Diagram of the 100m transect locations inside and outside of the Tabugon MPA

Survey ID	Inside or outside MPA?	Depth (m)	Easting	Northing
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MPA - In - 6m - A	Inside MPA	5	731746	1124827
MPA - In - 6m - B	Inside MPA	6	731725	1125005
MPA - In - 6m - C	Inside MPA	6	731807	1125194
MPA - In - 6m - D	Inside MPA	6	731896	1125332
MPA - Out - 12m - A	Outside MPA	12	731772	1124497
MPA - Out - 12m - B	Outside MPA	12	731605	1124604
MPA - Out - 12m - C	Outside MPA	12	731675	1125093
MPA - Out - 12m - D	Outside MPA	12	731890	1125367
MPA - Out - 6m - A	Outside MPA	6	732280	1124533
MPA - Out - 6m - B	Outside MPA	6	732025	1124625
MPA - Out - 6m - C	Outside MPA	5	732226	1125505
MPA - Out - 6m - D	Outside MPA	6	732280	1125589

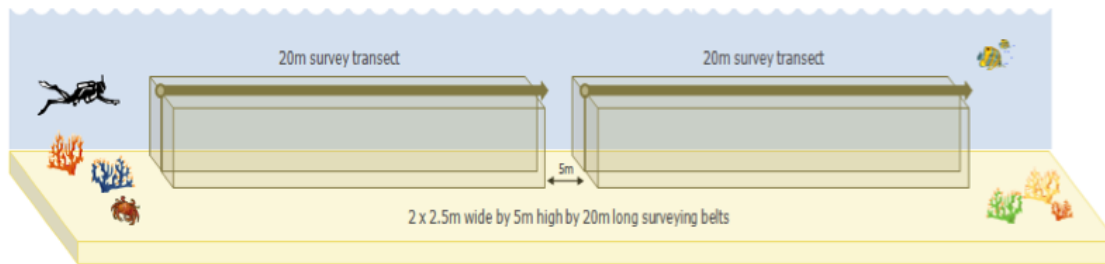


Figure - Image of the survey sites at Tabugon MPA (MPA demarcated with white polygon)

2.1.1 Fish

The fish diversity and abundance data was collected using Underwater Visual Census. Selected fish families and species recognised as being good indicators of fishing pressure, aquarium collection and reef health were recorded. Three families of commercially important fish were also recorded by size: Groupers, Parrotfish and Snappers.

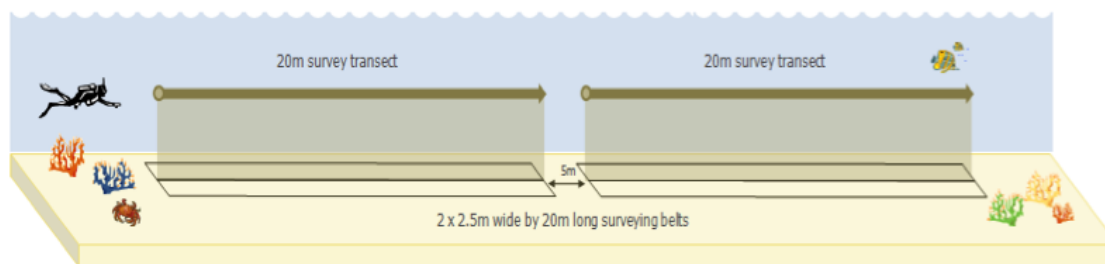
Fish data was recorded along a 'belt' transect, where fish were counted within an imaginary 5x5x5m box along the four 20m replicates (Figure 6). Surveying was carried out by two divers swimming slowly side by side along the transect and counting the indicator fish. The divers stopped every 5 metres and waited 1 minute for the indicator fish to come out of hiding before proceeding to the next 5 metre stop-point.



*Figure 6 – Survey method for recording fish.
The diagram shows 2 of the 4 replicates in a 100m transect.*

2.1.2 Invertebrates

The same areas used for the fish belt transect were used to record the diversity and abundance of selected invertebrate species typically targeted as food species, collected as curios or important to the ecological balance of the reef. The divers recorded invertebrates 2.5m either side of the transect line (Figure 7). Divers looked in holes and under overhangs to look for organisms such as lobsters, sea urchins or other cryptic species.

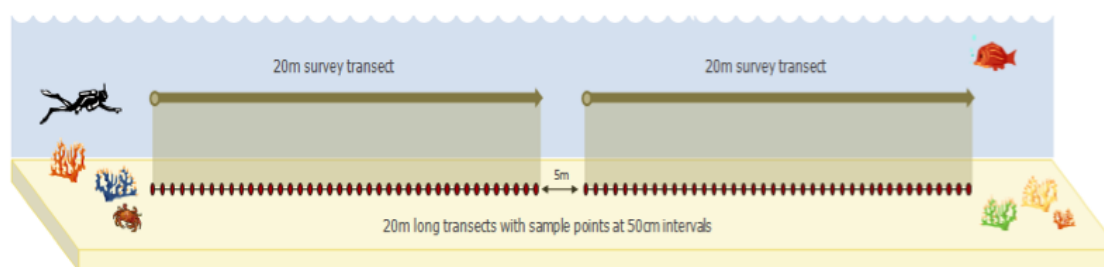


*Figure 7 – Survey method for recording invertebrates.
The diagram shows 2 of the 4 replicates in a 100m transect.*

2.1.3 Substrate

Benthic diversity was measured by recording living and non-living benthic categories along a point intercept transect. Along the transect line, benthic organisms and substrate types were recorded at 50cm intervals (Figure 8). To minimize bias, a plumb line was dropped at each designated 50cm point and the substrate type underneath was recorded. Every replicate contained 40 benthic points.

Benthic categories were: sand, rock, rubble, silt/mud, nutrient indicator algae, sponge, recently killed coral, soft coral, hard coral and any other biotic lifeforms. Hard corals were noted to species or genus level if the coral was a target species, otherwise, a note was made of the coral life form (see Appendix A).



*Figure 8 – Survey method for recording substrate data.
The diagram shows 2 of the 4 replicates in a 100m transect.*

2.1.4 - Impacts

Within the same area assessed for invertebrates divers recorded a number of impacts on the reef. They estimated the total percentage of bleached coral cover as well as the estimated percentage of each individual coral colony that was bleached. Coral diseases were recorded as a percentage of the colony infected and where possible, the disease was identified. Damage was recorded in three categories: boat/anchor, dynamite and other, on a categorical scale from 0 to 3 (0 = none, 1=low, 2= medium, 3 = high). Impact on the site from trash was recorded on the same scale and separated into general and fishing nets/traps.

2.1.5 – Visual Assessment

Much of the Tabugon MPA is shallow (<4m) and thus did not allow for the use of a standard CCC survey methodology. To assess these shallow areas, snorkelers observed the area looking for signs of fishing pressure and anthropogenic impacts. Photos were taken to provide a better idea of the habitat in the area.

2.2 Data Analysis

Each 20m belt transect was treated as an independent replicate. This produced n=16 inside the MPA and n=32 outside the MPA, when not considering depth. At 6m survey depths, there were n=16 replicates inside and outside the MPA each, and n=16 at the 12m depths outside the MPA. To test for statistically significant differences between inside and outside the MPA and between different depths, Mann-Whitney U tests were used. Preliminary inspection of the data revealed that the variances were not homogeneous and the data had a non-normal distribution. Transformations of the data did not sufficiently alter this to warrant using a parametric test.

Species diversity of fish and invertebrates was calculated using the Fishers α index. These index values too were then submitted to the Mann-Whitney U test to check for significant differences in fish and invertebrate diversity.

3. RESULTS

The assessment of the Tabugon MPA was conducted between the 4th of February 2014 and the 31st of March 2014. It was conducted over 32 dives by trained volunteer survey teams from Coral Cay Conservation. The weather throughout the survey period varied with equal amounts of sun and cloud cover. On average the air temperature was 27.0°C. The mean water temperature was 27.0°C at the surface and 26.6°C and 26.4°C at 3m and 10m respectively. Estimated horizontal visibility was 11m on average.

3.1 – Fish

The overall mean fish abundance was 24.02 ± 3.3 fish per 500m³ (mean $\pm$ SE) inside the MPA, 27.8 ± 2.8 and 12.8 ± 3.2 fish per 500m³ at 12 and 6m outside the MPA (Figure 9A). Fusiliers were removed from the data set for analysis as large schools of fusiliers of up to 120 individuals were observed on the 12m transects outside the MPA and skewed the fish abundance data. The 12m transects were found to have significantly higher fish abundances than both 6 m transects ($p = 0.01$ for 6m in vs 12m out and $p < 0.001$ for 6m in vs 6m out). Significantly more angelfish ($p = 0.04$), parrotfish ($p = 0.03$), and other spinecheek ($p < 0.03$) were observed outside of the MPA at 12m and likely contribute to the higher fish abundance observed there. Appendix B shows the overall abundance for each target fish species recorded both inside and outside the MPA.

The overall diversity of fish observed was slightly higher inside the MPA at 6m than outside the MPA but was not found to be significant (Figure 9B). The number of species of fish found at 6m outside the MPA was significantly lower than observed inside ($p = 0.004$) and outside ($p < 0.001$) the MPA at 12m. Butterflyfish diversity was significantly higher ($p < 0.04$) at 12m outside of the MPA with a Fisher's α of 2.4 ± 0.7 , where at 6m inside the MPA diversity was 0.7 ± 0.36 and 0.3 ± 0.2 at 6m outside the MPA (Figure 10). Throughout the entire area, many fish species and families occurred in very small numbers or not at all. Both inside and outside the MPA important food fish species such as Sweetlips, Humphead Wrasse and Jacks were entirely absent. No sharks, rays, turtles or sea snakes were observed.

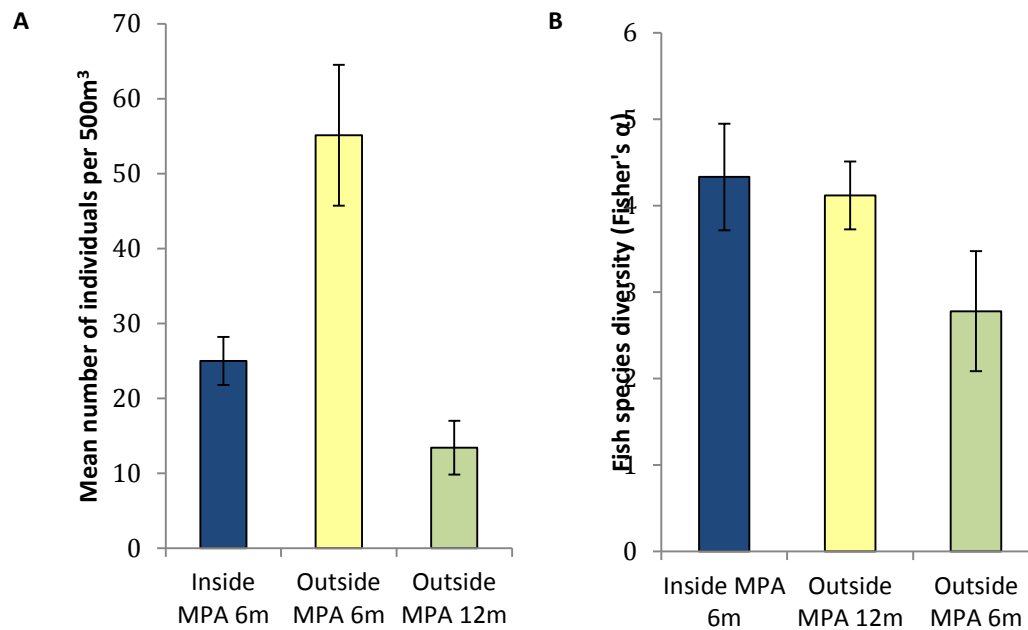


Figure 9 – Average abundance (A) and diversity (B) of fish inside and outside the MPA. Data are mean average per replicate; error bars indicate standard error of the mean.

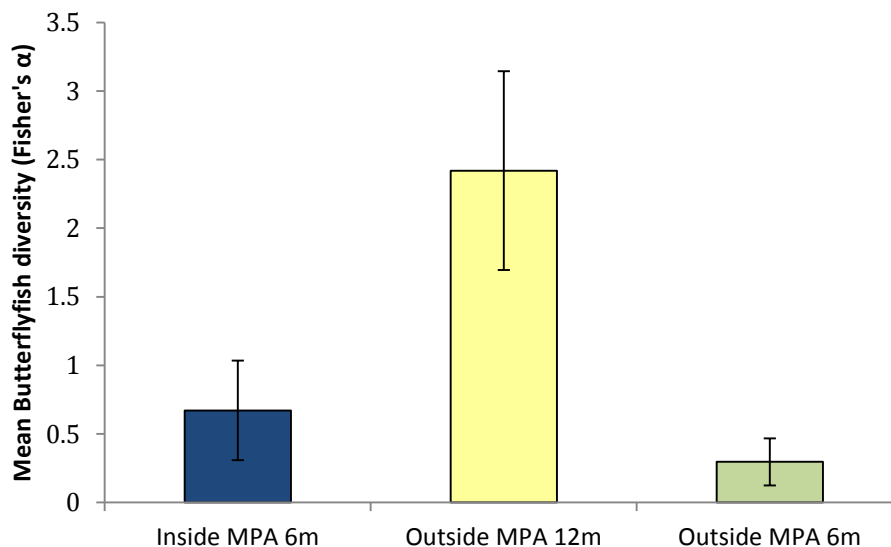


Figure 10 – Average diversity of butterfly fish inside and outside the MPA. Data are mean average per replicate; error bars indicate standard error of the mean.

Large commercially important fish species, including Snapper, Grouper and Parrotfish were observed in low numbers and were small in size across all the areas surveyed. As a result biomass values per 500m³ for these species were also low (Figure 11). Snapper and Grouper were observed with abundances of 0.25 ± 0.1 ; 0.38 ± 0.2 respectively per 500m³ inside the MPA and 0.5 ± 0.4 ; 0.5 ± 0.2 respectively per 500m³ outside the MPA at 6m. At 12m outside the MPA no Snappers were observed and only two Grouper were observed on one replicate. All observed individuals were less than 40 cm. Parrotfish were the most abundant commercially important species, although 23% of individuals observed during this study were below 10cm and 60% of all observed parrotfish were between 11-20cm. Only one

parrotfish greater than 31cm was observed. Similar trends were seen in Groupers and Snappers. The mean average biomass of these species inside the MPA was low at 0.007 ± 0.004 kg/500m³, 0.011 ± 0.006 kg/500m³, and 0.491 ± 0.214 kg/500m³ respectively for Grouper, Snapper, and Parrotfish species (Figure 11). Biomass outside the MPA at 12m was higher than within the MPA. The absence of large, commercially important species and the low biomass described indicate that overfishing is occurring in the area. Overfishing is further discussed in section 5.4.

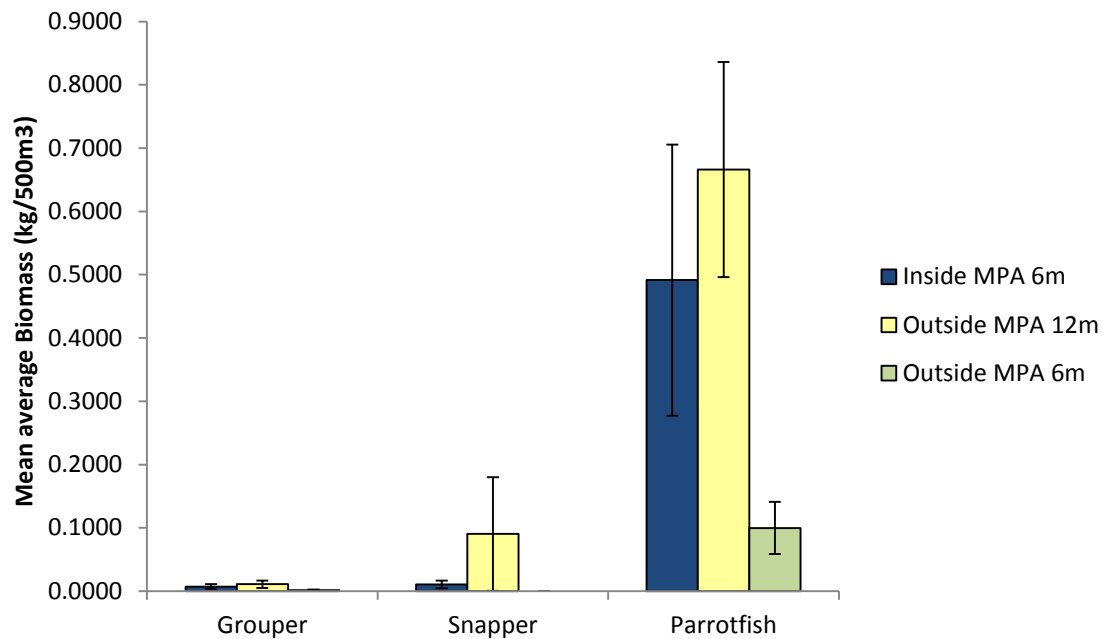


Figure 11 – Biomass of Grouper, Snapper, and Parrotfish inside and outside the MPA.

Comparing fish abundance and diversity by site reveals trends not seen in the overall data (Figure 12 A-F). Separating the results by transect reveals that overall the sites towards the south (replicates A and B) had higher fish abundance and diversity. The area to the south is higher in coral cover and rock, while the northern area is dominated by sand. Natural variations in topography likely explain the differences in fish abundance and diversity seen throughout the area.

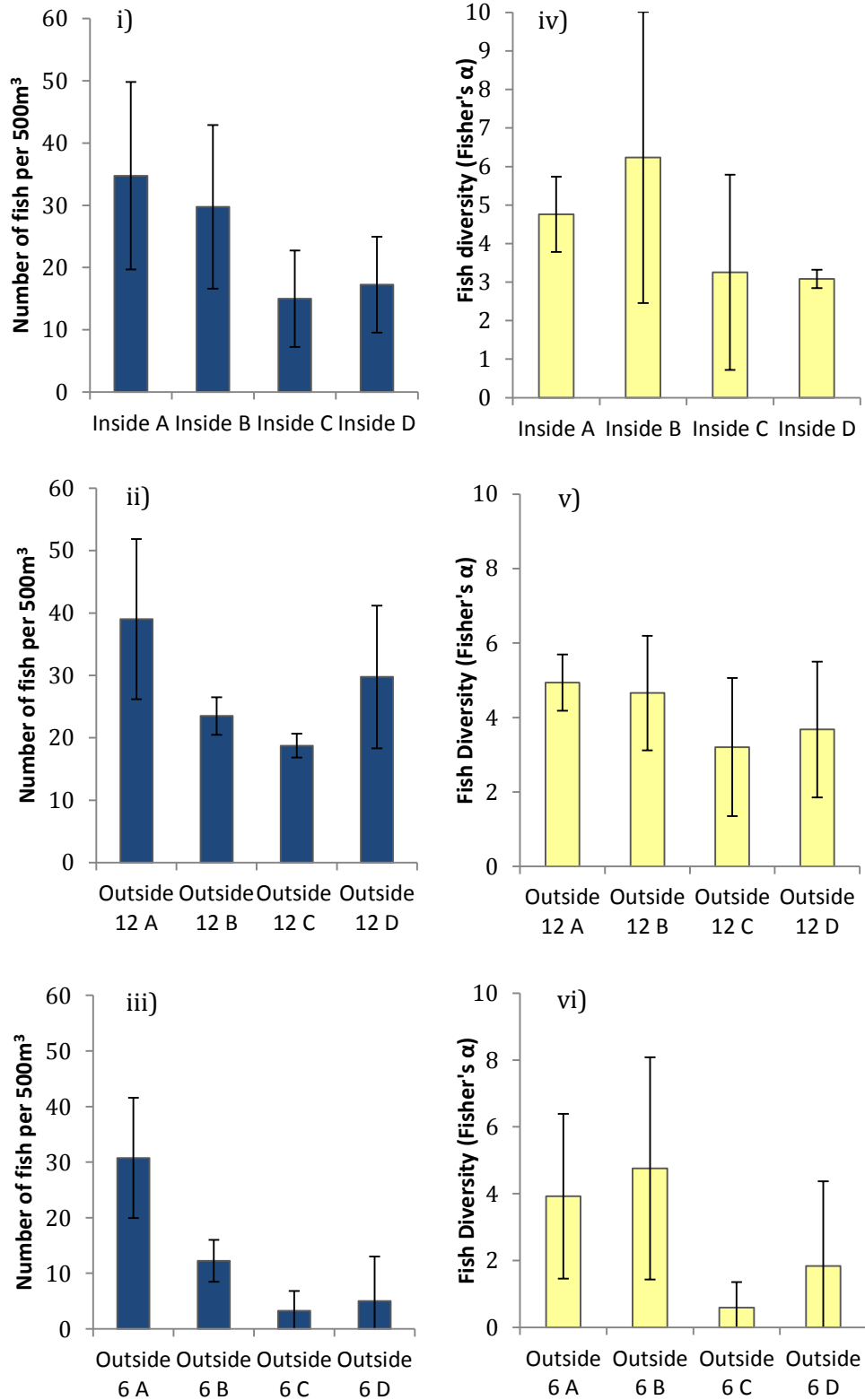


Figure 12 – Average abundance (A-c) and diversity (D-F) of invertebrates inside and outside the MPA. Data are mean average per replicate, error bars indicate standard error of the mean.

3.2 – Invertebrates

The average overall abundance of invertebrates inside the MPA is 92.6 ± 10.2 per 100m^2 , 121.8 ± 26.4 per 100m^2 outside at 6m and 81.5 ± 10.2 per 100m^2 outside the MPA at 12m (Figure 12A). The differences in invertebrate abundance between inside and outside at 6m or 12m was not significantly different. A number of target species and families were observed at significantly different abundances inside the MPA and outside at 12m, including shrimp (inside: 33.0 ± 7.1 per 100m^2 , outside: 10.8 ± 1.6 per 100m^2 , $p= 0.03$), Feather stars (inside: 3.4 ± 0.5 per 100m^2 , outside: 15.1 ± 2.7 per 100m^2 , $p= 0.001$) and nudibranchs (inside: 0.6 ± 0.2 per 100m^2 , outside 2.1 ± 0.5 per 100m^2). When comparing the area inside the MPA to 6m depths outside the MPA, a significant difference in the abundance was observed in the invertebrates previously listed, as well as in other sea cucumbers, with significantly fewer sea cucumbers observed at 6m outside. Although invertebrate diversity (Fisher's α) outside at 6m was lower than at 12m (Figure 13B), it was not found to be significant. Appendix C shows the overall abundance for each target invertebrate species recorded both inside and outside the MPA.

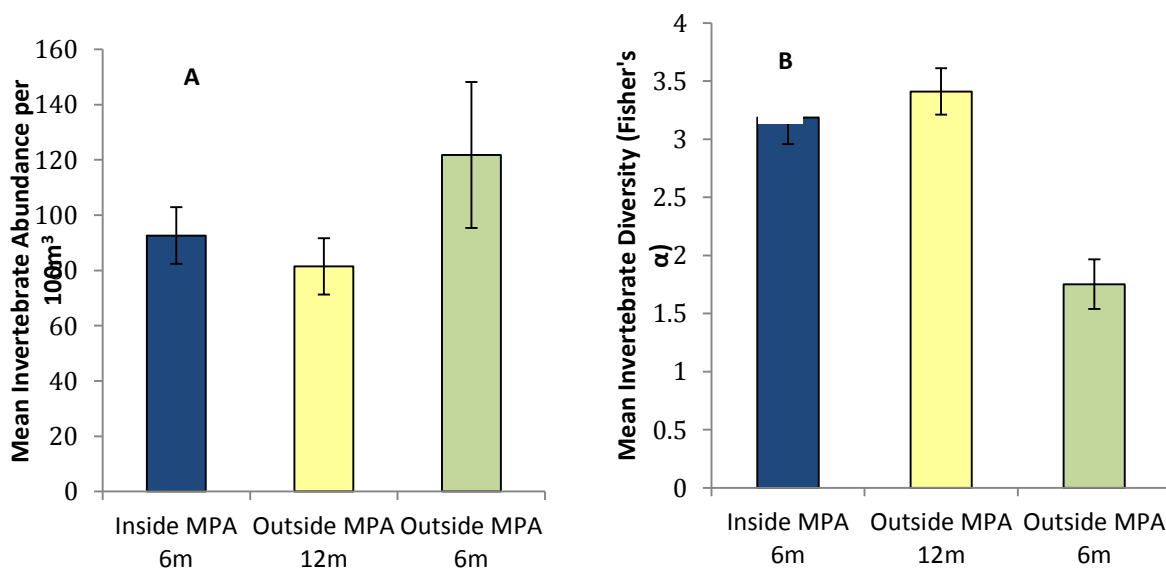


Figure 13 – Average abundance (A) and diversity (B) of invertebrates inside and outside the MPA. Data are mean average per replicate, error bars indicate standard error of the mean.

The number of invertebrate species observed at 6m inside and outside the MPA was not significantly different (inside: 10.2 ± 0.4 per 100m^2 , outside: 6.6 ± 0.9 per 100m^2 at 6m and 10.5 ± 0.5 per 100m^2 at 12m). Several species and families were completely absent on the surveys, including lobster, Triton's Trupest (*Charonia tritonis*), and most target species of sea cucumber (for a full list of target species see Appendix A). Two pinkfish sea cucumbers were observed within the MPA and small giant clams (less than 30cm) were observed both inside and outside the MPA. Crown of Thorns sea stars (CoTs) (*Acanthaster planci*) were observed in low numbers both inside and outside the MPA (<1 per 100m^2).

As with the fish abundance and diversity, comparison by site reveals that overall invertebrate abundance and diversity was typically higher in the southern transects, sites A

and B for all depths, and is likely due to the habitat structure found in the southern sites (Figure 14 A-F).

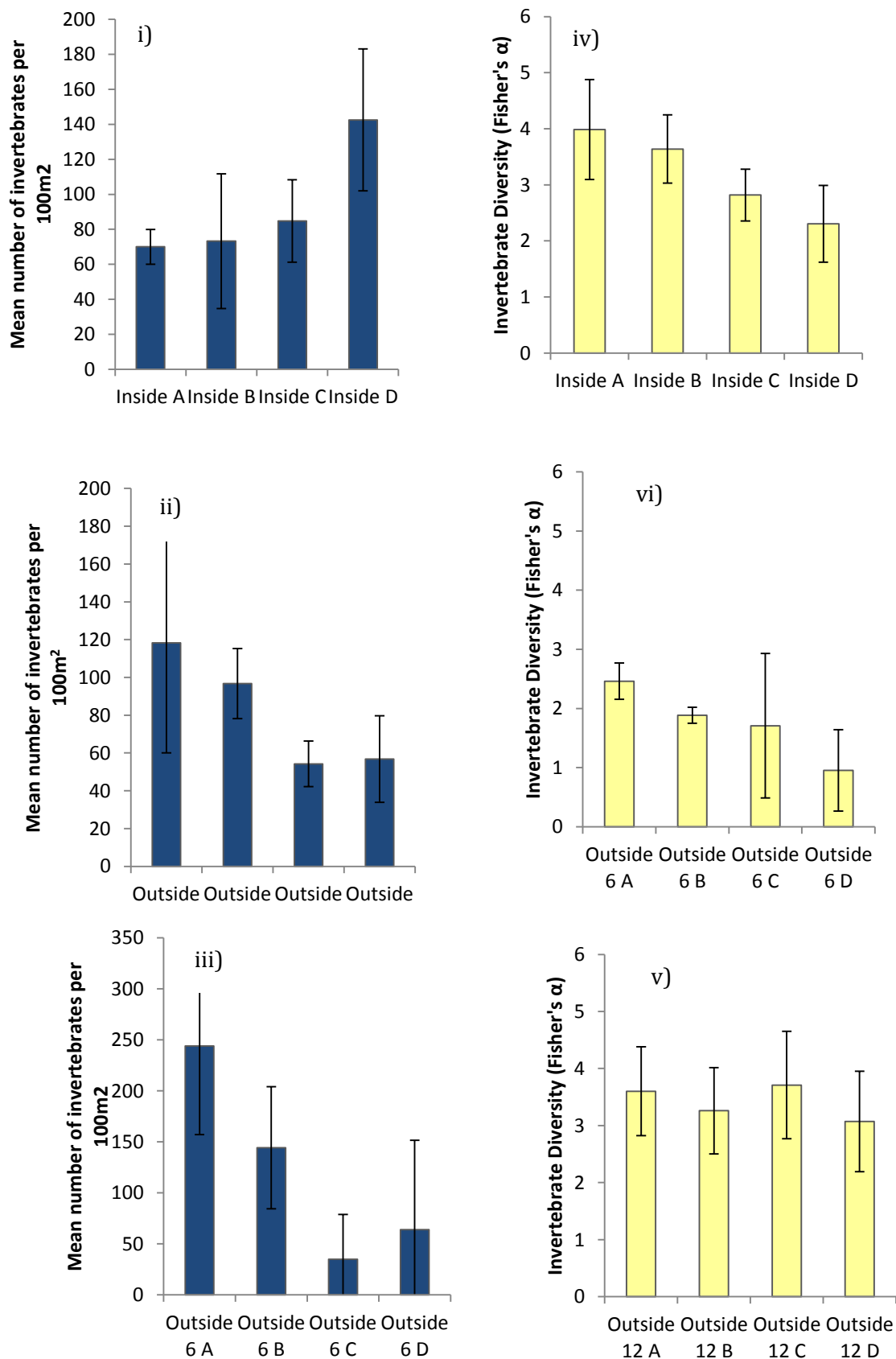


Figure 14 – Invertebrate abundance (A-C) and diversity (D-F) by transect.

3.3 - Substrate

Inside the MPA the most commonly recorded substrate category was sand, followed by rock and hard coral (Figure 15). Outside the MPA at 6m, sand was the most common substrate followed by rock and rubble. Hard coral accounted for 15% of the substrate coverage for both inside and outside the MPA at 12m. The amount of recently killed coral (RKC) within the MPA was significantly higher than 6m and 12m outside the MPA (6.1% substrate cover inside vs 1.9% and 3.0% at 12m and 6m outside $p = <0.004$ for inside 6m vs outside 6m and $p = 0.02$ for inside 6m vs outside 12m) while the amount of observed rubble was significantly higher outside the MPA (9.7% vs 19.7% at 12m outside, $p = 0.03$). The 6m area outside the MPA is characterized by a high abundance of sand, rock and rubble with patches of hard coral. In general soft coral, sponges, and nutrient indicator algae were found in low abundance both inside and outside the MPA (Figure 15). Organisms that fall under the “Other” category including anemones, tunicates and gorgonians were recorded in very low abundance if at all (for a full list of organisms in the category “Other”, see Appendix A).

Inside the MPA, 9 different target species of hard coral were recorded. Outside the MPA 15 target species of hard coral were recorded at 12m and 10 target species of hard coral at 6m (see Appendix C). The most commonly recorded hard coral category inside the MPA was *Non-Acropora*, Massive. Outside the MPA the most common hard coral category was *Non-Acropora* encrusting at 12m and *Non-Acropora* branching at 6m. *Massive porites* was the most common species of hard coral within the MPA, with *Porites cylindrical* also common. Outside at 12m the most commonly recorded hard coral species was also *Massive Porites* followed closely by *Diploastrea Heliopora* and *Favia* sp. At 12m *Porites cylindrical* was most common with *Massive Porites* also commonly occurring.

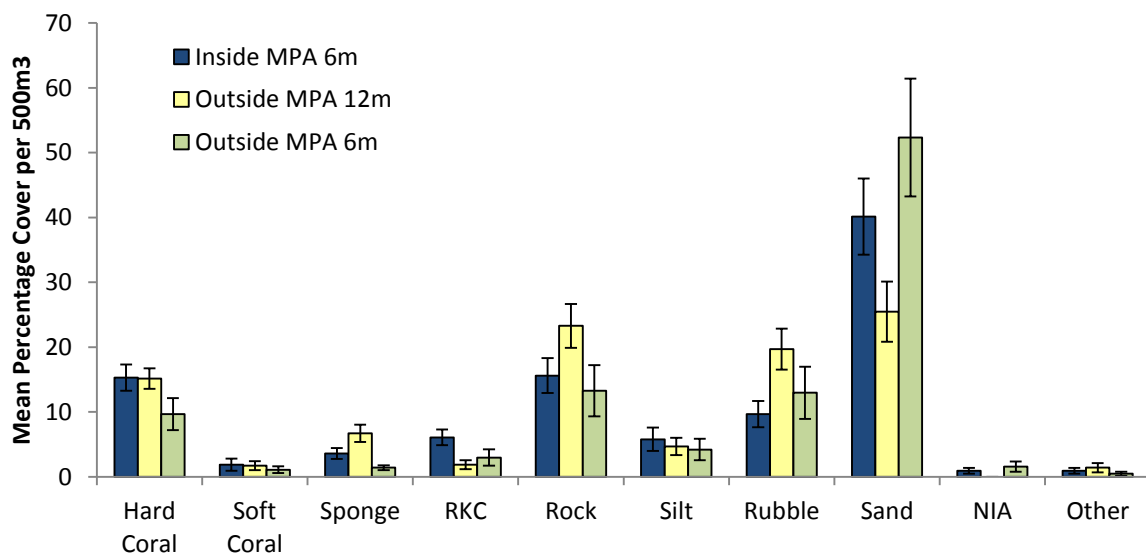


Figure 15 – Average abundance of substrate categories inside and outside the MPA overall. NIA = nutrient indicator algae, RKC = recently killed coral. Data are mean average per replicate, error bars indicate standard error of the mean.

Viewing the substrate cover by transect reveals detailed data on variations in habitat by site and explains the generally higher fish and invertebrate abundance and diversity in the southern sites (Figure 16).

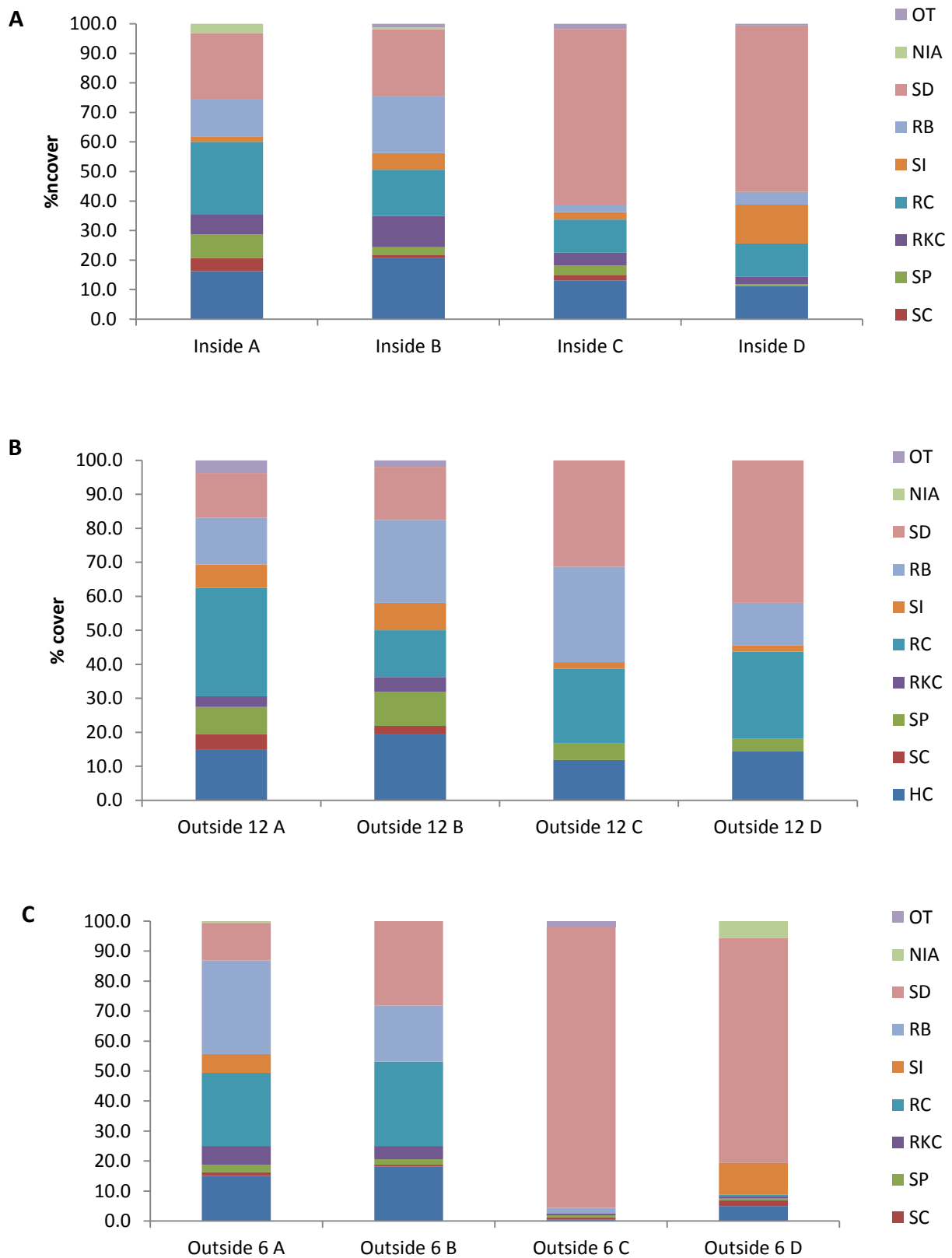


Figure 16 – Substrate per site for inside the MPA (A), outside the MPA at 12m (B) and outside the MPA at 6m (C).

3.4 - Anthropogenic Impacts

Anthropogenic impacts were obvious both inside and outside the MPA and trash was frequently observed on the reef. Inside the MPA household trash was found at an impact scale of 1.3 ± 1.0 per replicate, where 81% of the replicates were found to have at least one piece of trash and 38% of the replicates to have 2 pieces of trash or more. At 12m outside the MPA household trash was observed at a level of 1.50 ± 1.21 on the impact scale and 69% of the replicates had at least one piece of household trash present. In the 6m depths outside the MPA 56% of replicates had 2-4 pieces of household trash and 25% of the replicates had 5 pieces of household trash or more. High levels of trash were recorded at 6m outside the MPA as well, with an impact level of 2.06 ± 1.24 for household trash. At 12m 82% of the replicates had at least one piece of household trash and 56% of the replicates had 5 pieces or more.

Trash categorized as discarded or lost fishing gear was also apparent both outside and inside the MPA. Within the marine protected area, an impact level of 0.50 ± 0.82 was observed. Fishing-related trash was higher outside the MPA with an impact level of 1.13 ± 0.96 , where one replicate was found to have 15 pieces of trash related to fishing. At 6m inside and outside the MPA, at least one piece of fishing related trash was seen on 69% of the replicates. At 12m, fishing related trash was found at an impact level of 0.19 ± 0.40 with only 19% of the replicates found to contain at least one piece of discarded fishing gear. The 6m depth replicates outside the MPA were found to have significantly higher levels ($p = 0.04$) of fishing trash than observed at 12m.

Coral predation was more commonly observed inside the MPA at 6m compared to outside the MPA at 6m, 1.06 ± 1.61 and 0.19 ± 0.40 respectively. For the most part this predation was attributed to *Drupella* species. Coral bleaching was recorded at a very low overall level across the entire assessment. No coral disease was recorded on any of the surveys.

4. VISUAL ASSESSMENT



Figure 17 – Coral bommies were characteristic of the area



Figure 18 - Nutrient Indicator Algae was common in the shallows at Tabugon



Figure 19 - Long Spine Sea Urchins were observed in high densities



Figure 20 - CCC survey team collecting data on the reef



FIGURE 21 & 22- SMALL *ACROPORA* RECRUITS INDICATE THE AREA IS RECOVERING FROM THE COTS OUTBREAK IN 2012

5. DISCUSSION

The assessment of the area inside the Tabugon MPA gave the impression of a reef ecosystem in a generally poor status of health. Fish abundance and diversity is low both inside and outside the MPA and discarded fishing gear within the protected area suggests the MPA is not being properly managed. The low numbers or complete absence of commercially important fish species and lack of large fish indicate the area is overfished. Invertebrate abundance and diversity is also low, and commercially important species such as giant clams and triton's trumpet were rare or absent. Anthropogenic impacts at this site were high due to the amount of trash found on the reef. Sand, rock, and rubble dominate throughout the area and hard coral cover was found to be 15% or less. The northern transects within the MPA were mostly sand and re-drawing the boundaries of the MPA to encompass the more biodiverse areas outside of the MPA to the south should be considered. Furthermore, the MPA was very shallow, and extending the MPA to greater depths would also likely improve the functions of the MPA. Currently the MPA lacks proper enforcement and effective management; however, there are a number of trends in the data that are worth discussing in relation to improving management and reducing negative impacts. In this section these trends are reviewed and recommendations for future management are presented.

5.1 – Fish

Fish abundance and diversity inside and outside of the MPA was relatively low and indicative of overfishing in the area. Abundance of fish was significantly higher outside the MPA at 12m compared to inside. The high abundance outside at 12m is due to variances in habitat, as the 12m outside the MPA was found to have less sand, and more rock and rubble than at 6m inside the MPA. Outside the MPA at 12m a significantly higher number of parrotfish, angelfish, and butterflyfish were also observed. Angelfish are dependent upon rocks and boulders for shelter and the higher amount of rock and rubble outside the MPA at 12m may explain their increased abundance here. Including the deeper areas within the MPA would improve the overall health of the MPA.

Parrotfish are herbivorous fish that eat algae and prevent overgrowth of algae on the reefs. They are vital to the coral reef ecosystem and facilitate the recruitment, growth, survival and resilience of the reef. The low abundance of parrotfish within the MPA indicates fishing pressure in the area and is cause for concern as removal of parrotfish can affect the whole ecosystem. The implications of these trends shall be discussed in Section 5.4.

Butterflyfish were found to be significantly more abundant outside the MPA at 12m. Many species within this family are corallivores, feeding on the polyps of living corals. Their greater abundance outside the MPA is likely therefore linked to the higher hard coral diversity, for reasons of increased food resource availability and suitable habitat. Although the percentage of hard coral cover was the same at 6m inside and outside the MPA, increased coral diversity outside the MPA may explain the greater fish abundance and diversity seen here.

The most noteworthy result of this MPA assessment was the absence or low abundance of large predatory fish, namely Groupers, Snappers, Sweetlips, Emperors, Humphead Wrasse and Jacks. These families are highly prized by commercial and subsistent fishers alike. Parrotfish, are also key species for human consumption and were observed in greater numbers outside the MPA but were generally small in size. The implications of these trends shall be discussed in Section 5.4.

5.2 – Invertebrates

The overall abundance of invertebrates was not significantly different between inside and outside the MPA. However, Shrimp, Feather Stars and Nudibranchs were observed at significantly different abundances between inside and outside the MPA. The higher abundance of Shrimp species inside the MPA is likely due the significantly lower abundance of fish. Many fish feed on shrimp, and with less fish inside the MPA more shrimp are likely to survive here. Feather Stars and nudibranchs were significantly more abundant outside the MPA. Feather Stars filter-feed using their velcro-like arms to pull particles out of the water column. Thought to have few predators, it is likely that increased food availability outside the MPA explains the higher abundances of feather stars observed here. Numerous species of invertebrates such as shrimp and squat lobster, as well as fish such as the Ornate Ghost Pipefish, use feather stars as shelter and they play an important role in invertebrate diversity and abundance. Nudibranchs are known to feed on invertebrates such as tunicates, sponges, or even other nudibranchs. Although invertebrate abundance was slightly lower outside the MPA, the higher amount of sponges or other prey may explain the increased nudibranch abundance here. Substrate composition varies little between outside and inside the MPA and is unlikely to have an effect on the abundance of these species.

The high occurrence of Long Spine Sea Urchins, particularly outside the MPA at 6m, bears some cause for concern. Long Spine Sea Urchins feed on algae that are also the preferred diet of herbivorous fish species including Parrotfish and Surgeonfish. High numbers of Long Spine Sea Urchins could indicate that competition for these algae from the fish has been reduced which has allowed the urchins to increase in numbers. Many large aggregations of Long Spine Sea Urchins were also observed in the shallows of the MPA during snorkel. This trend will be discussed further in section 5.4.

Several of the species that were found in low numbers or were absent entirely, are targeted for consumption. Many of these species, such as the Triton's Trumpet and Giant Clam, are important species in maintaining the stability of the coral reef ecosystem. These two specific examples are known to be instrumental in suppressing populations of CoTs. Possible consequences of the low abundances of these species will be discussed further in section 5.4. The lack of target species; Prickly Redfish (*Thelenota ananas*), Greenfish (*Stichopus chloronotus*) and squid is of concern as these are prized as food species. Their absence may be an indication of extensive extraction pressure. This trend will be discussed more in section 5.4.

Crown of Thorns starfish were observed in low numbers across the whole survey area (2 inside and none outside). This is a positive sign for the reef as a high abundance could indicate that the reef may be at risk of an outbreak. In 2012 a CoTs outbreak occurred in the Tabugon MPA and it appears the extractions that were carried out in area were a success. Continued monitoring of CoTs numbers should be undertaken to ensure that outbreaks are reported quickly.

5.3 – Substrate

Substrate varied little between inside the MPA and outside at 6m, and differences throughout the entire area were attributable to natural distribution. The shallower areas are more sandy thus less suitable for hard coral to settle which explains the lower percentage of coral cover at 6m outside the MPA. In the shallows a large amount of Nutrient Indicator Algae (NIA) was observed. Algae compete with coral for space and can overgrow and kill corals. The high abundance of NIA here is potentially a consequence of pollution and nutrient runoff into the sea and indicates poor practices inland are affecting the health of the MPA.

It is important to bear in mind that substrate recorded as “Rock” includes coral that has been dead over a year. Much of the “Rock” observed at this site was dead coral heads of *Porites massive* and are likely the consequence of the CoTS outbreak in the summer of 2012. Despite the amount of dead coral observed, many small recruits were observed growing on dead corals and rocks and indicate the reef is slowly recovering from the CoTS outbreak. Rock and Rubble dominate the transects found at 12m, and an extension of the MPA could incorporate these areas where corals have the potential to grow.

5.4 – Impacts

Levels of trash, both from general household use or from discarded fishing gear, were relatively high and indicate the need for improved waste management. Trash can have a large impact on the survival of marine organisms. Plastics such as cellophane and polystyrene do not biodegrade but break down into smaller and smaller pieces. Plastics can be confused with food when floating in the water column and are ingested by many animals. Ingested plastics release toxins into the animal which are not only harmful to the animal itself but to the entire food chain, which often culminates in human consumption. Plastics also take up space in the animals’ stomach which often leads to starvation. Furthermore, when plastics are deposited on the reef they release toxins into the environment and also prevent corals from getting proper amounts of nutrients. Tabugon is located near the mouth of a river and this is the likely source of much of the trash. These findings serve as an important reminder that poor waste management inland as well as coastally, can have severe effects on the marine environment.

High fishing pressure was evident in the data. As mentioned in previous sections, several species of fish and invertebrates that are known to be popular for consumption were only observed in low numbers or were completely absent from the surveyed area. The most

concerning aspect of these findings is that several of these species are known keystone species. This means that these organisms play a vital role in the ecosystem and if removed can seriously affect the stability of the entire ecosystem. This can happen in two ways: (1) direct effects or (2) indirect effects.

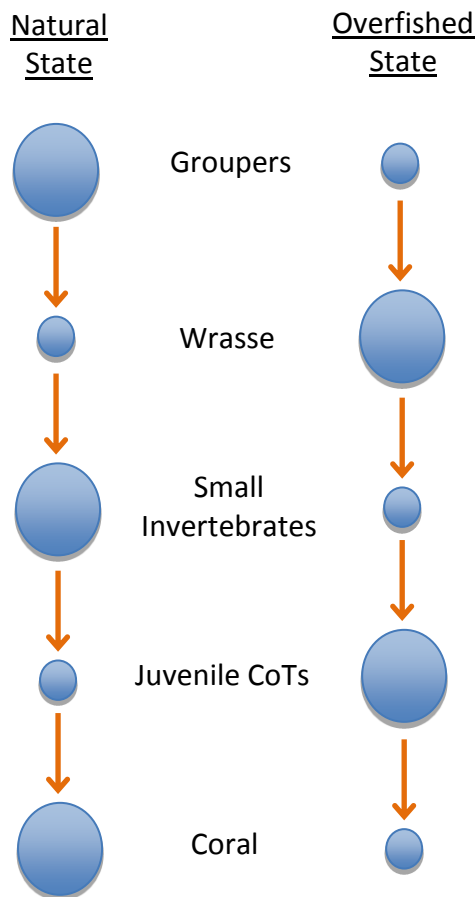


Figure 23 – Representation of the indirect effects that overfishing of predatory fish, in this example Groupers can have on the entire coral ecosystem. The size of the circle represents the relative abundance of that organism or trophic level.

Direct effects occur when predators are removed from an ecosystem and facilitate the ecological release of prey species. For example the removal of predators such as Titan Triggerfish (*Balistoides viridescens*) which are known to feed on CoTs can result in an expansion in CoTs numbers through a lack of predation pressure. Indirect effects are more complex as they often involve many species of families and cascade down through trophic levels. In severe cases this can lead to phase shifts and alter ecosystem dynamics.

The removal of top predators lead to trophic cascades which can affect the whole ecosystem (Figure 23). With the removal of apex predators such as Groupers, prey species including Wrasse suffer less predation pressure and populations increase. Many Wrasse species feed on benthic invertebrates that in turn predate juvenile settlement stage CoTs. With an increase in Wrasse numbers there is a corresponding decline in these invertebrates and thus an increase in juvenile CoT survivorship. This cascade effect through the trophic levels leads to problems such as CoTs outbreaks because fewer predators are around to keep the CoTs population in check. Indirect top-down effects from depletion of apex predators have been shown to have wide spread impacts on ecosystems around the world (Myers et al. 2007).

The high numbers of Long Spine Sea Urchins observed inside the Tabugon MPA and surrounding area may be another sign of overfishing. Similar to the removal of apex piscivorous fish leading to an increased number of CoTs, overfishing of herbivorous fish such as Parrotfish, Rabbitfish, and Surgeonfish, can lead to an increased abundance of Long Spine Sea Urchins. By fishing out the populations of herbivorous fish, the Long Spine Urchins have more algae to feed on and increase in numbers, becoming the dominate grazers on the reef. Long Spine Urchins in high densities are vulnerable to outbreaks of disease which can lead to mass die off events within the urchin population. If this were to occur in Tabugon there is not enough grazing pressure to keep algae at healthy levels on the reef.

The observed size and biomass of commercially important species such as Parrotfish, Snapper, and Grouper, further support the concern that the area is overfished. For instance, 23% of recorded Parrotfish were below 11cm and 83% of all Parrotfish were below 21cm. However, many common species of Parrotfish reach sexual maturity around 15.5 cm and their fecundity, or ability to reproduce, continues to increase as they grow (Froese and Pauly, 2001). It is therefore vital to have larger fish in the population to support reproduction in the area and produce juvenile Parrotfish for future generations. A similar example is seen in the Snapper population. All Snapper (Maya Maya) recoded during this study were smaller than 40cm yet Snappers do not reach sexual maturity until they are approximately 54.6 cm in length (Froese and Pauly, 2001). Again, as Snappers grow in size they become more beneficial at replenishing the population. For example, one 12.5 kg female Snapper produces as many eggs as 212 Snappers that weigh 1.1kg each (Bohnsack, 1990). The biomass and size of Snappers at Tabugon indicates a trend for removal that if left unaddressed could see the population being unable to repopulate itself in the area.

Signs of unsustainable fishing pressure observed inside and around the Tabugon MPA indicate that the MPA is not reaching its full potential. The MPA was put in place to provide a sustainable food source and income for future generations, but this will only occur once the rules and regulations of the MPA are enforced and abided by. As shown in the case studies of Apo Island and Sumilon Island (Box 1), full recovery of certain species will take a substantial amount of time. Recovery can only begin once the MPA is being effectively managed and when overfishing is no longer occurring. This must be done before the populations here reach critically low levels. Once abundances of fish and invertebrates begin to increase, it is vital that proper enforcement continues as poaching inside an MPA can destroy years of recovery.

6 RECOMMENDATIONS

Given the variations between sites, the MPA should be expanded or re-zoned to incorporate the more productive habitat to the south of the MPA in 6m and to the west of the MPA at 12m (Figure 24). The northern sites within the MPA (Sites C and D) mainly contained sand and very little hard coral cover or rock and have low potential to improve fish populations in the area. These sandy areas are of little use to the MPA and do not provide substrate for coral to attach and grow on. It is common to find greater species abundance and diversity on deeper reef slopes compared to the shallower reef crest as there are often a greater range of micro-habitats on the reef slope. Changing the MPA boundaries to incorporate the deeper reef crest at 12 m, as the more biodiverse area to the south of the MPA, will allow for the MPA to become more efficient and serve the area better as a whole. While re-zoning the MPA will produce a more effective area of fish production, proper and on-going management of the MPA is key.

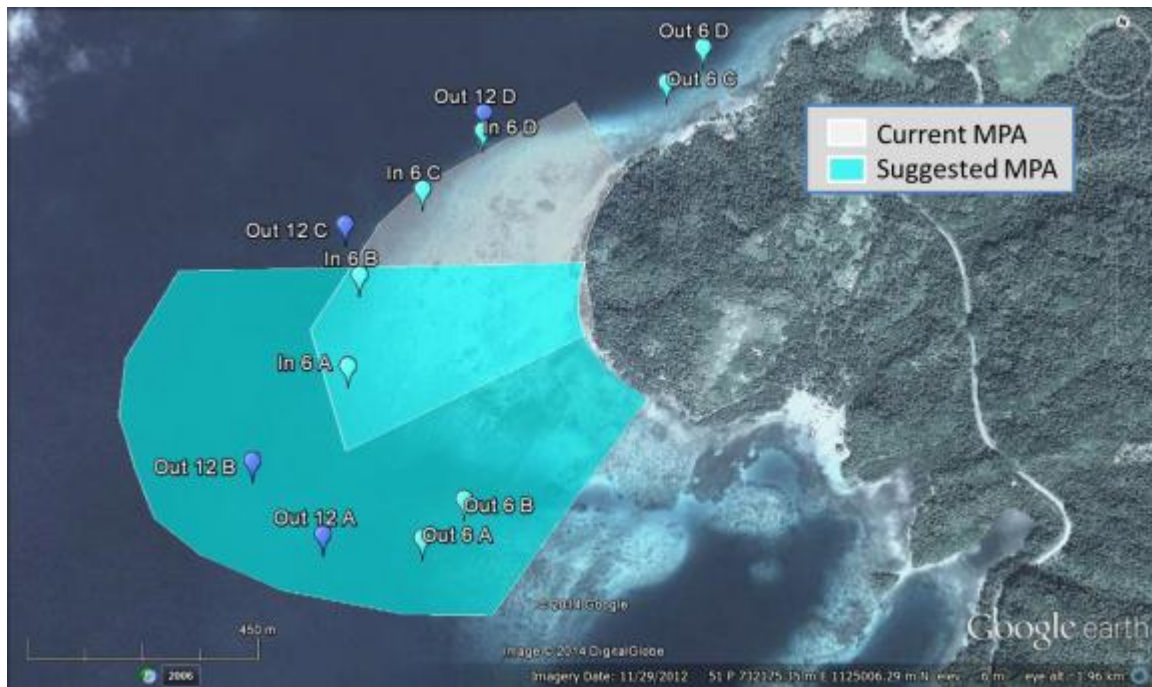


Figure 24 –Suggested area for the Tabugon MPA

The strongest force behind effectively managing the Tabugon MPA lies in the community. Increasing the compliance of fisherfolk with the rules and regulations of the Tabugon MPA can be accomplished by (1) effective enforcement and (2) broadening the understanding of what the MPA can do for the livelihood of current and future generations. Effective enforcement of the Tabugon MPA is lacking, and although there is a guard hut, it appears to be rarely occupied. The observed presence of poaching in the area and discarded fishing gear further suggest that proper management is needed.

To improve MPA management, local stakeholders should identify partners able to provide support and specific training for the MPA managers. While NGO's can be of great help in the short term, the long term partnership should be with provincial and national agencies such as PENRMO and DENR. The Provincial Environment and Natural Resources Management Office in particular, being the body in charge of the MPA's management in the whole province, should also be notified of major initiatives concerning the MPA and its management. It is our opinion that the long experience with the topic makes this office a strong ally to face the challenges of managing an MPA.

The MPA Management Effectiveness Assessment Tool (MPA MEAT) was designed by the Philippines government and allows local stakeholders and managers to identify areas of MPA management that are good as well as aspects that need improving. The MPA MEAT uses simple criteria to outline the current management situation regarding the MPA and can be used to plan steps to improve the management. The methodology and more information can be obtained from the CCC Project Scientist. Only when the coral reef ecosystem inside the MPA is given a proper chance to recover from unsustainable fishing pressure, will the benefits of protection become evident. Action towards achieving this is needed in the near

future in order to avoid the damage to the ecosystem to reach such an extent that recovery will take decades rather than years.

The health of the MPA at Tabugon not only depends on the community, but the biogeography of the area as well. For coral reefs to grow and improve in health, there needs to be available substrate for coral to settle on. The current area at Tabugon is shallow and mainly comprised of sand. Through MPA expansion and re-zoning, followed with effective management and enforcement of the MPA, the MPA at Tabugon can begin to improve. The reef is resilient and improved enforcement of the MPA rules is likely to lead to recovery of coral cover and fish stocks over time.

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APPENDIX A: Target Species Lists

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>Seriatopora 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	Drupella	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

Target Fish

Common Name	Latin Name	Visayan Name
Angelfish	Pomacanthidae	Adlo
Barracuda	Sphyraenidae	
Blenny	Blenniidae	
Butterflyfish*	Chaetodontidae	Alibangbang
Cardinalfish	Apogonidae	
(Damsel fish)	(Pomacentridae)	
Anemonefish	<i>Amphiprion</i> sp.	
Sergeant Damsel fish	Pomacentridae	
Emperor	Lethrinidae	Katambak
Filefish	Monacanthidae	Ilak
Fusilier	Caesionidae	Dalagang bukid
Goatfish	Mullidae	Timbongan
Goby	Gobiidae	
Groupers	Serranidae	Lapu-lapu
Flagtail Grouper	<i>Cephalopholis urodeta</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	Racoon 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 B: TARGET FISH FAMILY ABUNDANCE

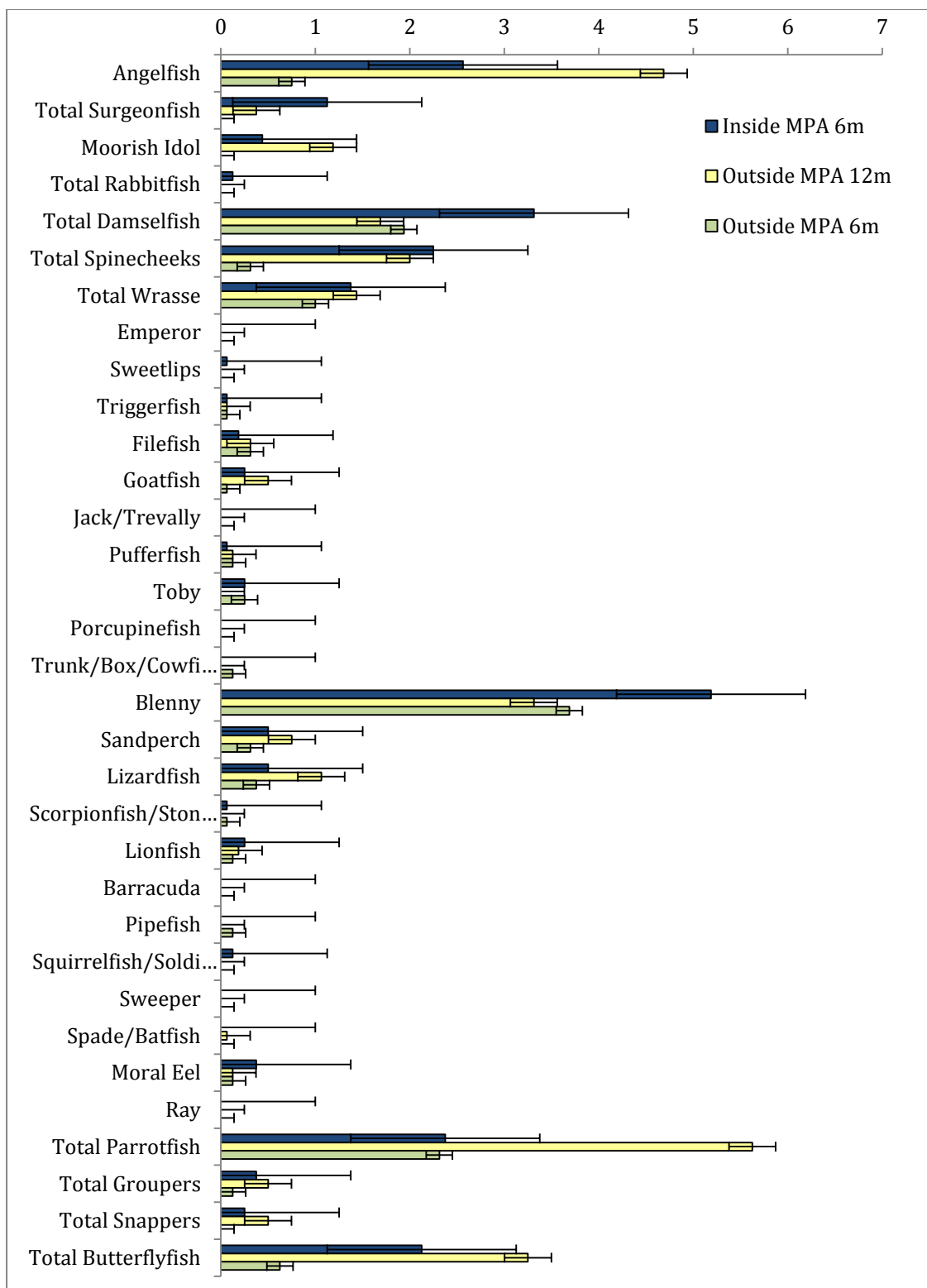


Figure 25 – Average abundance of target fish families. Data are mean average per replicate, error bars indicate Standard Error of the Mean.

APPENDIX C: TARGET INVERTEBRATE ABUNDANCE

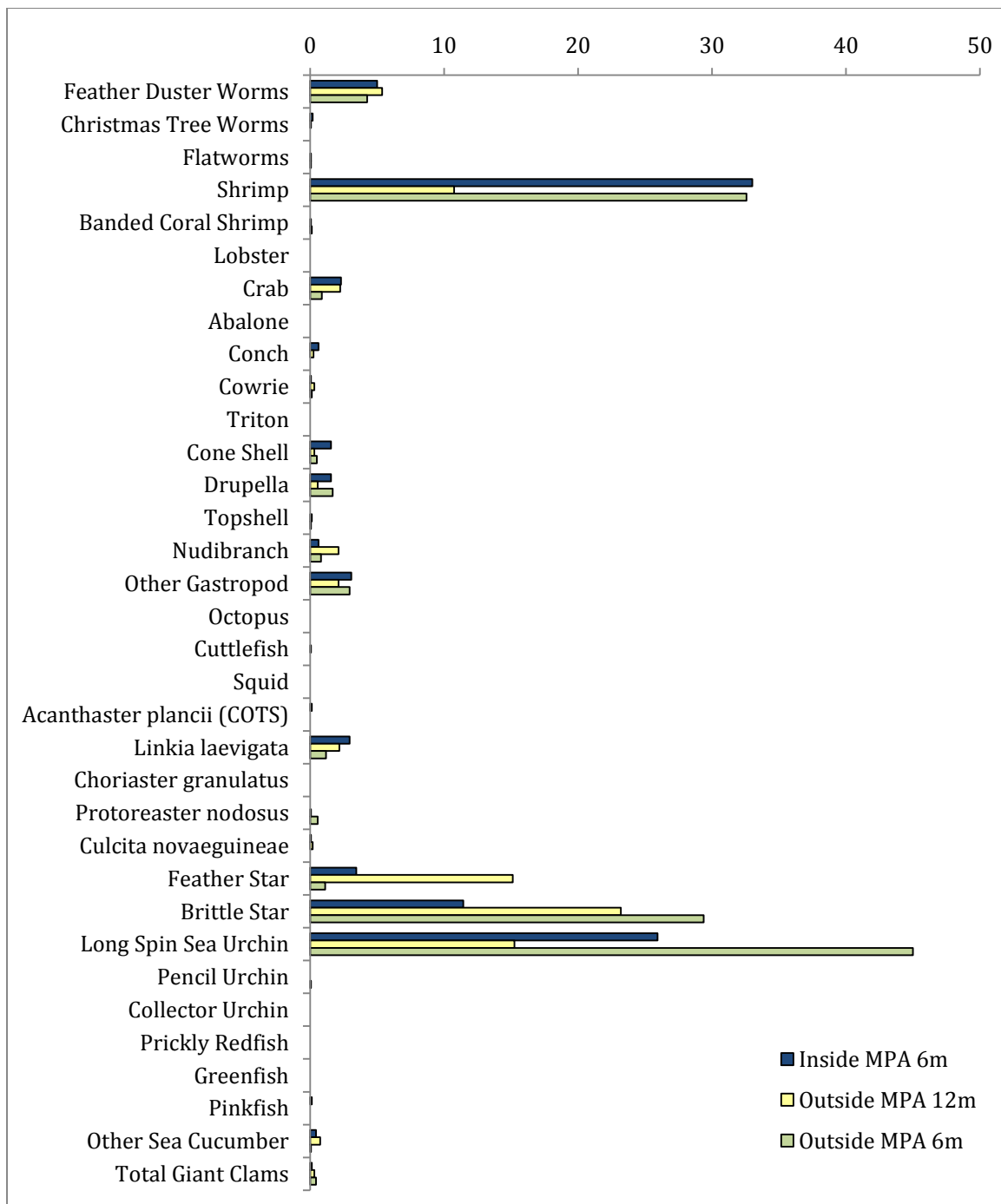


Figure 26 – Average abundance of target invertebrate species and families. Data are mean averages per replicate, error bars indicate standard error of the mean.

APPENDIX D: TARGET SUBSTRATES ABUNDANCE

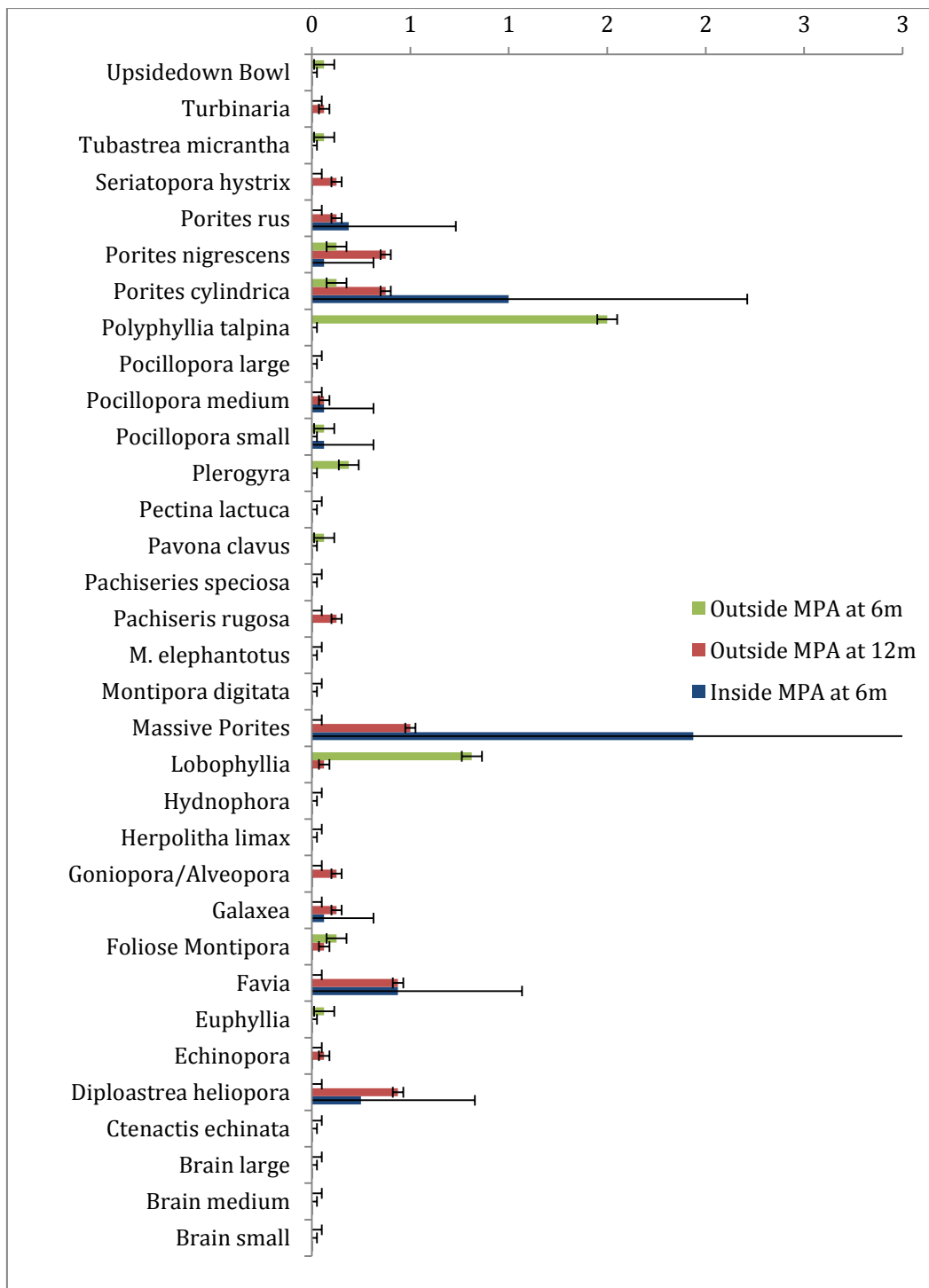


Figure 27– Average abundance of hard coral lifeform, target coral species and benthic organisms classed under ‘other’. Data are mean average per replicate, error bars indicate Standard Error of the Mean.