

Coral Cay Conservation Philippines;

The influence of Barangay
Napantao's MPA on coral
reef community
assemblages in 2019





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Coral Cay Conservation Philippines; The Influence of Barangay Napantao's MPA on Coral Reef Community Assemblages in 2019

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Abstract

In March and October of 2019, Coral Cay Conservation surveyed the coral reefs of Barangay Napantao (municipality San Francisco), to assess the communities of fishes, invertebrates, substrates and anthropogenic impacts. An enhanced Reef Check methodology was used to complete a total of 8 transects at 12m depth, half of which were inside and half outside of the Napantao Marine Protected Area (MPA).

Mean target fish abundance did not differ significantly between the protected and unprotected areas ($154.62 \pm 29.34 \text{ } 500\text{m}^{-3}$, $136.25 \pm 19.62 \text{ } 500\text{m}^{-3}$), however the mean abundance of fish on all transects in Napantao were higher than other recently surveyed reefs in the area. Protection status positively influenced the abundance of Grouper (Epinephelinae) and Snapper (Lutjanidae), and the biomass of Epinephelinae and Parrotfish (Scaridae). A higher abundance of juvenile (<10cm) Scaridae outside the MPA suggests that there is spillover occurring from the reserve. However, no commercially important fish >40cm were recorded outside the MPA, and no individuals >50cm inside the MPA, suggesting the size of the MPA may be insufficient to protect the home range of larger growing species.

Invertebrate abundance was significantly higher outside the MPA, although a lack of commercially important species suggests no recovery from historical exploitation. Coral predating invertebrates were more abundant outside the MPA, possibly linked to fewer predators. Substrate composition analysis revealed high hard coral coverage both inside and outside the MPA (42.33% and 43.44% respectively) that is almost double the regional average of 22%. Coral coverage was not influenced by protection status, and an even distribution between coral life traits suggests Napantao reefs have high resilience to disturbance events.

No direct anthropogenic impacts were recorded in Napantao, however indirect impacts to coral colonies from physical damage or predation were observed. Fishing trash was present in higher levels outside the MPA, however 8.21% of replicates inside the reserve had medium levels (2-5 incidents) of fishing trash. Coral bleaching affected a higher proportion of individual colonies in October, however overall incidence was low throughout the year on all transects. This assessment suggests that the Napantao reef systems are healthy and resilient, and that the MPA is being well-managed, however its small size means it cannot protect larger fish species, so potential benefits are not maximised.

Keywords: ecological spatial assessment, Marine Protected Area, coral reefs, community assemblages, nearshore fishery

1. Introduction

Occupying less than 0.1% of the ocean, yet providing a home for an estimated third of all marine

species (Spalding and Grenfell, 1997), tropical coral reef environments are often described as 'underwater rainforests'. Humans have long reaped the benefits of high productivity associated with coral reefs, primarily as a food source and the provision of coastal protection, and in more recent times for tourism and medicinal

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research (Wali et al., 2019; Woodhead et al., 2019). These ecosystem services provided by coral reefs form the basis of many economies and livelihoods within coastal communities (Weijerman et al., 2018). Today, millions of people rely directly on coral reefs for both subsistence and livelihoods, with an estimated 6 million direct reef fishers, over half of which are found in South East Asia (Teh et al., 2013). However, the number of direct reef fishers is difficult to accurately quantify due to scarcity in data and unreported catches of localised, largely unregulated, small scale fisheries (Drammeh, 2001).

Since long haul flights have increased in frequency and decreased in price, global travel to visit tropical coral reefs has become much more accessible to people on a global scale (Cesar et al., 2003). Large tourism industries have been built around the viewing of coral reefs through activities such as scuba diving, snorkelling and glass bottom boat trips, with estimates that 1 km² of coral reef can generate anywhere from \$480,000 to \$7,000,000 per year, with a collective estimated value of \$36 billion (Spalding et al., 2017).

Coral reefs have been subjected to a multitude of anthropogenic pressures that has led to a global trend in declining coral coverage. Threats vary from localised (e.g. dynamite fishing) to global (e.g. ocean warming/acidification) and can have far reaching consequences across the greater reef ecosystem. Direct human caused threats to coral reefs include overfishing, destructive fishing methods, coastal development, sedimentation, nutrient run-off, pollution and physical damage from boat anchors or tourists (Burke et al., 2011).

Atmospheric CO₂ concentrations have been rapidly increasing, and are currently over 130ppm higher than pre-industrial levels. Increasing atmospheric and upper ocean temperatures caused by CO₂ emissions has triggered global mass bleaching events, decreased productivity, shifted species distributions and increased incidence of coral disease (Hoegh-Guldberg and Bruno, 2010). During the longest mass bleaching event on record in 2016, an estimated 29% of shallow water corals were lost from Australia's Great Barrier Reef (Great Barrier Reef Marine Park Authority, 2017).

As various anthropogenic threats interact with and amplify the effects of each other, it is becoming increasingly important to take steps towards protecting these vitally important ecosystems (Wood et al., 2008).

Defined areas of ocean can be designated as Marine Protected Areas (MPA), whereby certain restrictions are implemented with the aim of reducing fishing pressure (Di Franco et al., 2016), preserving biodiversity of the ecosystem (Aburto-Oropeza et al., 2011), increasing the biomass of fishes inside the reserve, and therefore ensuring sustainability of the surrounding fished waters (Francini-Filho and Moura, 2008). Spill-over of economically important fishes into unprotected waters means that local fishers benefit from an increase in catch, providing an incentive to create the reserves. A properly managed no-take MPA is one of the most effective ways of preserving a coral reef ecosystem, helping to restore complexity and increase resilience (Mellin et al., 2016; Sala and Giakoumi, 2018). The presence of healthy reefs can replenish and help restore surrounding degraded areas by supplying them with coral larvae (Hughes et al., 2000), a process thought to be critically important when there are few colonies left at a site (Coles and Brown, 2007).

It is essential that MPAs are designed and implemented with local communities in mind, otherwise they risk causing social harm or conflict that can lead to disregard of the protected status of a reef (Oracion, 2003). MPAs that are supported by local stakeholders and governed efficiently are more likely to achieve their ecological and socio-economic goals (Bennett and Dearden, 2014).

1.1. The Philippines

Like most countries in South East Asia, the Philippines has experienced a decline in fish stocks and coral cover due to localised anthropogenic stresses such as Malthusian practices, overfishing, and pollution (Licuanan et al., 2019). The nation is made up of 7,641 islands with a total reef area of approximately 25,000 km², the third largest in the world (Ambal et al., 2012). Part of the famous 'coral triangle', the Philippines has some of the highest recorded levels of coral biodiversity (Devantier, 2017), providing habitat and food for many shore fishes.

Despite a history of under-representation and under-reporting, small scale subsistence fisheries have a large impact on the health of coral reef ecosystems in the Philippines (Barut et al., 2003; Bundy and Pauly, 2001). Local governance of coastal resources has led to the creation of over 1,600 locally managed marine areas (LMMAs) throughout the nation, the most of any country in the world, although their efficacy has been questioned (Muallil et al., 2019). Monitoring is an important part

of MPA management, enabling effectiveness and performance to be quantified and used to guide and advise stakeholder governance (Ahmadia et al., 2015).

1.2. Coral Cay Conservation

Coral Cay Conservation is a UK based non-governmental organisation that was established in 1986 and has run conservation projects all over the globe. Coral Cay Conservation has been active in the Philippines since 1995, initially working on terrestrial conservation, before shifting focus to marine ecosystems. Coral Cay Conservation has the following mission statement:

“Providing resources to help sustain livelihoods to alleviate poverty through the protection, restoration and management of coral reefs and their associated ecosystems”

In 2002 the Provincial Government of Southern Leyte (PGSL) invited Coral Cay Conservation to work within Sogod Bay, leading to the formation of the Southern Leyte Coral Reef Conservation Project (LRCP). Initially the LRCP was based in the west of Sogod Bay in Malitbog, before relocating to the east to Barangay Napantao, San Francisco Municipality in 2008. Funded through a volunteer financing scheme, working alongside governmental partners and stakeholders, Coral Cay Conservation utilises highly trained citizen scientist SCUBA divers to survey various reefs in the region, providing critical bio-physical data on the condition of complex coral reef ecosystems (Fig. 1). The collected data have guided the creation process of MPAs; providing further insight into the performance of MPAs alongside resilience to global reef stressors. The LRCP has worked collaboratively with local stakeholders and government bodies by providing technical support, ecological data, scientific reports and management plans.

Additionally, Coral Cay Conservation offers month long scholarship placements to Filipino nationals every month, offering SCUBA diving training, coral reef organism identification and surveying methodology skills, making marine conservation more accessible to Filipinos who may not have otherwise been able to gain experience in the field, and therefore building capacity within country. Additionally, through working with schools in nearby communities, Coral Cay Conservation runs environmental education programs with the aim of increasing awareness and inspiring the next generation of local coral reef advocates through lessons and activities.



Figure 1: Schematic diagram showing the process that Coral Cay Conservation uses to implement change within host country. By working closely with local and regional governing bodies, a bottom up management approach ensures that the wants and needs of local communities are put first, promoting the protection, restoration and sustainable use of natural resources.

1.3. Barangay Napantao Fish Sanctuary

Implemented in 1996 and covering 5 hectares of reef, the Napantao Fish Sanctuary is a long-established reserve for local marine life. It is located in the Barangay Napantao, San Francisco Municipality, Southern Leyte, which is home to approximately 480 people. The boundaries of the MPA are marked with demarcation buoys, however these are regularly displaced during storms, often resulting in a variation in MPA boundary. The MPA's ordinance includes a no-take zone (NTZ), where all fishing activities and boat anchoring is banned, SCUBA divers are not allowed to wear gloves or enter at night, and must pay a fee to enter. Around the NTZ is a 50m buffer, where hook and line fishing is permitted.

The MPA's ordinance is enforced by a Bantay Dagat, a local member of the Barangay's Council, who has access to a paddle boat and a watch tower with equipment, although the latter is rarely used and the Bantay Dagat is not always present. The primary role of the Bantay Dagat is to collect fees from visiting recreational dive boats, which are predominantly from Padre Burgos. Fishing gears are mostly deployed from non-motorised boats in the surrounding waters of the

MPA, and are non-destructive (i.e. no poison fishing, blast fishing, or Muro-Ami). Common forms of fishing that occur outside of the MPA are spearfishing and gill-netting, with an increased amount of fishing occurring in the two weeks prior to a full moon. Some poaching is still thought to occur inside the boundaries. The reefs of the Napantao MPA have consistently been found to have higher than the national average hard coral coverage (national average = 22.8% (Licuanan et al., 2019)), with a gradual increase being observed in the surrounding unprotected waters since 2013 (Broadribb et al., 2019; Broadribb and Dallison, 2019).

2. Methodology

2.1. Study Site

The MPA is rectangular and covers 5 hectares of gradually sloping reef in the north, and a vertical wall that experiences strong currents in the south (Fig. 2). Coral reef depth ranges between <1m at low tide on the fore reef and >30m. There is a mouth of a river around 1.3km south along the coast, which is around 80m wide and may provide occasional siltation to the reef. There are no direct sources of sewage or industrial waste to the reef, however plastic pollution is sometimes transported to the reef by ocean currents.

The region is subject to two distinct seasons that result from the natural phenomenon that causes a reversal of the trade wind direction. During Habagat (July - October), winds blow from the south west into Sogod Bay, causing high frequency wave action. Amihan (November - June) is characterised by NE wind directions, with the east of Sogod Bay being shielded, resulting in calm flat waters and little to no wave action. Sea surface temperatures are highest in June, and lowest in January, generally ranging between 27-29°C. The Napantao reefs are surveyed every year in March before the start of Habagat, and October, immediately after Habagat season has ended.

Horizontal underwater visibility ranged from 15 – 30m throughout the survey period and all transects were at a depth of 12m. The weather varied but was mostly sunny, sometimes cloud cover was present and on one day in March it was raining. There was an average air temperature of 27.5°C in March and 31.0°C in October. There was a 1°C drop in water temperature between the surface and 10m in March, and a 2°C drop in October, with average water temperatures of 27.1°C and 29.1°C respectively.

Table 1: Coordinates (UTM, N51) of each surveyed permanent transect both inside (I0) and outside (O0) of the Barangay Napantao Marine Protected Area, San Francisco, Southern Leyte, Philippines

Transect	Easting (UTM)	Northing (UTM)
I01	733902	1113083
I02	733986	1113333
I03	733951	1113448
O01	733900	1113612
O02	733827	1113790
O03	733712	1113963

2.2. Survey Methods

The area was surveyed twice throughout 2019 to account for seasonal variability. The initial phase of surveying started on the 11/03/2019 and ended on the 20/03/2019, followed by a second-round of surveys beginning on the 28/09/2019, ending the 04/10/2019. All surveys were conducted between 9:00 am and 10:00 am with the exception of one survey (Transect I04 surveyed in October), which began at 2:07 pm.

An enhanced Reef Check method was used to conduct the ecological assessments of the site. In response to the high biodiversity of the region, CCC has augmented the methodology by adding in additional target corals, fish and invertebrates (Appendix A.2; Appendix A.3; Appendix A.4). All data collectors undertake extensive training over two weeks, prior to conducting surveys.

The start and end points of transects are permanently marked with rebar inside and outside the MPA. Three 12m transects, inside and outside the MPA, were surveyed, parallel to shore in a North to South direction (Table. 1, Fig. 2) Each transect was 100m in length and segmented into four 20m samples separated by 5m gaps (Fig. 3). No data were collected in these 5m sections.

2.2.1. Fish Community Assemblages

SCUBA Underwater Visual Census (UVC) methods were used to collect data on the abundance and sample diversity of target fishes (Appendix A.2). In each 20m sample, all present fish were recorded within a 5m x 5m x 20m 'box' (WxHxL), resulting in surveyed volume of 500m³ per sample. Surveyors waited for 3 minutes prior to recording data. This provided time for fishes to resume natural behaviour reducing the influence of divers on the collected data. Surveyors would subsequently pause for 1 minute intervals every

5m along the transect line, continuously recording data. Care was taken for surveyors to record data at a consistent pace throughout the survey.

Target Butterflyfishes (Chaetodontidae) were placed into two categories; obligate corallivores (diets consisting of >80% coral (Cole and Pratchett, 2014)); and facultative corallivores (diets consisting of <80% coral). Two target Chaetodontids were considered obligate corallivores, Redfin (*Chaetodon lunulatus*) and Eastern Triangle (*Chaetodon baronessa*), and all others considered facultative corallivores (Berumen et al., 2005).

Commercially important fish families Parrotfish (Scaridae), Grouper (Epinephelinae), and Snapper (Lutjanidae) were sized by Total length (TL) and placed into 10cm bins ranging from <10cm to >60cm. The biomass (kg) of these recorded fish families was then approximated through Length Weight Relationships (LWR) (Equation 1). Allometric coefficients a and b for each commercially important fish family were generated from Fish Base (www.fishbase.org), and geometric means were calculated taking body shape, location and the genus of each target commercially important fish into account.

Equation 1. Length-Weight relationship (LWR) used to approximate the biomass (kg) of each commercially important fish recorded during Underwater Visual Census (UVC) surveys.

$$W = aL^b \quad (1)$$

Where W = mass (g), a = the condition factor, b = species-specific growth parameter. L = total length (TL) measured of the individual fish.

2.2.2. Invertebrates and Impacts

The abundance and diversity of target invertebrate samples (Appendix A.3) was recorded using the same transect placements for fishes. Invertebrates were recorded by surveyors 2.5m either side of the central transect, producing a total surveyed area of 100m². Giant Clams (*Tridacna spp.*) were sized by shell length to the nearest 10cm from <10cm to >60cm. Target invertebrates Crown of Thorns Seastar, or COTS (*Acanthaster planci*) and gastropods of the genus *Drupella*, were categorised as being coral predators.

Impact data were collected simultaneously, with divers recording the presence of coral bleaching, disease and damage to the reef including incidents of trash. The

percentage of bleaching was estimated at the individual colony scale as well as at the sample scale considering the total amount of bleached colonies in the entire 100m² of surveyed reef. Coral disease was identified, and the percentage of diseased coral was recorded at individual colony scale. Damage was recorded in three categories, boat/anchor, dynamite and other on an ordinal scale from 0-3 (0 = none, 1 = low, 2 = medium and 3 = high). The impact of trash was recorded on the same scale and distinguished into two categories, general and fishing gear. True counts of damage and trash were also recorded for greater resolution.

2.2.3. Benthic Composition

A point intercept transect (PIT) methodology was deployed to collect data on the substrate composition, with a surveyor using a plumb line to record substrates at 40x50cm intervals along 20m samples. Benthic groups included abiotic and biotic categories, with hard corals further sub-classified by life-form (Appendix A.4). Lifeforms were subsequently grouped into three conservation classes; disturbance-adapted fast growing corals, competitor corals and stress tolerant corals (Edinger and Risk, 2000).

2.3. Data Analysis

Due to the spatio-temporality of the data, and repeated measures by season, the data violated statistical assumptions of non-independence and therefore, General Linear Mixed Models (GLMM) were utilised. Global GLMMs investigated the influence of fixed effects (covariates: seasonality (October — March/April) and protection status (protected — not protected) on dependent variables recorded through the sample period: abundance of all fishes; abundance of Chaetodontidae; abundance of commercially important fishes (Scaridae, Epinephelinae and Lutjanidae); collected sample richness (fishes); collected sample evenness (fishes); commercially important fish biomass (kg) (Scaridae, Epinephelinae, Lutjanidae); invertebrate abundance; invertebrate corallivore abundance (*Acanthaster planci* and *Drupella spp.*); benthic substratum composition; and Scleractinian Lifeform composition. The non-independence violations of the data were accounted for by considering ‘Sample’ as a random effect in the models. ‘Sample’ is defined by each 20m section of the surveyed 100m transect with categorisation applied by ‘Season’. This produced a total of $n=48$ observations categorised in $n=24$ groups.

The dependent variables, that included count data, were tested for distribution. Appropriate models were

subsequently built considering distribution of the data. Where data were found to fit Gaussian-log distributions, Penalized Quasi-Likelihood (PQL) GLMMs from the package MASS were constructed (Venables and Ripley, 2002). PQL GLMMs were also constructed for under-dispersed data. Data that were found to best-fit negative binomial distributions, negative binomial and log link functions using the glmer command in the lme4 package were used (Bates et al., 2015). Other distributions, such as Gamma and Poisson, were constructed and models using the glmer command (lme4 package). Benthic substratum data were converted to proportion data and GLMMs constructed using the glmmTMB command with beta distributions and logit family link function (glmmTMB package) (Brooks et al., 2017). An information theoretic approach was used to select for best-fit models. A subset of models was created from the global model which included all possible combinations of the covariates. Akaike's Information Criterion correct (AICc) for small bias values were used to rank models. If the top performing models had a delta AICc <2, model averaging was performed to produce average parameter estimates based on top performing models. Cumulative AICc weights were then utilised to evaluate which covariate(s) had the strongest influence on functional fish group abundance. Before any model was conclusively selected, residual checking was undertaken to visually assess model fit. Where possible, the magnitude of covariate effect (%) was reported.

3. Results

3.1. Fish Community Assemblages

In 2019, a total of 3710 individual fishes were recorded inside the MPA, with 2890 in March, and 820 in October respectively. Overall the mean abundance of fish inside the MPA was $154.62 \pm 29.34 \text{ 500m}^{-3}$, with seasonal means of $240.83 \pm 46.90 \text{ 500m}^{-3}$ and $68.33 \pm 5.43 \text{ 500m}^{-3}$ in March and October respectively (4).

A total of 3270 individual fishes were recorded outside the MPA, with 1695 in March, and 1575 in October respectively. Overall the mean abundance of fish outside the MPA was $136.25 \pm 19.62 \text{ 500m}^{-3}$, with seasonal means of $141.25 \pm 26.64 \text{ 500m}^{-3}$ and $131.25 \pm 29.93 \text{ 500m}^{-3}$ in March and October respectively (4).

Fish abundance did not differ significantly inside compared to outside the MPA ($p \Rightarrow 0.05$). The wet season in October had a negative influence on fish abundance inside the Napantao MPA ($-0.80 \pm$

$18, t = -4.44, p = 0.2$).

In both survey periods, 76% of target fishes were recorded inside and outside the MPA, with 73% in October across the total survey area. In March, Fusiliers (Caesionidae) were the most recorded fish both inside and outside the MPA ($124.25 \pm 36.35 \text{ 500m}^{-3}$ and in $43.21 \pm 17.86 \text{ 500m}^{-3}$, respectively). In October, Caesionidea maintained dominance outside the MPA with Chaetodontidae the most abundant inside the MPA ($40.67 \pm 18.92 \text{ 500m}^{-3}$, and $13.11 \pm 2.84 \text{ 500m}^{-3}$ respectively).

Inside the MPA in March, mean species richness of collected samples was $24.8 \pm 1.27 \text{ 500m}^{-3}$, Shannon Weiner Diversity (H') was $2.24 \pm 0.17 \text{ 500m}^{-3}$ and Pielou's evenness (J) was $0.70 \pm 0.05 \text{ 500m}^{-3}$, whereas in October they were $20.2 \pm 0.96 \text{ 500m}^{-3}$, $2.69 \pm 0.05 \text{ 500m}^{-3}$ and $0.90 \pm 0.01 \text{ 500m}^{-3}$ respectively.

Outside the MPA in March, sample species richness was $18.2 \pm 1.13 \text{ 500m}^{-3}$ with H' and J recorded at $2.17 \pm 0.11 \text{ 500m}^{-3}$ and $0.76 \pm 0.04 \text{ 500m}^{-3}$ respectively. In comparison, samples recorded in October were $15.7 \pm 1.42 \text{ 500m}^{-3}$, $1.99 \pm 0.13 \text{ 500m}^{-3}$, and $0.75 \pm 0.05 \text{ 500m}^{-3}$ respectively.

Both protection status and season were found to have negative effects on the species richness of samples, with those collected outside the MPA and during the wet season reduced ($\beta = -0.28, SE = 0.07, z_{(48)} = -4.32, p < 0.001$; $\beta = -0.18, SE = 0.07, z_{(48)} = -2.77, p < 0.001$). The random effect of Sample (variance = 2.77 ± 1.67) was not found to significantly influence the species richness of samples.

Protection status had no effect on sample evenness, however there was a significant increase in the evenness of samples collected during the wet season ($0.16 \pm 0.07, t = -2.22, p < 0.05$).

3.2. Chaetodontidae Sample Composition

In March, a total of 71 Chaetodontidae were recorded inside the MPA, representing 100% of target species, with a mean abundance of $5.92 \pm 1.09 \text{ 500m}^{-3}$, compared to October, where a total of 31 were recorded (representing 100% of target species with a mean abundance of $2.58 \pm 0.65 \text{ 500m}^{-3}$) (5). The most

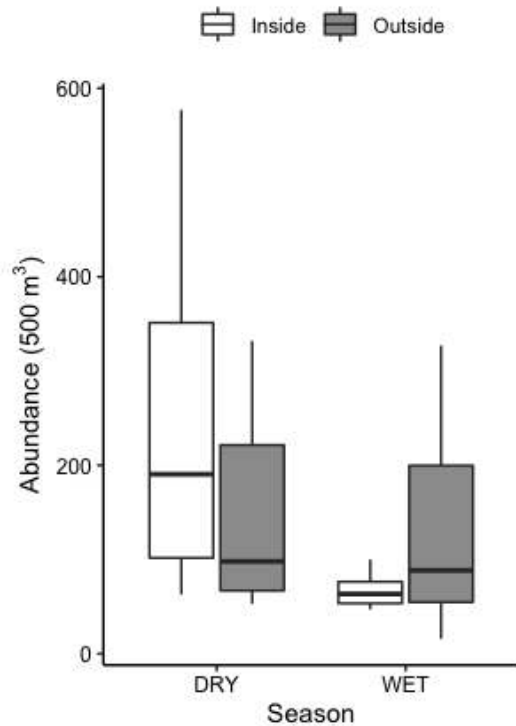


Figure 4: Recorded fish abundance throughout the sample period both inside and outside the Napantao Marine Protected Area within each sampled season; Dry and Wet.

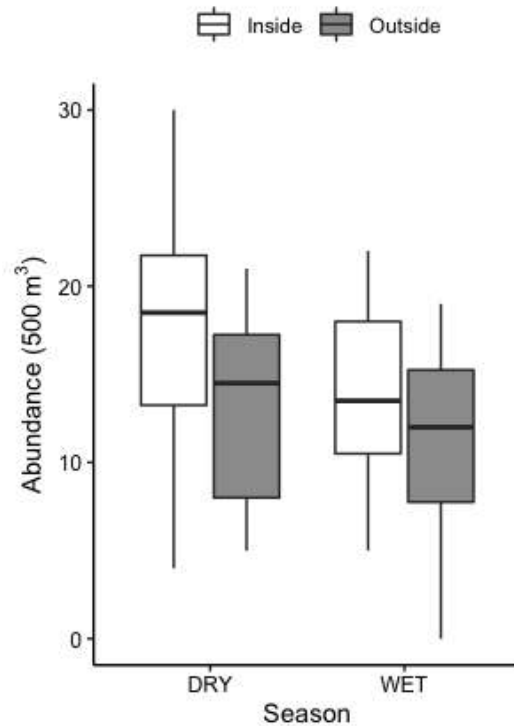


Figure 5: Recorded Butterflyfish (Chaetodontidae) abundance throughout the sample period both inside and outside the Napantao Marine Protected Area within each sampled season; Dry and Wet.

represented species inside the MPA throughout the year were *Chaetodon baronessa*, *Chaetodon lunulatus* and un-classified ('Other').

The same number of Chaetodontidae were recorded in both March and October outside the MPA, with a total abundance of 8 recorded fish across both seasons, giving a mean of $0.67 \pm 0.40 \text{ 500m}^3^{-1}$. In March and October 62.5% and 87.5% of target species were recorded (5). The most represented species outside the MPA throughout the year were *C. baronessa*, *C. lunulatus* and un-classified (Other).

In the wet season of October, significantly fewer Chaetodontidae were recorded in Napantao (0.23 ± 0.08 , $t = -3.01$, $p < 0.001$). Protection status had no significant effect on abundance.

Inside the MPA in March, a mean of $9.58 \pm 0.88 \text{ 500m}^3^{-1}$ obligate corallivores and $5.92 \pm 1.09 \text{ 500m}^3^{-1}$ facultative feeders were recorded, compared with October where a mean of $8.75 \pm 0.65 \text{ 500m}^3^{-1}$ obligate corallivores and $2.58 \pm 0.65 \text{ 500m}^3^{-1}$ facultative feed-

ers were recorded. Outside the MPA in March, a mean of $11.41 \pm 1.38 \text{ 500m}^3^{-1}$ obligate corallivores and $0.67 \pm 0.64 \text{ 500m}^3^{-1}$ facultative feeders were recorded, compared with the abundance of obligate corallivores ($9.58 \pm 1.67 \text{ 500m}^3^{-1}$) and facultative feeders ($0.67 \pm 0.40 \text{ 500m}^3^{-1}$) in October.

3.3. Commercially Important Fishes

Inside the MPA in March, 11.13% (322) of fishes recorded were categorised as being commercially important (Parrotfish (Scaridae), Grouper (Epinephelinae) and Snapper (Lutjanidae)), giving an amalgamated mean commercial fish abundance of $26.76 \pm 3.15 \text{ 500m}^3^{-1}$. In October 24.04% (197) of recorded fishes were considered to be commercially important, equating to a mean commercial fish abundance of $16.41 \pm 2.22 \text{ 500m}^3^{-1}$. In both seasons, Scaridae constituted the greatest proportion of commercially important fish (77.59% in March and 67.02% in October), followed by Epinephelinae (14.04% in March and 25.38% in October) and Lutjanidae (8.39% in March and 7.61% in October). Inside the MPA in March the mean abundance of Scaridae, Epinephelinae and Lutjanidae were

$20.83 \pm 2.47 \text{ 500m}^{-3-1}$, $3.75 \pm 0.57 \text{ 500m}^{-3-1}$, and 2.25 ± 0.68 respectively. Comparatively in October the mean abundance of the same three commercially important fish families were $11.00 \pm 1.65 \text{ 500m}^{-3-1}$, $4.17 \pm 0.75 \text{ 500m}^{-3-1}$ and $1.25 \pm 0.49 \text{ 500m}^{-3-1}$ respectively.

Outside the MPA in March, 11.87% (202) of fishes recorded were categorised as being commercially important, giving an amalgamated mean abundance of $16.82 \pm 2.43 \text{ 500m}^{-3-1}$. In October 13.35% (211) were commercially important, giving a mean abundance of $17.61 \pm 4.74 \text{ 500m}^{-3-1}$. In both seasons, Scaridae were the most abundant (91.14% in March and 87.66% in October), followed by Epinephelinae (7.43% in March and 6.64% in October) and Lutjanidae (1.49% in March and 5.69% in October). Outside the MPA in March the mean abundance of Scaridae, Epinephelinae and Lutjanidae were $15.33 \pm 2.06 \text{ 500m}^{-3-1}$, $1.25 \pm 0.49 \text{ 500m}^{-3-1}$, and $0.25 \pm 0.18 \text{ 500m}^{-3-1}$ respectively. Comparatively in October the mean abundance of the same three commercially important fish families were $15.42 \pm 4.86 \text{ 500m}^{-3-1}$, $1.17 \pm 0.32 \text{ 500m}^{-3-1}$ and $1.00 \pm 0.52 \text{ 500m}^{-3-1}$.

Protection status was found to influence Epinephelinae abundance with samples recording a greater abundance inside the MPA in comparison to outside (0.86 ± 0.19 , $t = -4.50$, $p < 0.001$), however no effect from season was recorded. Scaridae abundance in Napantao was found to be significantly lower during the October wet season (-0.38 ± 0.13 , $t = -2.83$, $p < 0.01$), and was not affected by protection status. In comparison, Lutjanidae abundance was not affected by season, but was significantly higher inside the MPA (-0.53 ± 0.22 , $t = -2.45$, $p < 0.05$).

Throughout the survey period, Scaridae ranged from <10cm – 50cm, Epinephelinae <10cm – 50cm, and Lutjanidae <10cm – 40cm, inside the MPA. In comparison with the unprotected reef outside the MPA, recorded Scaridae ranged from <10cm – 40cm, Epinephelinae <10cm – 40cm, and Snapper <10cm – 40cm. Small Scaridae (<10cm) constituted the highest proportion of all commercial fish recorded both inside and outside the MPA, making up 16.16% and 30.46% of all commercial fish respectively.

3.3.1. Commercially Important Fish Biomass

The total standing biomass (kg) of commercially important fishes recorded inside the MPA in 2019 was 75.08kg ($12.51\text{kg} \pm 4.77 \text{ 500m}^{-3-1}$). Parrotfish

(Scaridae) recorded the greatest contribution (55.06kg), with a mean biomass of $2.29 \pm 0.49\text{kg 500m}^{-3-1}$. The recorded biomass for both Snapper (Lutjanidae) and Grouper (Epinephelinae) were comparatively lower (10.6kg, $0.44\text{kg} \pm 0.13 \text{ 500m}^{-3-1}$, and $9.48\text{kg} \pm 0.11 \text{ 500m}^{-3-1}$, respectively) (6).

The most represented size class of Scaridae and Epinephelinae was <10cm, both inside and outside the MPA. Lutjanidae did not follow this trend, with no individuals <10cm recorded inside the MPA, and 21-30cm being the most represented size class instead. Outside the MPA 11-20cm was the most represented size class of Lutjanidae.

The total standing biomass (kg) of commercially important fishes recorded outside the MPA in 2019 was 20.0kg ($3.33\text{kg} \pm 1.70 \text{ 500m}^{-3-1}$). In line with observations from inside the MPA, Scaridae standing biomass was the greatest (16.4kg), with a mean biomass of $0.68\text{kg} \pm 0.12 \text{ 500m}^{-3-1}$, followed by Epinephelinae (2.16kg), with a mean biomass of $0.09\text{kg} \pm 0.04 \text{ 500m}^{-3-1}$, and Lutjanidae (1.45kg) with a mean biomass of $0.06 \pm 0.03 \text{ 500m}^{-3-1}$ (6).

Epinephelinae and Scaridae biomass was significantly lower outside the MPA (-0.26 ± 0.11 , $t = -2.45$, $p < 0.05$ and -0.12 ± 0.18 , $t = -0.64$, $p < 0.01$, respectively), but was not influenced by season. Lutjanidae biomass was not found to be influenced by protection status or season.

3.4. Invertebrate Community Assemblages

A total of 3289 invertebrates were recorded within the MPA, representing 61.33% of all target organisms, with a mean abundance of $169.67 \pm 23.11 \text{ 100m}^{-2-1}$ in March and $104.42 \pm 13.65 \text{ 100m}^{-2-1}$ in October (7). The most recorded organisms were Brittle Stars (Ophiuroidea), Feather Stars (Crinoidea) and gastropods of the genus *Drupella spp.* ($59.75 \pm 10.24 \text{ 100m}^{-2-1}$, $26.71 \pm 5.31 \text{ 100m}^{-2-1}$ and $19.08 \pm 4.06 \text{ 100m}^{-2-1}$, respectively).

A total of 3840 invertebrates were recorded outside the MPA, representing 67.7% of all target organisms, with a mean abundance of $114.67 \pm 16.50 \text{ 100m}^{-2-1}$ in March and $205.33 \pm 43.34 \text{ 100m}^{-2-1}$ in October (7). The most abundant organisms inside the MPA were also dominant outside the MPA; Ophiuroidea ($66.3 \pm 14.1 \text{ 100m}^{-2-1}$), Crinoidea ($34.5 \pm 3.77 \text{ 100m}^{-2-1}$) and *Drupella spp.* ($27.75 \pm 6.31 \text{ 100m}^{-2-1}$). Invertebrate abundance was significantly lower outside the MPA (-0.53 ± 0.14 , $t = -3.85$, $p < 0.001$), and was not affected by season.

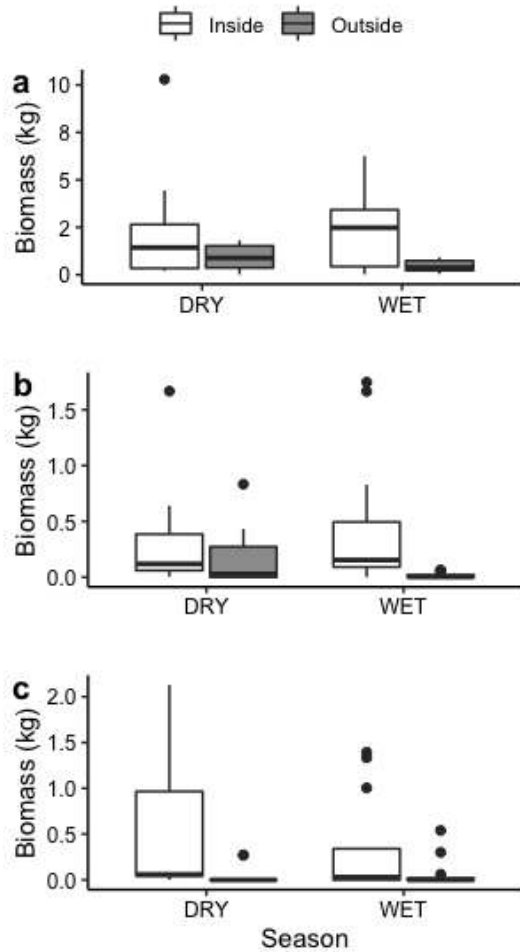


Figure 6: Biomass (kg) of commercially important fishes recorded throughout the sample both inside and outside the Napantao Marine Protected Area throughout both Dry and Wet seasons. Parrotfishes (Scaridae) (a), Grouper (Epinephelinae) (b), and Snapper (Lutjanidae) (c), are all presented.

Coral predators accounted for a mean of 14.19% of the total recorded invertebrates inside the MPA, with $19.42 \pm 4.28 \text{ } 100\text{m}^2^{-1}$, in contrast to a mean of $117.64 \pm 22.67 \text{ } 100\text{m}^2^{-1}$ non corallivore invertebrates (8). Outside the MPA, coral predators accounted for a mean of 17.4% of the recorded invertebrates, with $27.9 \pm 6.44 \text{ } 100\text{m}^2^{-1}$, in contrast to a mean of $132.1 \pm 26.6 \text{ } 100\text{m}^2^{-1}$ non-corallivore invertebrates (8), however the difference in abundance was not deemed to be influenced by protection status or season. COTS were present both inside (8) and outside (4) the MPA, with a mean abundance of $0.33 \pm 0.21 \text{ } 100\text{m}^2^{-1}$ inside the MPA and $0.17 \pm 0.13 \text{ } 100\text{m}^2^{-1}$ outside the MPA.

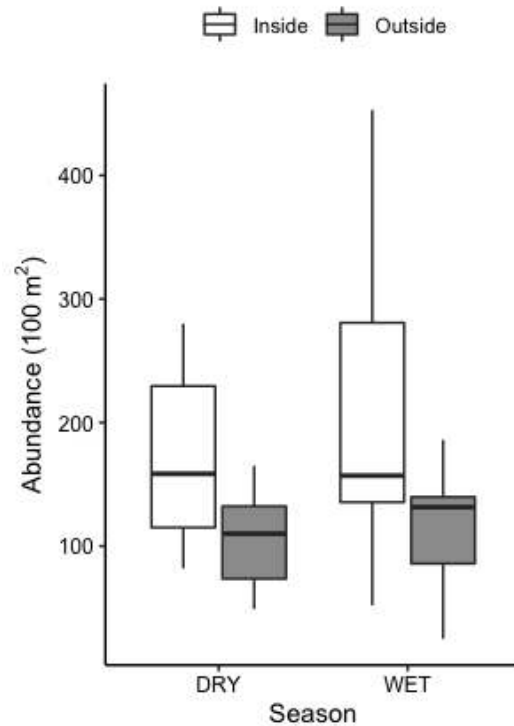


Figure 7: Recorded abundance of target invertebrates throughout the sample period both inside and outside the MPA in Dry and Wet seasons.

Mean invertebrate species richness of samples inside the MPA, throughout both sample periods, was recorded as $0.34 \pm 0.50 \text{ } 100\text{m}^2^{-1}$, compared to $9.08 \pm 0.41 \text{ } 100\text{m}^2^{-1}$ outside the MPA, however this was not deemed to be influenced by protection status or season. Mean H' over both sample periods within the MPA was $H' = 1.44 \pm 0.06 \text{ } 100\text{m}^2^{-1}$, compared to $H' = 1.55 \pm 0.05 \text{ } 100\text{m}^2^{-1}$ outside the MPA. Mean J was found to be $J' = 0.62 \pm 0.02 \text{ } 100\text{m}^2^{-1}$ inside the MPA and $J' = 0.71 \pm 0.02 \text{ } 100\text{m}^2^{-1}$ outside the MPA. Sample evenness was recorded lower outside of the MPA (-0.03 ± 0.01 , $t = -3.02$, $p < 0.01$).

In both seasons a total of 13 Giant Clams (*Tridacna* spp.) were recorded inside the MPA, with a mean of $0.09 \pm 0.03 \text{ } 100\text{m}^2^{-1}$. They were present in sizes from <10cm - >50cm, however no individuals were of the size 11-20cm. The most represented size category was 41-50cm, with a total of 4 recorded individuals. Outside the MPA, 2 *Tridacna* spp. were recorded ($0.08 \pm 0.06 \text{ } 100\text{m}^2^{-1}$) representing a single size class of 11-20cm.

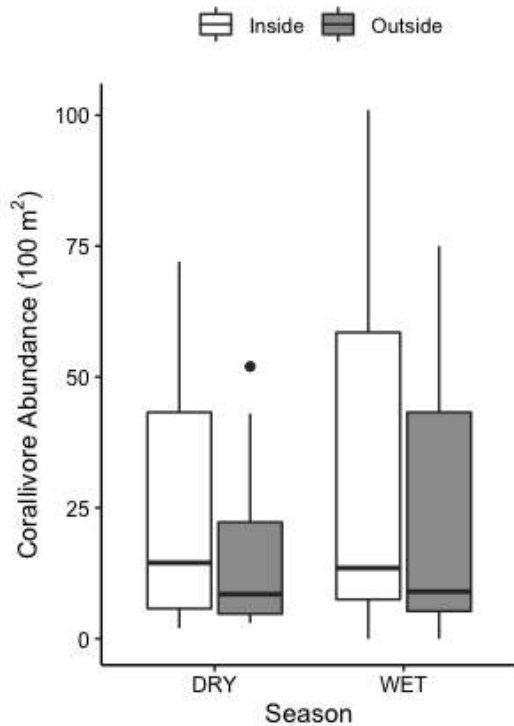


Figure 8: Recorded abundance of corallivore invertebrates (*Acanthaster planci* and *Drupella* spp.) throughout sample period both inside and outside the MPA in Dry and Wet seasons.

3.5. Benthic Composition

The most dominant substrate inside the MPA was Hard Coral ($36.96\% \pm 3.84\%$ 20m^{-1} in March, $47.71\% \pm 6.78\%$ 20m^{-1} in October), followed by Rock ($17.92\% \pm 2.06\%$ 20m^{-1} in March, $11.04\% \pm 2.21\%$ 20m^{-1} in October) and Rubble ($14.17\% \pm 11.98\%$ 20m^{-1} in March, $9.78\% \pm 1.91\%$ 20m^{-1} in October) which was found to be effected by Protection Status, with more rubble inside the MPA ($\beta = -0.39, SE = 0.19, z = -2.06, p < 0.05$) (9).

Hard coral composition recorded outside the MPA was similar to that recorded inside ($40.83\% \pm 5.04\%$ 20m^{-1} in March, $46.04\% \pm 6.78\%$ 20m^{-1} in October) however it was not found to be influenced by protection status. The two other most dominant substrates outside the MPA were Sand ($19.79\% \pm 7.87\%$ 20m^{-1} in March, $12.50\% \pm 6.78\%$ 20m^{-1} in October) and Rock ($17.71\% \pm 2.79\%$ 20m^{-1} in March, $12.71\% \pm 6.78\%$ 20m^{-1} in October) (9), which was found to be negatively influenced by the wet season of October ($\beta = -0.37, SE = 0.17, z = -2.15, p < 0.05$).

Nutrient Indicator Algae was slightly higher inside the MPA ($1.89\% \pm 0.70$ 20m^{-1} in March, $2.29\% \pm 0.84\%$ 20m^{-1} in October) than outside (0% 20m^{-1} in March, $1.46\% \pm 0.72\%$ 20m^{-1} in October), but was not effected by season or protection status.

The most dominant life form within the Hard Coral category was Branching *Acropora* spp. both inside ($28.9\% \pm 2.20\%$ 20m^{-1}) and outside ($22.4 \pm 2.09\%$ 20m^{-1}) the MPA, however life-form sample richness was not found to be affected by season or protection status.

Of all hard coral recorded inside the MPA, 36.1% were categorised as Fast Growing Corals (FGC) and 33.21% as Stress Tolerant (ST), which was similar to the distribution from outside the MPA of 34.76% FGC and 32.89% ST. Neither FGC or ST coral proportions were significantly affected by protection status or season. Inside the MPA, Competitor Corals (CC) made up 12.50% in March and 18.27% in October, in comparison to 12.95% in March and 19.42% in October outside the MPA. There was a significantly higher proportion of Competitor Corals recorded in Napantao in the wet season of October ($0.51 \pm 0.13, z = 3.81, p < 0.001$). There was an associated increase in the proportion of FGC of 3.37% inside and 1.68% outside the MPA. ST corals made up similar proportion of hard cover coverage throughout the year both inside and outside the MPA.

3.6. Coral Reef Impacts

During the survey, no direct anthropogenic impacts were recorded (boat/anchor/dynamite damage) either inside or outside of the MPA. Unidentifiable coral damage was recorded in low levels (1 incident) on 29.22% of all replicates, and in high levels (>5 incidents) on 20.75% of all replicates in Napantao. Outside the MPA 29.20% of replicates had medium incidents of "other" coral damage, in comparison to 16.76% inside the MPA. More fishing trash was recorded outside the MPA, with 33.33% of all replicates outside the MPA having 2-4 pieces, compared with inside the MPA where 8.32% of replicates had medium levels of fishing trash. Inside the MPA 62.50% of replicates had no trash and 4.17% had medium levels, in comparison to 58.30% that had no trash and 16.60% with medium levels outside the MPA. No replicates in Napantao had high levels (>5 pieces) of either general or fishing trash.

Inside the MPA during October sampling, the severity of bleaching per colony was greater than

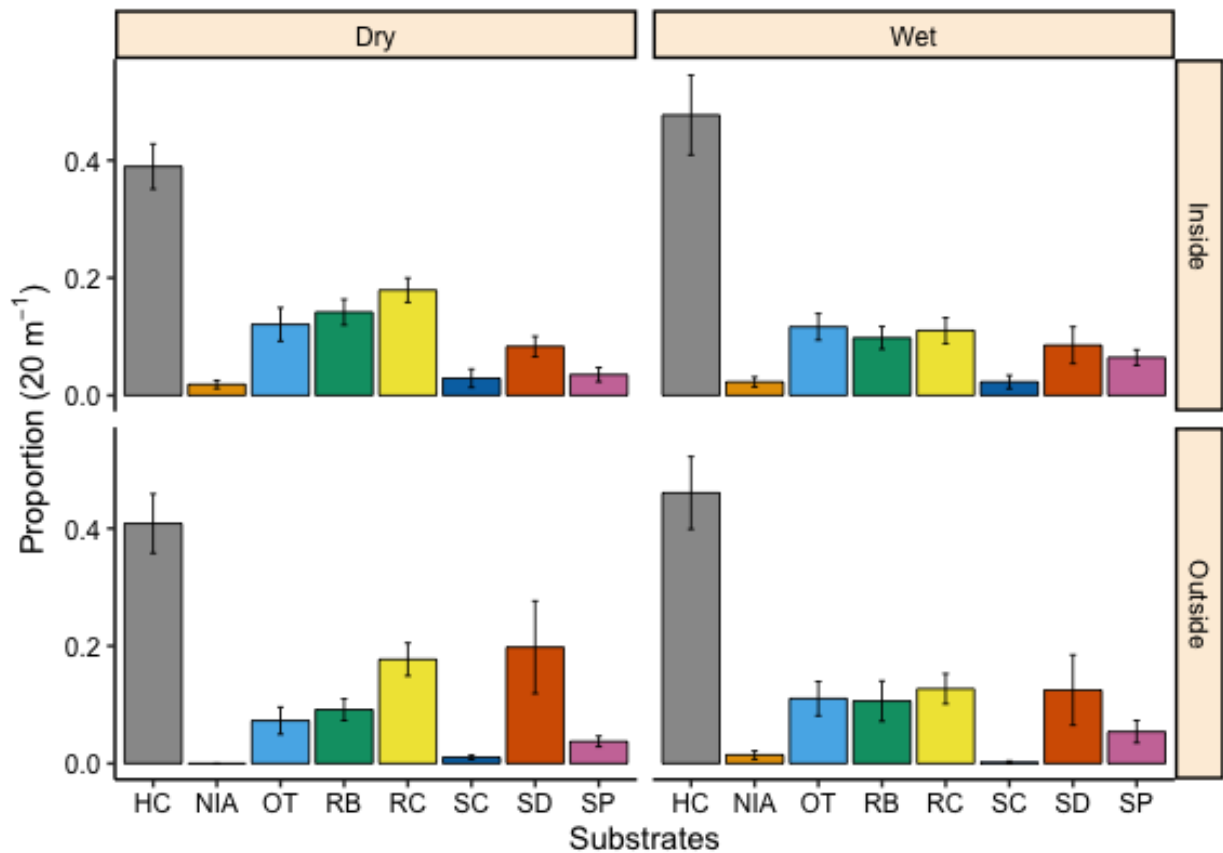


Figure 9: Proportional (0-1) representation of recorded substrate categories (HC (Hard Coral); NIA (Nutrient Indicator Algae); OT (Other); RB (Rubble); RC (Rock); SC (Soft Coral); SD (Sand); SP (Sponge)) both inside and outside the Napantao Marine Protected Area across Dry and Wet seasons. Error bars represent the standard error of the mean.

those recorded during March. In October, <1% of surveyed colonies exhibited bleaching with each colony bleaching by 21.66%. This is in comparison to colonies recorded in March where <1% of the population were bleached and with a mean bleaching area of 4% per colony. Two incidences of White Band Syndrome were recorded in March, throughout the sampling period. Outside the MPA, <1% of all colonies exhibited bleaching in both seasons, however in March individual colonies exhibited a mean of 18.33% of total coral area bleached, and a mean of 33.58% in October. No incidents of Black Band Disease were recorded in Napantao in either sampling periods.

4. Discussion

This study assessed the condition of the coral reefs that fringe Barangay Napantao in the year 2019, through

the collection and analysis of spatial biophysical data. The results of this study should be considered in the long-term marine management strategy for the Napantao MPA.

4.1. Fish Community Assemblages

Overall fish abundance in 2019 was similar to that recorded in 2018, however Napantao was once again found to have higher numbers of fish in comparison to other reefs in Sogod Bay (Broadribb and Dallison, 2019). The results presented in this report, reflecting no influence of the MPA or season on abundance are supported by studies of the Napantao coral reef communities conducted in 2017 and 2018 (Broadribb et al., 2019; Broadribb and Dallison, 2019). Although overall there was no significant difference in fish abundance inside the MPA, certain fish families such as Grouper (Epinephelinae), Triggerfish (Balistidae), Surgeonfish (Acanthuridae) and Rabbitfish (Siganidae) were almost

twice as abundant inside in both the wet and dry seasons, suggesting the potential spill-over of these fish families from inside the MPA, and that they are being caught by fishers in surrounding unprotected waters. When comparing Napantao mean fish abundance with 2019 assessments of nearby MPAs such as Himbangan ($130.30 \pm 23.32 \text{ } 500\text{m}^3\text{ }^{-1}$) and Manglit ($63.31 \pm 11.30 \text{ } 500\text{m}^3\text{ }^{-1}$) (Heney and Dallison, 2019a,b) it becomes apparent that even the unprotected area of reef in Napantao sustains higher densities of fish than both the Himbangan and Manglit MPAs. The lack of significant effect from Protection Status on overall fish abundance is therefore likely to be explained by high levels outside the MPA.

One contributing factor to fish density is the home range of species, which is defined as spatial movements of animal behaviour that is related to its life cycle (Burt, 1943). Studies have found that MPAs need to be relatively large, ($>900\text{ha}$) and protect multiple types of habitats to encompass a range of fish species home ranges to provide effective protection of their populations (Garcia et al., 2014). Many reef fish have small home ranges of $<100\text{m}^2$ which are likely to show the highest increase in reserves (Kramer and Chapman, 1999). However, home ranges of reef fish may be as large as 1000ha (Fabrizio et al., 2014). Due to the small size of the Napantao MPA (5ha), many fish species will have a home range that exceeds the area of the MPA, meaning their populations are not as receptive to protection as species with small home ranges are, contributing to the similarity in overall fish abundance both inside and outside the Napantao MPA.

Without data on fisherfolk's catch, it is difficult to infer the levels of spillover happening from the Napantao MPA, however comparatively low abundance of certain fish families such as Balistidae, Acanthuridae and Siganidae suggest that local fishers are experiencing economic benefits from catching these fish families that most likely originated inside the MPA. Fish abundance was significantly lower both inside and outside of the MPA in the wet season of October, possibly due to being prior to the main fish spawning season in the Visayan Sea, which is from November – February for certain fish species (OCEANA, 2014).

Although fish abundance was not significantly higher inside the MPA, there are other indications of positive ecological benefits from protection status. Analysis of diversity indices found that the species richness of samples was found to be significantly higher inside the

MPA, suggesting higher resilience of fish communities inside the MPA (Downing et al., 2012) and possibly indicating the targeting of certain fish species outside the MPA. It should be noted that since only a proportion of the total amount of present fish species are recorded, the diversity indices are biased towards the target surveyed fish species, particularly Butterflyfish. Anecdotal evidence from speaking to local fisherfolk suggest that Napantao reef fish are more abundant in the two weeks prior to a full moon, which is when most people will go fishing. The decrease in overall fish abundance and diversity in the wet season of October may be linked to the moon cycle, since during the March surveying period, the moon was initially waxing, then was full for half of the surveying days. The October surveying period occurred during a new moon, with the moon beginning to wax towards the end of the survey period.

Fusiliers (Caesionidae) were the most dominant fish both inside and outside of the MPA with the exception of inside the MPA in October, when Chaetodontidae were the most dominant. Although not categorised as a commercially important fish, Caesionidae often compromise a significant proportion of artisanal multi species catches in small scale reef fisheries (Carpenter, 1988). When reef structure and currents create favourable conditions for crustacean plankton to thrive, groups of planktivorous species such as Caesionidae congregate to utilise the high concentrations of food in the water column (Sheppard et al., 2018). Visibility was lower during March, suggesting higher concentrations of planktonic food of Caesionidae, which may explain the higher abundance during this sampling period. It should be noted that UVC methodology can be biased towards schooling fish families such as Caesionidae, since their presence leads to variability in estimates and groups can be difficult to count accurately (Kulbicki et al., 2010).

4.2. Chaetodontidids

Closely linked with overall coral condition, Chaetodontidae abundance and diversity was recorded to assess an indication of change in reef health (Crosby and Reese, 1996). The feeding habits of Chaetodontidids either categorises them as obligate corallivores with diets compromised of over 80% coral, or facultative corallivores whose diets consist of a lower proportion of coral (Pratchett et al., 2006). Obligate corallivore Chaetodontidae species recorded in this survey show strong preference to eating FGC Acroporid species, providing an additional dimension of sensitivity to the system (Cole and Pratchett, 2014).

Facultative corallivores have been found to be more resilient than obligate corallivores during periods of coral decline due to their lower dependence on coral (Pratchett et al., 2006).

Both inside and outside the MPA there was a higher proportion of obligate corallivores in comparison to facultative corallivores, which is attributed to the high hard coral coverage and structural complexity in Napantao. However not all Chaetodontidae species were recorded so the feeding habits of all 'Other Butterflyfish' was unknown and not accounted for.

There were significantly less Chaetodontidae recorded in the wet season of October, both inside and outside the MPA. This is associated with a significantly higher proportion of Competitor Corals in the same month, suggesting reduced prey availability of Acroporid species resulting in a decrease in respective abundance.

4.3. *Commercially Important Fishes*

Fish families that are considered to be commercially important are key to record since their abundance is closely linked with the well-being of local fisherfolk. An important role of many MPAs is to support and protect the livelihoods of local people who depend on the ecosystem services of coral reefs, such as protein provision and/or economic streams, by sustainably managing commercially important fish populations. The piscivorous fish families Grouper (Epinephelinae) and Snapper (Lutjanidae) are both particularly vulnerable to exploitation due to their late maturity, slow growth rate, sporadic reproduction and recruitment, and vulnerability during spawning (DeMartini et al., 2008). They also often exhibit sexual dimorphism during maturation, and may not be sexually mature until they are 4-6 years old (Shapiro, 1989; Sadovy et al., 1994).

The herbivorous family Parrotfish (Scaridae) are ubiquitous on most coral reefs worldwide, and are considered as key influencers of benthic biota and reef structure (Mumby, 2006). Scaridae have experienced increasing fishing pressure due to preference for larger-bodied fish, and they are vulnerable due to being conspicuous, having shallow depth distributions, small home ranges and being easily targeted during the night (Taylor et al., 2014). The age of female maturation has been found to be the best predictor of vulnerability of various Scaridae species (Taylor et al., 2014).

Factors such as demand for particular species of commercially important fish, and various life traits that make a species more or less vulnerable to the exploitation interact to effect the dynamics of species' populations. Species within the three categories of commercially important fish families can grow to large sizes of over 1m in some cases, which have higher market value in comparison to smaller individuals so are more desirable to fisherfolk. Studies have found that a preference for sexually mature male Epinephelinae can result in biased sex ratios with either too many males or females (Koenig et al., 1996; Domeier and Colin, 1997).

Throughout the sample period, the Napantao Fish Sanctuary positively influenced the abundance of both Epinephelinae and Lutjanidae with no influence detected in Scaridae populations. When comparing the mean abundances, Scaridae populations are much higher than Lutjanidae and Epinephelinae, but are dominated by small, sexually immature individuals with TL <10cm. Although their mean abundance is higher, fewer large Epinephelinae and Lutjanidae are likely to be worth more than small Scaridae.

The MPA appears to be having the desired effect of protecting large, sexually mature individuals since the largest size categories of each fish family were only recorded inside the MPA. Conversely, small Scaridae (<10cm) were most abundant outside the MPA, suggesting there is spill-over into the surrounding unprotected waters of smaller sized fish, but not of larger fish, resulting in the similar total Parrotfish abundance both inside and outside of the MPA. The pattern of smaller sized herbivorous fish is in line with other studies of spill-over, most likely due to the small herbivorous fish being driven out of the protected area by the increase in predators (Abesamis and Russ, 2005; Da Silva et al., 2015). Despite the higher overall abundance of small parrotfish outside the MPA, biomass of Parrotfish was significantly higher inside the MPA, due to a higher frequency of larger individuals inside the MPA, suggesting that the MPA is providing a refuge for fish development.

Although there is inter-species variation in the size of adult Scaridae, generally individuals >30cm are considered to be sexually mature (DeMartini and Howard, 2016), meaning that most of the Scaridae outside the MPA are incapable of reproducing. This highlights the importance of the Napantao MPA as a refuge for larger Scaridae with higher fecundity. It also suggests that any large Scaridae that leave the MPA are being caught, providing fisherfolk with higher value

catch in comparison to juveniles.

Recovery of fish populations is often different for piscivorous and herbivorous functional groups, and will also be dependent on which families are targeted by fisherfolk (Abesamis and Russ, 2005). Herbivorous fishes, such as Scaridae, are a crucial component of a healthy coral reef ecosystem, maintaining algae levels to prevent overgrowth and smothering of corals (Bonaldo et al., 2014). The high abundance of Scaridae in Napantao suggest that the reefs are more resilient to climate change (Obura and Grimsdith, 2009).

Epinephelinae are often heavily exploited from reefs, being among some of the highest priced market species since they are highly regarded for the quality of their meat (Sadovy de Mitcheson et al., 2013). Epinephelinae are effectively being protected within the Napantao MPA, however there are low abundances, especially of large individuals in unprotected waters. It is likely that Epinephelinae are not abundant outside the MPA due to territorial and docile behaviour, therefore making them especially susceptible to spearfishing (Giglio et al., 2014, 2017), which is a common method of fishing in the area. Despite the MPA protecting some larger individuals, Epinephelinae spawning aggregation sites in Sogod Bay are unknown, potentially leaving individuals susceptible during reproductive seasons. The size of the MPA may only effectively protect the less mobile small Epinephelinae species that have small home ranges, since larger species home ranges are much larger than typical dimensions of MPAs (Farmer and Ault, 2011).

Although Lutjanidae abundance was significantly higher inside the MPA, their overall abundance was still low in comparison to Scaridae and Epinephelinae. Although this observation is in line with previous studies of the Napantao MPA, it again suggests that the MPA is not working to effectively protect this fish family, most likely linked to the small size of the reserve.

Total biomass of commercially important fish in both protected and unprotected reef in Napantao has increased each year since 2017 (Broadribb et al., 2019) with overall biomass being almost 80% higher inside the MPA in 2019 in comparison with the previous year's study. This is a promising trend which if it continues in the coming years may mean that abundance of Epinephelinae and Lutjanidae can recover to healthier levels.

4.4. Invertebrate Community Assemblages

Abundance of invertebrates were significantly higher outside the MPA, predominantly composed of Brittle Stars (Ophiuroidea) and Feather Stars (Crinoidea), matching the findings of a 2018 study of Napantao (Broadribb and Dallison, 2019). Despite these invertebrate groups not being of economic importance, each have ecological significance. Ophiuroidea are generally scavenging detritivores, and sometimes predators, contributing to nutrient cycling on a reef (Stöhr et al., 2012). Crinoidea contribute to maintaining optimum water quality for photosynthesising organisms by removing detritus and suspended particles from the water column (Macurda and Meyer, 1970), therefore decreasing turbidity. Filter feeding organisms also act as biofilters, potentially reducing disease risks within the reef biome (Burge et al., 2016).

Commercially important target invertebrate species such as Prickly Redfish Sea Cucumber (*Thelenota ananas*), Pinkfish Sea Cucumber (*Holothuria edulis*), Squid (Teuthida), Greenfish Sea Cucumber (*Stichopus chloronotus*), Lobster (*Palinurus* spp.), and Triton's Trumpet (*Charonia tritonis*) were not recorded within Napantao during either of the survey periods. This observation matches last year's study of the area, suggesting that historical exploitation of these slow growing species has meant little to no recovery of their populations, despite protection.

Giant Clam (*Tridacna* spp.) abundance was much lower outside the protected area, and present in just a single size class as opposed to the range of juvenile to adult sizes that were observed within the MPA. This indicates that poaching of individuals is limited or absent inside the MPA, but harvesting has potentially occurred outside the MPA since 2017, when the abundance of *Tridacna* spp. was higher (Broadribb et al., 2019). *Tridacna* spp. have high ecological importance within a reef system, as the tissue, faeces and gametes act as a food source for predators or opportunistic feeders, providing discharge of live zooxanthellae, creating hard substrates for potential settlement, increasing topographic heterogeneity and even potentially counteracting eutrophication via water filtration (Neo et al., 2015).

In healthy numbers, coral predation can increase overall coral diversity by reducing the dominance of fast growing species (Porter, 1972; Enochs and Glynn, 2017), however in certain environmental conditions

corallivores can reproduce unchecked, acting as vectors for disease that infect Scleractinian corals, resulting in outbreaks that can cause significant reef degradation (Nicolet et al., 2018).

When corallivorous gastropods *Drupella* spp. aggregate in large numbers, they can be detrimental to hard coral coverage, targeting branching *Acropora* spp. and *Montipora* spp. corals (Al-Horani et al., 2011). Despite *Drupella* spp. being some of the most abundant invertebrates within the surveyed area, respective densities were lower than previously defined levels of outbreak of 0.95 individuals m⁻² (Bessey et al., 2018). However, there were over 3 times as many *Drupella* recorded outside the MPA, possibly due to more favourable conditions and fewer natural predators of both their adult and larval forms.

The better known corallivore COTS (*Acanthaster planci*) was present inside and outside the MPA, although in much lower densities than the considered definition of an outbreak of 25-30 individuals ha⁻¹ (Pratchett et al., 2014). In early 2020, *A. planci* levels have been recorded as exceeding the defined outbreak density, meaning that either due to their nocturnal and cryptic behaviours, surveyors in 2019 failed to locate some individuals, or their population size has increased substantially since October 2019. They may also be concentrated in certain patches and depths of the reef that surveys did not cover, since they are commonly sighted in the shallows of Napantao reefs <5m.

4.5. Substrates and Hard Coral Lifeforms

Forming the basis of the entire ecosystem, hard coral cover and heterogeneity is a good indicator of overall reef health, since it is closely linked to fish and invertebrate abundance and diversity (Komyakova et al., 2013; Idjadi, 2006). In Napantao, Hard Coral was the most abundant substrate category, regardless of the effect of protection status or season, hosting >43% which is almost double the national average of 23% (Licuanan et al., 2019).

Coral coverage has increased outside the MPA, and has been maintained at the same level outside the MPA since the 2018 assessment (Broadribb and Dallison, 2019). This contrasts with the global trend of large scale degradation and decline in hard coral coverage that many reefs around the world are currently experiencing because of anthropogenic stressors and climate change (Hughes et al., 2017). Throughout

the last decade, an estimated third of all coral reefs in the Philippines have been lost (Licuanan et al., 2019).

Rock and rubble were the next most abundant substrates inside the MPA, in comparison to sand and rock outside. Of these three substrates, rock is the most suitable habitat for new coral recruits, since the mobility of sand and rubble means that wave action or strong currents can upturn or bury any small coral colonies that have settled on these unconsolidated substrates. There was significantly more rubble inside the MPA, possibly attributed to the recreational use by scuba diving tourists. With up to five different diving companies visiting the Napantao MPA per day, it receives high numbers of visitors, divers with poor buoyancy skills may be contributing to the increase in coral rubble inside the MPA.

Factors that contribute to the overall resilience of coral reefs to environmental stress have been identified by scientists (McClanahan et al., 2012), including pollution, sedimentation, herbivory, algae coverage, coral diversity, coral recruitment, disease prevalence, bleaching resistance, physical impacts, fishing pressure and sea surface temperature variability. Although not all of these metrics were recorded in this study, results suggest that due to the high level of coral cover, many of these conditions are likely present in Napantao, favouring coral growth. Areas of reef with high coral coverage also supply larvae to surrounding reefs. Connectivity between reefs is facilitated by ocean currents, with coral larvae connectivity playing an important role in recovery of reefs that have been damaged (Hughes et al., 2000). The reefs of Napantao are likely to be supplying coral larvae to other sites in Sogod Bay, increasing the economic value of the area, and adding to the importance of protection.

By using coral coverage as a metric for reef health alone, areas of reef with high percentages of a single species coral appear to be in perfect condition, when in reality they may exhibit low spatial complexity and provide relatively poor fish habitat (Roberts and Ormond, 1987). In comparison to identifying corals down to species or even genus level, which requires sometimes years of extensive training, citizen scientists can be taught to identify coral morphology in a matter of weeks. Coral morphology can then be used to classify corals into groups that allow for accurate predictions about coral species richness, rare species occurrence and habitat complexity that would otherwise be unknown (Edinger and Risk, 2000).

Analysis of hard coral lifeforms identified branching Acroporids (ACB) to be the most abundant inside and outside the MPA, which is categorised as a Fast-Growing Coral (FGC) with rapid growth and mechanical fragility (Edinger and Risk, 2000). Napantao reefs are not dominated by one morphological group, with even distribution between FGC, STC and CC. Other reefs with similar coral functional group distribution have been found to have high coral species diversity, habitat complexity and rare species occurrence, contributing to high conservation value that is deserving of priority for protection (Edinger and Risk, 2000). Coral communities have not changed since the previous year's study in 2018 (Broadribb and Dallison, 2019), suggesting that the populations are stable both inside and outside the MPA.

Very low nutrient indicator algae coverage was recorded in Napantao, again adding evidence that the reefs are in good condition and are capable of resisting stresses that can eventually lead to phase shifts towards algae dominated reefs after degradation (McManus and Polsenberg, 2004).

Despite being subject to the effects of fishing, a factor which can reduce the overall resilience of a reef (McClanahan et al., 2012), the corals outside the MPA match the same even coral functional group distribution that was observed inside the reserve. This may be due to the highly resilient corals inside the MPA supporting the overall health and resilience of the adjacent areas of reef through the supply of diverse coral larvae.

4.6. Coral Reef Impacts

The lack of direct anthropogenic pressures in Napantao is a promising sign that destructive fishing methods are no longer deployed in the area. However, on 20% of transects there were over 5 incidents of damage to coral classified as "other", either from predation where the predator was no longer visible, damage from other organisms or physical damage caused by divers or fishers.

As expected, higher levels of fishing trash were found outside the MPA, however on almost 10% of all replicates inside the MPA, medium levels of fishing trash were recorded, suggesting that low levels of illegal fishing may be occurring inside the reserve.

Bleaching followed the expected seasonal trend of increasing in October after the hottest summer months of

the year, with very low levels of bleaching in the cooler month of March. Sea surface temperatures in Napantao reach an annual peak in May and June, resulting in larger portions of individual colonies bleaching, although still only affecting <1% of all Napantao corals in October. Globally, coral reefs are experiencing bleaching events at increasing severities and frequencies, reducing the amount of time corals have for recovery in-between incidents (Heron et al., 2016). Since bleaching levels were still low overall in Napantao, it is another sign that environmental factors may contribute to the reefs resilience to climate change related threats, possibly due to supply of deep cooler currents from Sogod Bay. Two incidents of white band syndrome were recorded inside the MPA in March. As such, coral disease is not an apparent threat to the reefs of Napantao.

5. Conclusion

Overall, fish communities inside the MPA suggest that it is well-managed with a high level of compliance, and that the area is successfully protecting larger fish with high fecundity. The low abundances of commercially important fish outside the MPA suggests that any spill-over is being quickly utilised by local fishers. The Napantao MPA is successfully conserving populations of these high-value fish families and allowing individuals to reach sexual maturity. The small size of the MPA may also make it insufficient to protect certain fish species with home ranges larger than the reserve.

Invertebrate communities in Napantao appear to be healthy, despite there being no commercially important species recorded, as this is an observation that is common within the region of Sogod Bay (Heney and Dallison, 2019a,b). Populations of corallivorous *Drupella spp.* and *Acanthaster planci* should be monitored to ensure that densities do not surpass what is considered to define an outbreak, which could impact the overall abundance of corals in Napantao.

The combination of high abundance of herbivorous Scaridae, low algae coverage, high hard coral cover, low disease and bleaching prevalence, suggests that the coral reefs within and surrounding the MPA are especially resilient to environmental changes and anthropogenic stresses. It is likely that the Napantao reefs are supplying nearby more degraded and unprotected reefs with coral larvae, highlighting the importance of protection.

Higher levels of trash outside the MPA suggests that waste management practices could be improved to reduce the amount of trash entering the ecosystem. Fishing trash found inside the MPA may be evidence that illegal fishing is occurring, suggesting a need for better management and monitoring of the reserve by a Bantay Dagat for optimal ecological benefits from the MPA.

In summary, the Napantao MPA provides various ecosystem services to the local community through the provision of fish into unprotected waters, the sustainability of fish populations, increased value in fish that are allowed to grow inside the MPA, through the draw of tourists and also the supply of coral larvae to any degraded reefs in the region. Due to the implied high resilience, the Napantao MPA will continue to provide these services as long as compliance is maintained, additional stressors are not introduced and current stressors are mitigated.

6. Study Limitations

All data were collected using underwater visual census SCUBA methodology, which has been found to introduce bias due to the influence on fish behaviours by divers, especially in fished areas where wariness is high (Lindfield et al., 2014; Goetze et al., 2017). Fish surveys also do not account for species with nocturnal behaviour. Introduced human error from counting the same fish twice, not seeing certain organisms or misidentification may also slightly influence results, although high levels of training ensure this error is minimal. All recorded transects were located at 12m, so are not representative of the shallower portions of reef which are subject to slightly different environmental factors.

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Appendix A. Appendix

Table Appendix A.2: Target fishes recorded by Coral Cay Conservation Survey Teams throughout the study period. Targets are provided by common name and respective taxonomic nomenclature indicating resolution of collected data.

Common	Taxonomic	Common	Taxonomic
Angelfish	Pomacanthidae	Moray Eel	Muraenidae
Barracuda	Sphyraenidae	(Parrotfish)	Scaridae
(Butterflyfish)	Chaetodontidae	Bumphead Parrotfish	<i>Bolbometopon muricatum</i>
(Big) Longnose Butterflyfish	<i>Forcipiger flavissimus</i>	Pufferfish	Tetrodontidae
Eastern Triangle Butterflyfish	<i>Chaetodon baronessa</i>	Rabbitfish	Siganidae
Humphead Bannerfish	<i>Heniochus varius</i>	Sandperch	Pinguipedidae
Kleins Butterflyfish	<i>Chaetodon kleinii</i>	Snapper	Lutjanidae
Racoon Butterflyfish	<i>Chaetodon lunula</i>	Spinecheeks	Nemipteridae
Redfin Butterflyfish	<i>Chaetodon lunulatus</i>	Squirrelfish/Soldierfish	Holocentridae
Vagabond Butterflyfish	<i>Chaetodon vagabundus</i>	(Surgeonfish)	Acanthuridae
Cardinalfish	Apogonidae	Unicornfish	<i>Naso spp.</i>
(Damsel fish)	Pomacentridae	Sweetlips	Haemulidae
Anemonefish	<i>Amphiprion sp.</i>	Toby	<i>Canthigaster spp.</i>
Sergeant Damsel fish	<i>Abudefduf saxatilis</i>	Triggerfish	Balistidae
Emperor	Lethrinidae	(Wrasse)	Labridae
Fusilier	Caesionidae	Crescent Wrasse	<i>Thalassoma lunare</i>
Goatfish	Mullidae	Humphead Wrasse	<i>Cheilinus undulatus</i>
Grouper	Epinephelinae	Red-Breasted Wrasse	<i>Cheilinus fasciatus</i>
Jack/Trevally	Carangidae		
Lionfish	<i>Pterois spp.</i>		
Lizardfish	Synodontidae		
Moorish Idol	<i>Zanclus cornutus</i>		

Table Appendix A.3: Target invertebrates recorded by Coral Cay Conservation Survey Teams throughout the study period. Targets are provided by common name and respective taxonomic nomenclature indicating resolution of collected data.

Common	Taxonomic	Common	Taxonomic
Feather Duster Worms	Sabellidae	Christmas Tree Worms	<i>Spirobranchus giganteus</i>
Shrimp	Crustacea	Banded Coral Shrimp	<i>Stenopus hispidus</i>
Lobster	<i>Panulirus spp.</i>	Nudibranch	Nudibranchia
Triton's Trumpet	<i>Charonia spp.</i>	Cowrie	Cypraeidae
Top Shell	Trochidae	Cone Shell	<i>Conus spp.</i>
Drupella	<i>Drupella spp.</i>	Octopus	Octopoda
Other Gastropod	Gastropoda	Giant Clam	<i>Tridacna spp.</i>
Crown-of-Thorns Seastar	<i>Acanthaster planci</i>	Cuttlefish	Sepiida
Squid	Mollusca	Brittle Star	Ophiuroidea
Blue Sea Star	<i>Linkia laevigata</i>	Cushion Star	<i>Culcita novaeguineae</i>
Collector urchin	<i>Tripneustes gratilla</i>	Brittle Star	Ophiuroidea
Granulated Sea Star	<i>Choriaster granulatus</i>	Feather Star	Crinoidea
Greenfish	<i>Stichopus chloronotus</i>	Diadema	<i>Diadema spp.</i>
Pencil Urchin	<i>Heterocentrotus mamillatus</i>	Prickly Redfish Sea Cucumber	<i>Thelenota ananas</i>
Pinkfish	<i>Holothuria edulis</i>	(other) Sea Cucumber	Holothuroidea

Table Appendix A.4: Substrates and respective categories recorded by Coral Cay Conservation Survey Teams throughout the study period.

Substrate	Code	Substrate	Code
Soft Coral	SC	Sponge	SP
Recently Killed Coral	RKC	Rock	RC
Silt	SI	Rubble	RB
Sand	SD	Nutrient Indicator Algae	NIA
Other	OT**	Hard Coral	HC*
HC Lifeforms*			
<i>Acropora</i> Branching	ACB	<i>Acropora</i> Encrusting	ACE
<i>Acropora</i> Digitate	ACD	<i>Acropora</i> Tabulate	ACT
Non- <i>Acropora</i> Branching	CB	Non- <i>Acropora</i> Foliose	CF
Non- <i>Acropora</i> Sub-Massive	CS	Non- <i>Acropora</i> Fungia	CM
<i>Heliopora</i>	Blue Coral	<i>Millepora</i>	Fire Coral
<i>Tubipora</i>	Organ Pipe Coral		
Other **			
Anemone	Halimeda	Corallimorph	Tunicate
Zoanthid	Gorgonian	Hydrooid	

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