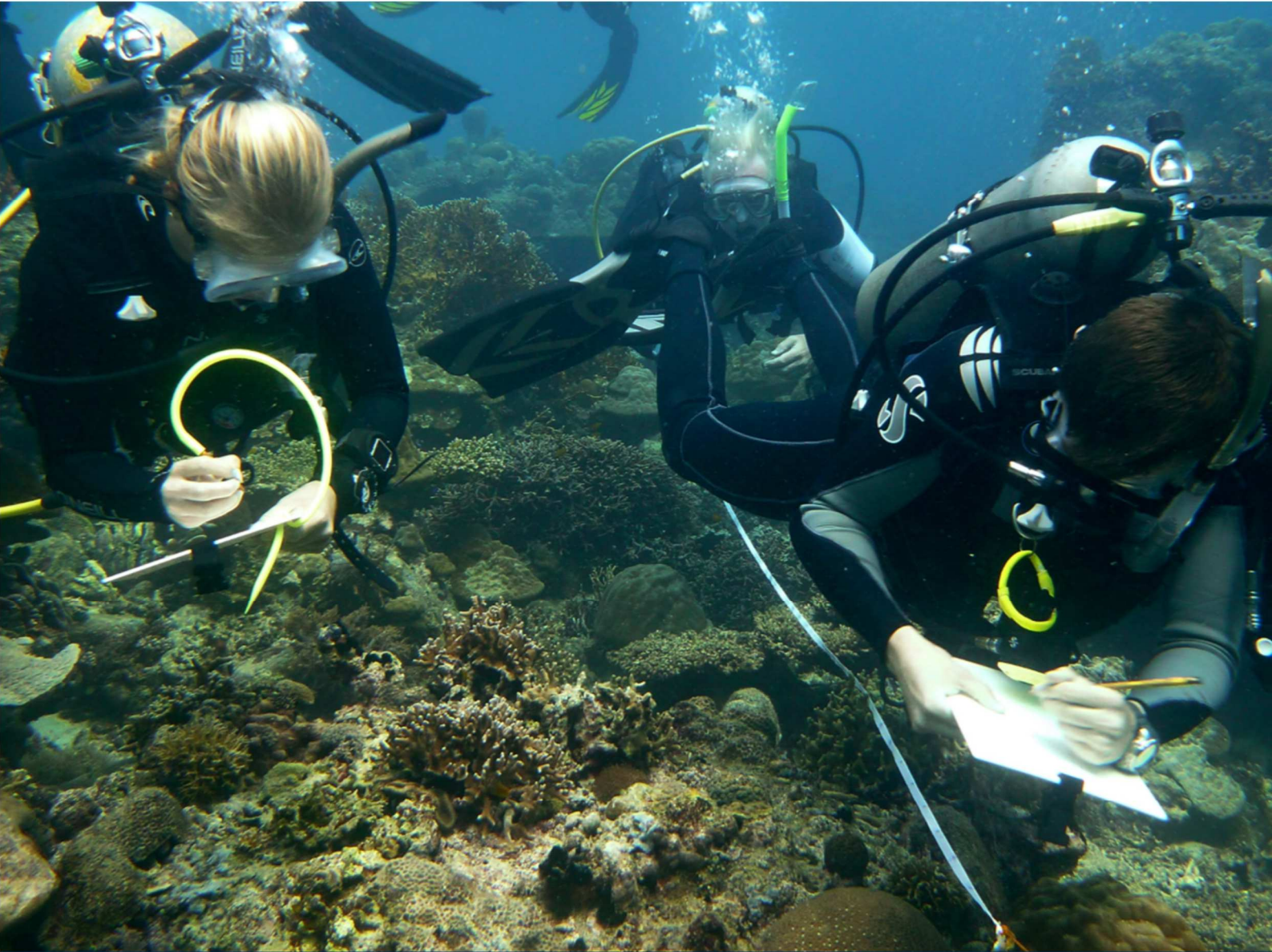




LRCP

Southern Leyte Coral Reef Conservation Project

Coral Cay Conservation Proposed Marine Protected Area Report: Barangay Dinahugan 2016

Report Date: November 2017

**CORAL CAY
CONSERVATION**



Expeditions

Felipe Lei, Tom Dallison

In partnership with the Southern Leyte
Provincial Government, Philippines





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thewaterloofoundation*

The Waterloo Foundation

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Executive Summary

- Coral Cay Conservation (CCC) assessed the reef fish, invertebrates, substrates and anthropogenic impacts within the proposed Marine Protected Area (MPA) in Dinahugan (Padre Burgos) during July and August 2016.
- At the request of Armando Gaviola of PENRMO, and after consulting the Barangay Captain in Dinahugan, CCC conducted Underwater Visual Census (UVC) protocols. An enhanced Reef Check methodology was used to survey 6 100m transects each containing four 20m replicates.
- Mean fish abundance was $N = 72 \pm 9.63$ per 500m³ and no significant differences were recorded for species richness (S) or Shannon's (H') diversity index between transects. However, the community recorded on transect O05 demonstrated a greater evenness than transect O06.
- Low abundance and small size (<30cm) of commercially important fishes is indicative of a highly-overfished area, posing a long recovery process. It is evident that any recovery would require site protection to reduce fishing pressure.
- Obligate corallivorous butterflyfish dominated ($N = 0.7 \pm 0.22$ per 500m³) in comparison to their facultative counterparts ($N = 0.025 \pm 0.025$ per 500m³), suggesting that there is a sufficient presence of scleractinian hard coral to support their feeding preferences. However, the abundance of butterflyfishes in the entire area was comparatively low.
- The mean abundance of invertebrates ($N = 174.75 \pm 20.66$ per 100m²) was found to be higher in comparison to Napantao MPA. However, in terms of species richness (S), Shannon's diversity (H') and Pielou's evenness (J), Dinahugan demonstrated lower values. Many commercially important species of invertebrates were absent from surveys suggesting intensive harvesting, either past or present.
- Throughout the total area surveyed for invertebrates (2,400m²), a total of 9 Crown-of-Thorns-Seastars (CoTs) were recorded. This abundance falls within guidelines on outbreak abundances that indicate such densities of CoTs can have highly detrimental impact to the coral reef within Barangay Dinahugan. Therefore, CoTs-focused surveying must be undertaken at the surveyed site, and if required, the CoTs must be removed.
- The dominating substrate was sand; however, the second most prevalent substrate was hard coral, followed by rock and rubble, which is a positive sign for future coral recruitment in the area. Overall, bleaching, recently killed coral and coral disease were low.
- CCC recommends creating an NTA buffered with designated MR zones allowing some restricted (hook and line only) fishing in Barangay Dinahugan, Padre Burgos. Protecting this area would allow the hard-coral cover to increase, allow fish stocks to recover and potentially create funding in the form of eco-tourism. However, before action must be taken, CCC must seek clarity from Barangay officials as there is a high possibility that the surveyed site does not reside within official Barangay coastal waters.

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List of Acronyms and Abbreviations

CCC	: Coral Cay Conservation
CoTs	: Crown of Thorns Seastars (<i>Acanthaster planci</i>)
HC	: Hard Coral
IUCN	: International Union for the Conservation of Nature
LGU	: Local Government Unit
LRCP	: Southern Leyte Coral Reef Conservation Project
MPA	: Marine Protected Area
MPA MEAT	: MPA Management Effectiveness Assessment Tool
MR	: Marine Reserve
NIA	: Nutrient Indicator Algae
NIPAS	: National Integrated Protected Area System
NTA	: No Take Area
OT	: Other
PAME	: Protected Area Management Enhancement
PENRMO	: Provincial Environmental and Natural Resource Management Office
PGSL	: The Provincial Government of Southern Leyte
PIT	: Point Intercept Transects
PRRCFI	: Philippines Reef and Rainforest Conservation Foundation Inc.
PRRP	: Philippines Reef and Rainforest Project
RC	: Rock
RKC	: Recently Killed Coral
SC	: Soft Coral
SD	: Sand
SE	: Standard Error ($\pm$)
SI	: Silt
SP	: Sponge
SST	: Sea Surface Temperature ($^{\circ}\text{C}$)
UVC	: Underwater Visual Census
S'	: Species Richness
H'	: Shannon H' Diversity Index
J'	: Pielou's J Evenness
N	: Abundance

Coral Cay Conservation

Initially founded in 1986, CCC is an internationally renowned non-governmental organisation (NGO), which provides host countries with appropriate resources for the protection and sustainable use of tropical ecosystems. This protection is established to enable future generations the continued use of local ecosystem resources. These goals are outlined in CCC's mission statement:

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

CCC achieves its mission via the formation of long-term programmes of collaborative research with local institutions and governments. Such research programmes require technical support from CCC, in the form of scientific data collection, data analysis and the production of reports and integrated coastal zone management plans. CCC also provides communities with education, training and alternative livelihood opportunities to strengthen local human resources to the point where research can be continued independently by the host country.

CCC has carried out conservation projects all over the world, including the Philippines, the Caribbean, Belize, Honduras, Malaysia, Cambodia and Fiji. CCC has successfully set up numerous Marine Protected Areas (MPAs) throughout these regions and provided essential scientific data for the management of their local marine resources. Historically, successfully established areas in the Philippines were a result of the Philippines Reef and Rainforest Project (PRRP). CCC established PRRP in collaboration with the Philippine Reef and Rainforest Conservation Foundation Inc. (PRRCFI) and the World Land Trust in 1995. Such protected areas include the coastal regions of the Southern Negros Occidental, Anilao, Palawan, Danjungan Island, the forests of North Negros and Padre Burgos.

In 2002, the PGSI invited CCC and the PRRCFI to conduct research in Sogod Bay. This resulted in the formation of the Southern Leyte Coral Reef Conservation Project (LRCP). The LRCP utilises trained volunteers to survey the region's coral reefs and provide training and conservation education opportunities for project counterparts. The aim of this is to develop local capacity and ensure the long-term protection and sustainable use of marine resources throughout Southern Leyte. Between 2002 and 2013, CCC focused on implementing baseline surveys throughout Sogod Bay to obtain information on the distribution of fishes and invertebrate populations, benthic cover and reef health. In 2013, having surveyed much of the accessible area in the Bay, CCC shifted its focus to concentrate on MPA monitoring surveys. Under this new protocol surveys are implemented inside and outside of existing MPAs to evaluate their efficacy and in unprotected areas to assess their potential for MPA installation



Schematic diagram demonstrating Coral Cay Conservation's implementation strategy within a specified host country. The sustainment of livelihoods and poverty alleviation are facilitated through the restoration and protection of valuable socio-economic ecosystems, accompanied by the promotion of sustainable resource exploitation and local capacity building.

1.0 Introduction

1.1. Marine Protected Areas

Marine resources are under increasing pressure from an ever growing global population (Jackson *et al.*, 2001). Strong declines in catch from worldwide fisheries, such as the North Atlantic Cod (Myers 1997) and Caribbean reef fisheries (Hardt 2009), have illustrated that biological marine resources are limited and highly vulnerable to overfishing (Jackson *et al.*, 2001; Pauly *et al.*, 2002). Additional pressures such as pollution, coastal development and climate change exacerbate this vulnerability. As a result, there is an increased drive for conservation efforts and resource management in the marine environment (Wood *et al.*, 2008; CBD 2010). The protection of marine areas can achieve conservation and resource management targets simultaneously and are therefore considered instrumental to sustainable ocean utilisation (Pauly *et al.*, 2002). The International Union for the Conservation of Nature (IUCN) defines an 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.”

MPAs have become vital tools in protective management for the conservation of marine resources. MPAs in the Philippines encompass No-Take Areas (NTAs), within which no form of extraction is permitted. These NTAs are surrounded by 50m “buffer zones” where only non-destructive fishing methods, such as single hook and line fishing, are permitted. These large areas of no extraction combat resource exploitation by providing local communities with a sustainable supply of goods; such as fish and invertebrates; and services, such as shoreline protection and tourism (World Bank, 2005).

To assess the beneficial impact of an MPA, resource managers often seek to measure its respective effectiveness. Effectiveness can be measured on a range of factors, however, most commonly addresses the goals established by the MPA. Measuring the MPA's impact on ecology, biodiversity, (Mora *et al.*, 2006; Selig and Bruno 2010), species conservation, the general ecological status and fishery productivity (Buxton *et al.*, 2006; McDaniel 2007) as well as meeting the stakeholder-defined parameters of success (Dahl-Tacconi 2005) can often satisfy the quantifiable conclusion of effectiveness. The definition of effectiveness was given by Pajaro (2010) and states that “...effectiveness is the achievement of the ecological, socio-economic, and governance objectives outlined during the planning process.”. However, generally, the most desired benefit of an MPA is to increase fish production and conserve respective fauna and flora of interest.

Increases in fish production occurs as a result of overspill and larval export from the NTA into surrounding waters (Fig. 1). Over time, the displacement of fishing effort from the MPA results in an increase in adult fish biomass and fecundity. This results in adult fish and larvae being exported to the buffer zone and its surrounding waters. Local fishery yields subsequently increase because they have a continual and sustainable supply of stock (Maliao *et al.*, 2004). In areas where there is the potential for increased tourism and anthropogenic pressure on the marine environment for food, recreation and other resources, the benefits and necessities of having a network of functioning MPAs are increased. Marine Reserves (MRs) are areas of the marine environment where fishing is restricted to non-destructive methods, such as single hook and line fishing. This reduces habitat damage often caused by destructive fishing methods, such as dynamite fishing, net fishing or trawling.

MRs are preferable to areas of no protection but are not as effective as MPAs because fishing pressure remains present. The fauna within the MR, their size, biomass and life-stage are all at the discretion of the by-laws set for the MR during the planning stage regarding levels of exploitation. Enforcement in this regard can be fully functioning through closed seasons or restrictions on certain gears and activities, or can be minimal resulting in high levels of exploitation of all cohorts. Therefore, when enforcement is minimal or non-apparent most fish and invertebrates within an MR can still be extracted. With by-catch being a void concept within tropical subsistence coral reef fisheries, it is often the case, as fishery production decreases, juveniles, unprecedentedly retain a social and economic value to fishermen. Thus, juveniles are often removed before they can reach sexual maturity, causing populations to decline. Environmentally important species, such as algae-grazing Parrotfish, are also removed, potentially allowing algae to proliferate and smother vital coral habitat.

"The key to success and broad acceptance, whether for multiple use MPAs or NTAs, is a clear articulation of the

management problem that the MPA is meant to solve. Such objective setting should be done with scientists working in concert with local communities, user groups and management authorities – not scientists in isolation."

Agardy *et al.* (2012)

The success of a protected area is entirely dependent upon the cooperation of local stakeholders (Polnac *et al.*, 2001). Research has shown that the involvement of resource users in the planning, implementation and management of their own MPA increases their sense of ownership and pride. Only when local stakeholders feel they are adequately considered and regularly consulted on their MPA's management, will it be possible for the full potential of the MPA to be attained (Green *et al.*, 2009, Human and Davies 2010). It is, therefore, essential that the local community is involved throughout entire process of protected area establishment. Stakeholders must be consulted about key aspects of the MPA establishment process, such as size and location whilst being directly involved in their management e.g. via community Bantay Dagats (marine guards).

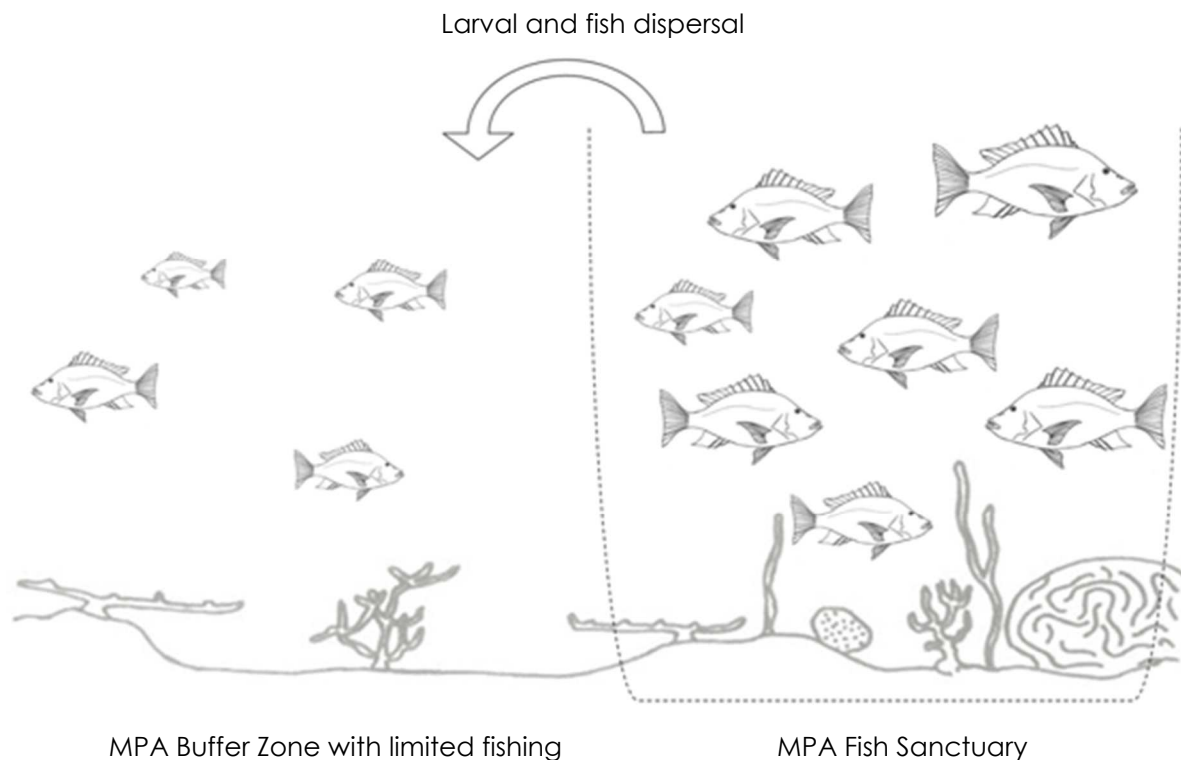


Figure 1. Schematic diagram of MPA functioning. Protected fish within the MPA fish sanctuary grow and produce offspring. This leads to 'overspill', increasing fish numbers inside and outside of the MPA. In addition, the corals inside the MPA are not disturbed by destructive fishing methods.

1.2 Coral Reefs and Marine Conservation in the Philippines

The Philippines lies within a region known as the Coral Triangle, which also includes Indonesia, Malaysia, Papua New Guinea, Timor-Leste and the Solomon Islands. It is recognised as the global centre of marine biodiversity as it is home to the oldest coral reefs and the largest expanses of mangrove forest in the world (Roberts *et al.*, 2002). More than 75% of the world's known coral species and over 30% of the world's coral reefs are found in the Coral Triangle (Veron *et al.*, 2009). The same extraordinary diversity is also found in other types of marine organisms; with over 3,000 species of fish recorded, even higher figures for molluscs and new species 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 98 million citizens live in coastal regions within 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 characterised 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 within the Philippines. Jacinto *et al.* (2000) stated that legislation concerning marine conservation in the Philippines is some of the most advanced within the Coral Triangle. Important laws currently instigated in the Philippines include:

- 1998 Fisheries Code (Republic Act 8550): 15% of municipal waters should be within an MPA.
- Marine and Coastal Resource Protection Act 2011: 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 roughly 1,869 MPAs in the Philippines. Of these MPAs, 33 have been declared at the national level as National Integrated Protected Area System (NIPAS) sites and the remainder are managed by Local Government Units (LGUs).

1.3 Characterisation of Study Region

1.3.1 Sogod Bay

The coral reefs of Southern Leyte remain some of the least disturbed habitats in the Philippines. The coastal regions that include Canigao Channel in the west, Sogod Bay, Cabalian Bay, the north eastern Pacific coast and the Surigao Strait are rich in marine life and are important fishing grounds for local communities. The area is rich in tuna, flying fish, herrings, anchovies, shellfish and Spanish mackerel. The region is also a feeding ground for attractive mega-fauna such as pilot whales, melon-headed whales, dolphins, manta rays and whale sharks. The coast is characterised by naturally limited mangrove areas, narrow fringing coral reefs, limited seagrass beds and narrow intertidal areas and beaches (Calumpong *et al.*, 1994).

CCC works alongside the municipalities with waters lying within Southern Leyte. Currently there are ~66 established MPAs covering an estimated 1,225.79 hectares. Nowadays, using reef check methodology CCC has been directly involved in the monitoring and survey of 26 different sites around Sogod Bay, these figures will increase in the coming years as more MPAs are in process of being established. Sizes of MPAs range from 3.5 hectares (Maujon/Juangon Fish Sanctuary) to 55 hectares (Limasawa Fish Sanctuary), with a



mean size of 11.7 hectares (± 2.2 SE) and a median of 7.9 hectares (PENRMO-CFRU, 2014). The sizes for several MPAs are not known, as accurate GPS coordinates are not available.

1.3.2 Dinahugan

The survey was requested by Sir Armando Gaviola of PENRMO on behalf of the PAME Project, which aims to establish MPAs within the LGUs of San Francisco, Liloan, Limasawa, Padre Burgos and Pintuyan, to help meet the aforementioned 1998 Fisheries Code (Republic Act 8550).

CCC surveyed the coral reefs located between 50-200m from the shoreline of Barangay Dinahugan located on Padre Burgos Municipality, on the western side of Sogod Bay. The proposed location for the MPA is close to the southern boundary of the barangay and the nearest population centre is next to the proposed area with an estimated population size of 808 (July 2016). Due to the semi-enclosed structure of the bay and the location of Padre Burgos Municipality, the reefs are sheltered from prevailing winds during the year. The last major storm with direct major effects on coral reefs recorded was Typhoon Nitang in 1984.



2.0 Methodology and Data Collection

2.1 Survey Sites

CCC's assessment of the proposed MPA site at Dinahugan was conducted between July 21st and August 18th, 2016, by trained volunteer survey teams (Fig. 2). The weather varied between sunny and partially cloud cover during this time with no major weather systems moving through the region. Mean air temperature during surveys was 33°C, Sea Surface Temperature (SST) was 29.8°C, and 29.6°C at a depth of 3m and 29.3°C at 10m. The mean estimated horizontal visibility throughout the survey was 18.3m.

From discussion with the Barangay Officials, occasionally, siltation can be an issue during heavy rainfall, the river located next to the proposed area deposits suspended sediments increasing the concentration of fine particles possibly proving detrimental to the coral reef. The proposed area is very

close to the Barangay, which is located directly on the shore; landscape dominated by rocky beach and palm trees, with a high number of houses and building on the northern half of the shoreline after the river mouth.

2.2 Biophysical Survey

The assessment of the proposed MPA site was conducted using an enhanced Reef Check methodology which is widely recognised and used to survey coral reefs around the world (Hodgson and Liebeler 2002). 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). Data from around the world is analysed on a yearly basis to enable the production of global coral reef status updates. Reef Check surveys produce a representation of the ecological status of a reef and its human impacts.

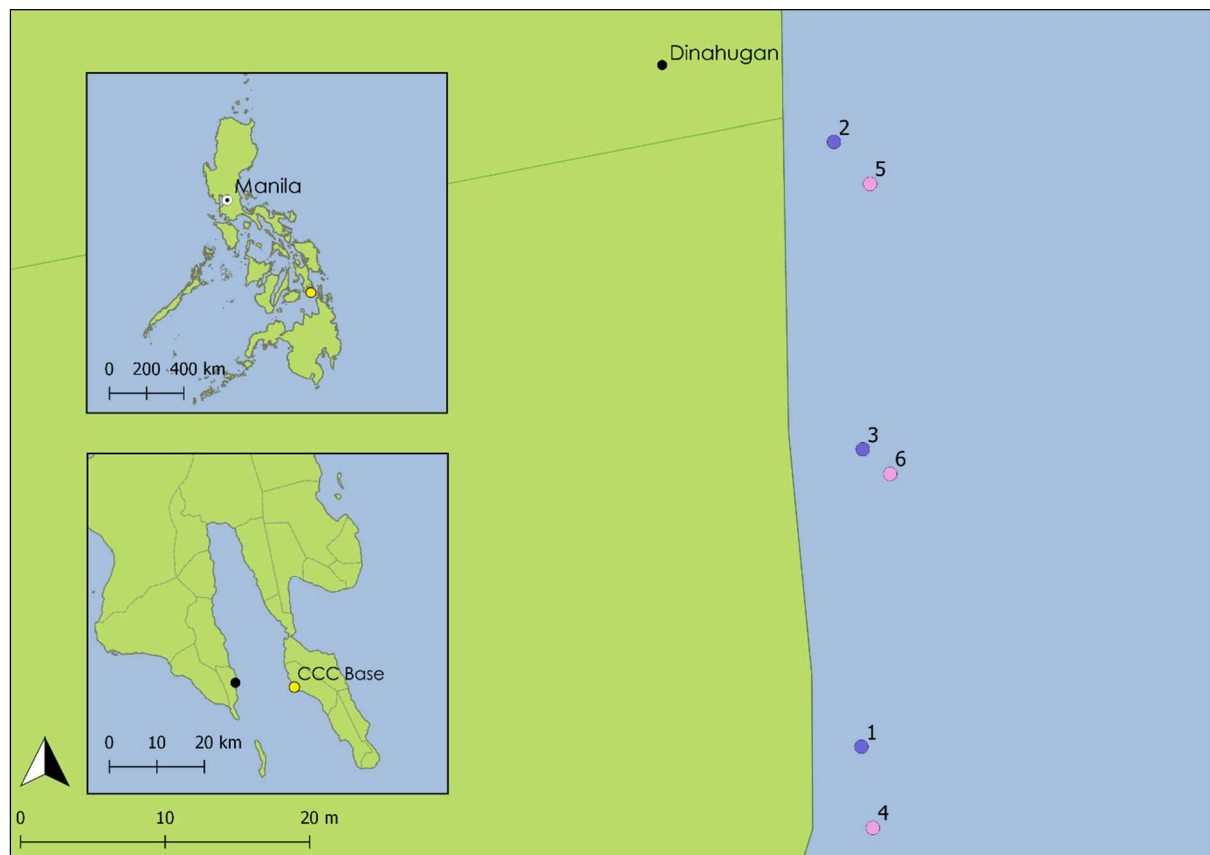


Figure 2. The Philippines (top), Southern Leyte (bottom) in relation to Coral Cay Conservation's (CCC) base (yellow) within Barangay Napantao. Six transects were completed within the coastal waters of Barangay Dinahugan (black) at depths of 6m (purple) and 12m (pink). Each transect is sequentially labelled.

CCC has augmented the methodology to reflect the high biodiversity of the area with the addition of extra target species of fish, coral and invertebrates (Appendix A).

Transects were laid along the reef, parallel to the shore, on a north to south bearing (Fig. 2). Three transects were situated at a depth of 6m and three transects were situated at a depth of 12m (Table 1). Each 100m transect was divided up into four 20m replicates, separated by 5m inter-replicate gaps in which no data were collected. This produced a total surveyed length of 80m. A distance of approximately 100m was left between each whole transect. This survey design allowed for robust statistical analysis of collected data.

Table 1. Depths (m) and coordinates (UTM) of 100m transects surveyed along the coast of Barangay Dinahugan, southern Leyte, the Philippines.

Transect Number	Depth (m)	Easting (UTM)	Northing (UTM)
O01	6	721796	1113878
O02	6	721777	1114297
O03	6	721797	1114084
O04	12	721804	1113822
O05	12	721802	1114268
O06	12	721816	1114067

2.2.1 Visual Assessment of Reef Fishes

Fish diversity and abundance data were collected using Underwater Visual Census (UVC) techniques. Selected fish families and species recognised as being good indicators of fishing pressure, aquarium collection and reef health were recorded. The abundance of three commercially important fish families: Parrotfish (Mol-mol, Scaridae); Groupers (Lapu-lapu, Serranidae) and Snappers (Maya-maya, Lutjanidae) were recorded and classified into size classes; 0-10cm, 11-20cm, 21-30cm, 31-40cm, 41-50cm, 51-60cm and >60cm (Appendix A). Commercial fish biomass (kg) was also investigated between transects and commercial fish species.

Data were recorded using 'belt' transects, where fish were observed along each replicate of the 100m transect within an imaginary 5x5x20m (WxHxL) box (Fig. 3).

Surveys were conducted by two surveyors swimming slowly along replicates, each counting indicator fish species 2.5m either side of the central transect line. Divers paused at 5m intervals along each replicate to wait one-minute for fish to acclimatise to surveyor presence. Data collection continued during this one-minute pause.

Butterflyfish were grouped into obligate corallivores (feed exclusively on coral), and facultative corallivores (feed non-exclusively on corals), since the presence of obligate corallivores on reefs can be used as an indicator of hard coral abundance. The two target obligate Butterflyfish, Redfin (*Chaetodon lunulatus*) and Eastern Triangle (*Chaetodon baronessa*) were grouped and the five other facultative target species, Longnose (*Forcipiger flavissimus*), Humphead (*Heniochus varius*), Klein's (*Chaetodon kleinii*), Raccoon (*Chaetodon lunula*), and Vagabond (*Chaetodon vagabundus*) were grouped with all other, unspecified Butterflyfish species (Berumen *et al.*, 2005).

2.2.2 Biomass Calculations

During UVC fish surveys the individual size of commercially important fish families were characterised through length ((L) cm) estimations, which were subsequently placed into appropriate size classes: 0-10cm; 11-20cm; 21-30cm; 31-40cm; 41-50cm; 51-60cm; >60cm. Length-weight relationships (LWR) (Equation. 1) were utilised to calculate the individual mass ((W) g) and biomass (kg). The individual weight of species in each sample can vary considerably, therefore within this study, specific steps were taken when assessing the W of individuals in each commercially important fish family in accordance with Froese *et al.* (2013) and Froese and Pauly (2000).

The biomass (kg) of each size class of family was derived through allometric LWRs. The relationship between L and W for fish species is expressed by equation (1):

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

Equation 1. Length-weight relationships were used to determine the biomass (kg) of each individual recorded on Barangay Dinahugan coral reef, Sogod Bay, southern Leyte, Philippines. W = mass (g), a = the condition factor (Hilborn and Walters, 1992), b = species specific growth parameter (Quinn and Deriso, 1999), L = the total length (TL) (cm) measured of the individual fish.

a and b are termed allometric coefficients, and each LWR requires both values. a is the condition factor in that it describes the body-shape of the species, where parameter b indicates the isometric growth of a species (Froese et al., 2013).

To determine the respective a and b coefficients for the three prescribed commercially important fish families, utilising data sources from FishBase (www.fishbase.org) (Froese and Pauly, 2000), the geometric mean value for a and b was calculated. This was due to the described potential variation of individual subjects. The components of each calculation were selected based on their reported location (Philippines, Central Indo-Pacific) due to natural abiotic impacts as well as differential spatial fishing intensity. Studies that categorically stated the species body-form and length measurements reported in TL were recorded. Therefore, standard Length ((SL) cm) studies and where FishBase listed the study as "doubtful" were excluded.

The respective genera within each family were individually analysed and the subsequent geometric mean determined for the allometric LWR coefficients. To establish the overall allometric coefficient values for the family, the geometric mean was also calculated.

For genera that did not supply studies of values that complied with this report's selection criteria, a Bayesian approach was taken in accordance with Froese et al.

(2013). If no Bayesian approach was readily available, the following geometric means were used for data deficient families of the three families: $a=0.0112$ and $b=3.04$. When a target species was categorised as a differing body-form to the status-quo of the family, such as Barramundi Cod (*Cromileptes altivelis*) considered as short and deep by FishBase, special consideration was taken with the species' respective allometric coefficients.

If the location of the study and reference were not obtainable, the species-range and native habitat were explored of the fish species through FishBase archives. If the species resided within the central Indo-Pacific region, the assumption was made that the allometric coefficients were obtained from individuals caught within the native habitat – the desired range. If the native range was outside the central Indo-Pacific region, the study was excluded.

Following the discussed process, the appropriate a and b values for each commercially important fish family were determined (Table 2).

2.2.3 Visual Assessments of Invertebrates

The diversity and abundance of selected invertebrate families and species were recorded along the same belt transect used for fish. Recorded species are typically targeted for food, collected as curios or important to the ecological balance of the reef (Appendix A). Giant clams (*Takubo*, *Tridacna gigas*) were recorded into the size classes 0-10cm, 11-20cm, 21-30cm, 31-40cm, 41-50cm, 51-60cm and >60cm.

Two divers each recorded invertebrates 2.5m either side of the transect line while swimming in a U-shaped search pattern (Fig. 4). Divers looked in holes and under

Table 2. The calculated Length-Weight allometric coefficients to determine the biomass (kg) of sized Grouper, Snapper and Parrotfish within Dinahugan proposed area, Southern Leyte, the Philippines.

Genera	Species	Common Name	Allometric Coefficients	
			a	b
Serranidae	Other	Grouper	0.0145	3.0225
	<i>Cromileptes altivelis</i>	Barramundi Cod	0.0138	3.28
Lutjanidae	Other	Snapper	0.0147	0.0312
Scaridae	Other	Parrotfish	0.0152	3.0398
	<i>Bolbometapon muricatum</i>	Green Humphead Parrotfish	0.0138	3.03

overhangs to find cryptic organisms such as lobsters and sea urchins.

2.2.4 Substrates

Benthic diversity was measured by recording living and non-living substrate categories along a 'point-intercept' transect (PIT) using a plumb line to minimize bias. Benthic organisms and substrate types directly underneath the transect line were recorded at 50cm intervals along each 20m replicate (Fig. 5). Every 20m replicate contained 40 benthic points. Benthic categories included: sand (SD), rock (RC), rubble (RB), silt/mud (SI), nutrient indicator algae (NIA), sponge (SP), recently killed coral (RKC), soft coral (SC), hard coral (HC) and any other sessile organisms. All hard corals were recorded to life form and level, with targets being recorded in greater detail (Appendix A).

Hard corals were further grouped and analysed for abundance in three conservation classes: disturbance adapted fast growing corals (i.e. *Acropora* spp., Fire coral (*Millepora* sp.), Blue coral (*Heliopora* sp.); competitor corals (i.e. branching, foliose, encrusting, mushroom non-*Acropora* spp.); and stress tolerant corals (i.e. massive, submassive, organ pipe (*Tubipora* sp.)), as defined by Edinger and Risk (2000).

2.2.5 Impacts

Within the same area assessed for invertebrates, divers recorded impacts on the reef. The total percentage of bleached coral cover was estimated together with the percentage of bleaching on each individual bleached coral colony. Coral diseases were identified where present and recorded as a percentage of the colony infected. Damage was

recorded in three categories: boat/anchor, dynamite and other, on an ordinal scale from 0 to 3 (0=none, 1=low, 2=medium, 3=high). The impact of trash was recorded on the same scale and separated into general and fishing nets/traps.

2.2.6 Data Analysis

Each 20m belt transect was treated as an independent replicate. This produced $n=12$ at 6 meters and $n=12$ at 12 meters. Shapiro-Wilks tests, typically used on small data sets to check for normality, showed much of the data was non-parametric (Shapiro and Wilk 1965; Thode 2002). Square root transformations of the non-parametric data did not sufficiently alter the data to warrant using a parametric analysis (O'Hara and Kotze 2010; Morris *et al.*, 2014). Thus, non-parametric Wilcoxon-Mann-Whitney U tests were used to test for statistically significant ($p = <0.05$) differences in the abundance of fishes, commercially important fishes, target butterflyfishes, invertebrates, and substrates between all transects.

Wilcoxon-Mann-Whitney U tests were also utilised to test for significant differences in biomass (kg) between commercially important fishes as well as invertebrate diversity. Species diversity of fish and invertebrates were determined using Species Richness (S), Shannon's Diversity Index (H'), and Pielou's Evenness (J'). S represents the number of different species found in an ecological community (Whittaker 1972). H' is used to characterize species diversity based on abundance and evenness and represents the degree of uncertainty relating to an individual's species identity (Morris *et al.*, 2014). J' is used to calculate species evenness by dividing (H') by (S) (Tuomisto 2012).

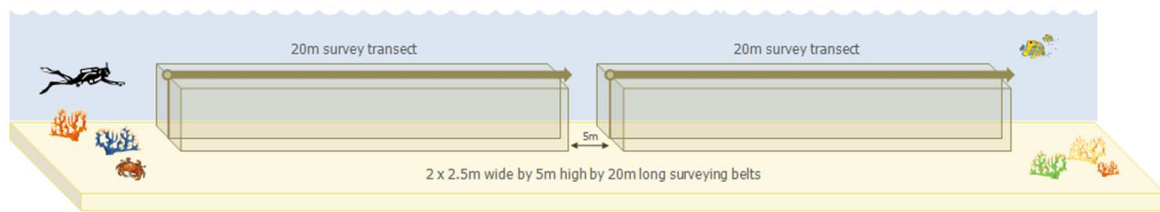


Figure 3. The augmented Reef Check methodology conducted for the assessment of the diversity and abundance of fishes within Barangay Dinahugan. Each conducted transect is separated into 4 x 20m replicates segmented by 5m inter-replicate gaps.

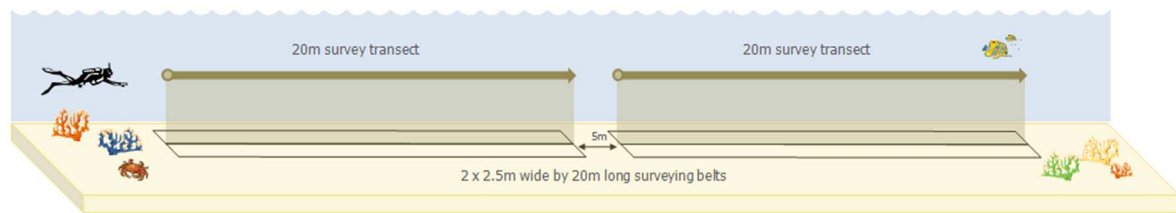


Figure 4. The augmented Reef Check methodology conducted for the assessment of the diversity and abundance of invertebrates within Barangay Dinahugan. Each conducted transect is separated into 4 x 20m replicates segmented by 5m inter-replicate gaps.

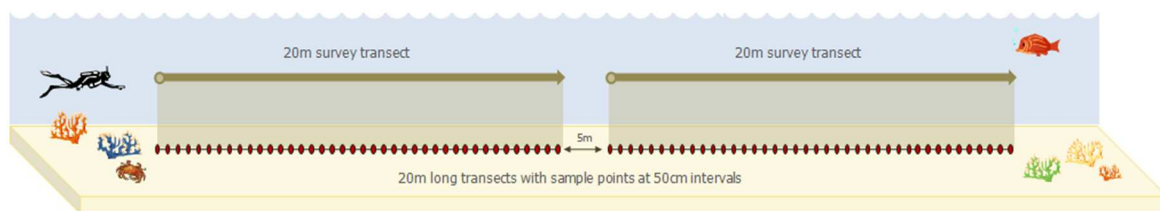


Figure 5. The undertaken point intercept methodology conducted for the assessment of benthic composition within Barangay Dinahugan. Each conducted transect is separated into 4 x 20m replicates segmented by 5m inter-replicate gaps with the respective benthic substrate recorded at 0.5m intervals. The presented schematic only represents two of the four 20m replicates.

3.0 Results

3.1 Fishes

Mean total fish abundance per transect was $N=72 \pm 9.63$ per 500m³ with transect O06 demonstrating the greatest mean abundance (Fig. 6). Transect O06 was found to be significantly greater ($p<0.05$) than transect O01 and transect O05 (Fig. B1).

Mean fish species richness (S) between all transects was $S=10.04 \pm 0.52$ per 500m³, mean Shannon's index (H') was $H'=1.88 \pm 0.06$ per 500m³ and mean Pielou's evenness (J) was $J=0.83 \pm 0.02$ per 500m³ (Fig. 7). No significant differences ($p>0.05$) were found for S or H' between transects, however, the communities recorded at transect O05 were significantly more even (J') ($p<0.05$) than those at transect O06 (Fig. B2).

3.2 Commercially important Fishes

Mean total commercial fish abundance was $N=2.25 \pm 0.57$ per 500m³ (Fig. 8). Transect O06 showed the highest abundance of commercially important species with a total of 22 individuals, whilst transect O01 and transect O02 recorded two individuals. Furthermore, transect O06 showed to be significantly higher ($p<0.05$) than transect O01 and O02 (Fig. B3).

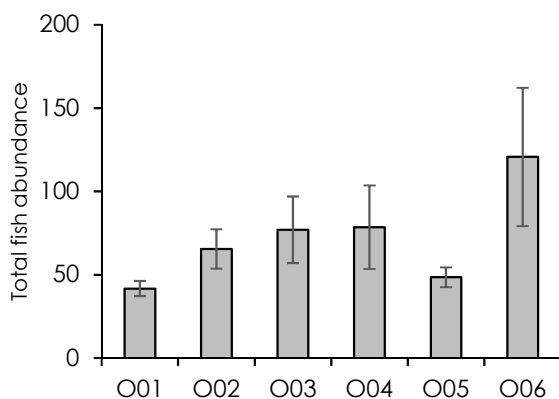


Figure 6. Mean total fish abundance with standard error (SE) across transects in Dinahugan proposed area, Southern Leyte, the Philippines.

Between the three-different commercially important species, Parrotfish were the most abundant with 41 individuals recorded; on the other hand, 9 Snappers and 4 Groupers were recorded. Mean Parrotfish, Grouper and Snapper abundances throughout the survey site were $N=6.83 \pm 2.12$, $N=0.67 \pm 0.67$, and $N=1.5 \pm 1.14$ per 500m³, respectively with Parrotfish dominant on transects O04 and O06 (Fig. 9).

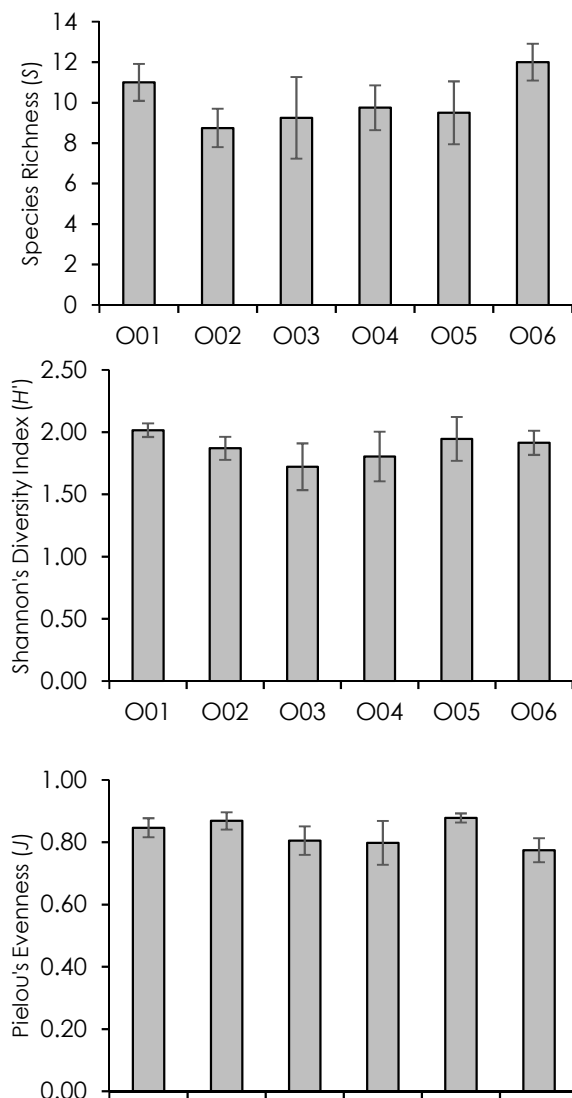


Figure 7. Total fish Species Richness (S), diversity (Shannon's Diversity H' Index), and evenness (Pielou's J' Evenness) with standard error (SE) across all transects, Dinahugan, Southern Leyte, the Philippines.

With regards to Grouper and Snapper numbers, no significant differences between transects were recorded. However, transect O06 showed a significantly higher Parrotfish abundance than transect O02 ($p = <0.05$) (Fig. 9 & B4).

The summed abundance of individual Parrotfish, Snapper and Grouper observed in Dinahugan were relatively small in size; no individuals were recorded greater than 30cm, and more than 55% where less than 10cm (Fig. 10).

Mean total commercial fish biomass was 0.03 ± 0.02 per 500m^3 (Fig. 11). With a total commercial important species biomass of 2.4 Kg between all transects, Parrotfish accounted for more than 84% (2.03 Kg) of that total biomass (Fig. 12), followed by Snapper (0.37 Kg) and Grouper (0.01 Kg).

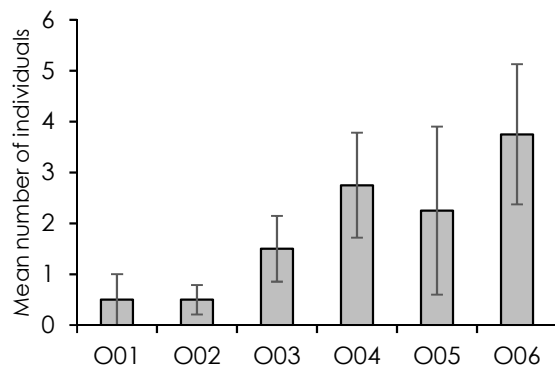


Figure 8. Mean total abundance of commercially important fish species observed per 500m^3 with standard error (SE) across all transects in Dinahugan, Southern Leyte, the Philippines.

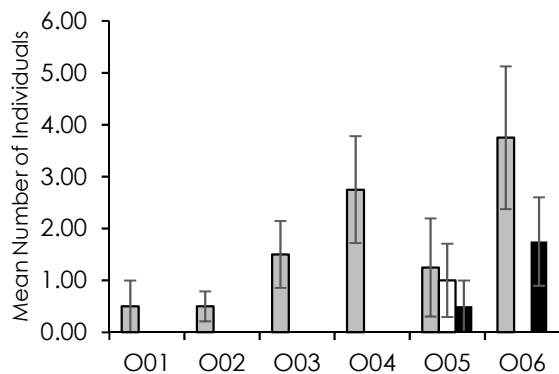


Figure 9. Mean abundance of Parrotfish, Grouper and Snapper observed per 500m^3 with standard error (SE) across transects in Dinahugan, Southern Leyte, the Philippines. Black = Snapper, Grey = Parrotfish, White = Grouper.

When looking individually at each species' biomass (kg) per transect, Grouper and Snapper mean biomass showed no significant difference between the transects. However, Parrotfish mean biomass was significantly higher on transect O06 than on transect O01, O02, O03 and transect O05 ($p < 0.05$) (Fig. 12 & B5).

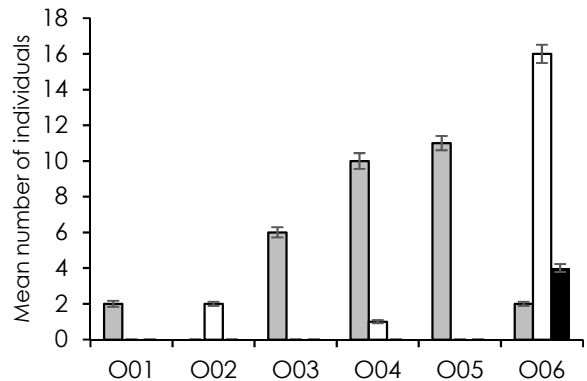


Figure 10. Cumulative abundance of Parrotfish, Grouper and Snapper in size categories 0-10cm (Grey), 11-20cm (white), 21-30cm (Black) per 500m^3 with standard error (SE) between transects in Dinahugan, Southern Leyte, the Philippines.

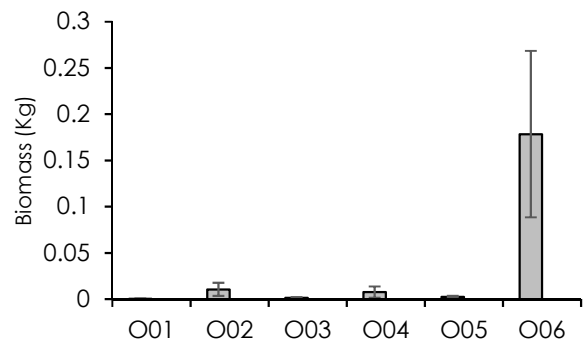


Figure 11. Mean total commercial fish biomass per 500m^3 with standard error (SE) between transects in Dinahugan, Southern Leyte, the Philippines.

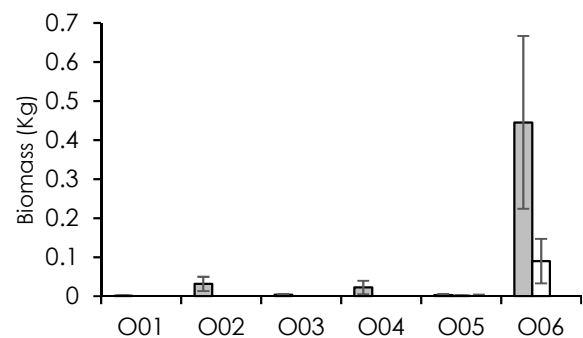


Figure 12. Mean commercial fish biomass by target family (Parrotfish (grey), Grouper (Black), Snapper (white)) per 500m^3 with standard error (SE) between transects in Dinahugan, Southern Leyte, the Philippines.

Other commercially important fish species including *Bolbometapon muricatum* (Bumphead Parrotfish), *Cromileptes altivelis* (Barramundi Cod), or *Plectorhincus* sp. (Sweetlips) were completely absent from the survey area.

3.3 Butterflyfish Diversity and Abundance

Mean Butterflyfish abundance per transect was $N=1.63 \pm 0.45$ per 500m³ (Fig. 13). Transect O01 showed a significantly higher Butterflyfish abundance than O06 ($p < 0.05$) (Fig. B6).

Mean Butterflyfish species richness was $S'=0.63 \pm 0.16$ per 500m³ (Fig. 14), and transect O01 was found to have a significantly higher abundance of butterflyfish species than transect O03 and transect O06 ($p < 0.05$) (Fig. B7). The mean Shannon's diversity index was $H'=0.1 \pm 0.48$ per 500m³ and no significant differences between the transects were found. Lastly, the mean Pielou's J' evenness was $J'=0.15 \pm 0.07$ per 500m³ and no significant differences were found.

A total of 36 Butterflyfish were counted during the survey, 92% of which were obligate corallivores. The mean abundance per transect of obligate corallivore butterflyfish was $N=0.7 \pm 0.22$ per 500m³ and the abundance of facultative corallivore butterflyfish was $N=0.025 \pm 0.025$ per 500m³ (Fig. 15). Furthermore, mean obligate corallivore butterflyfish abundance on transect O01 was significantly greater than transect O06 ($p < 0.05$) (Fig. B8).

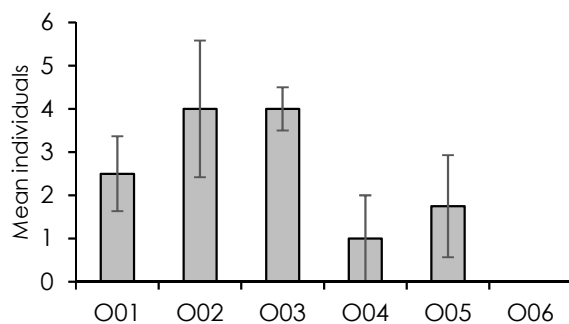


Figure 13. Mean total butterflyfish abundance per 500m³ with standard error (SE) across transects in Dinahugan, Southern Leyte, the Philippines.

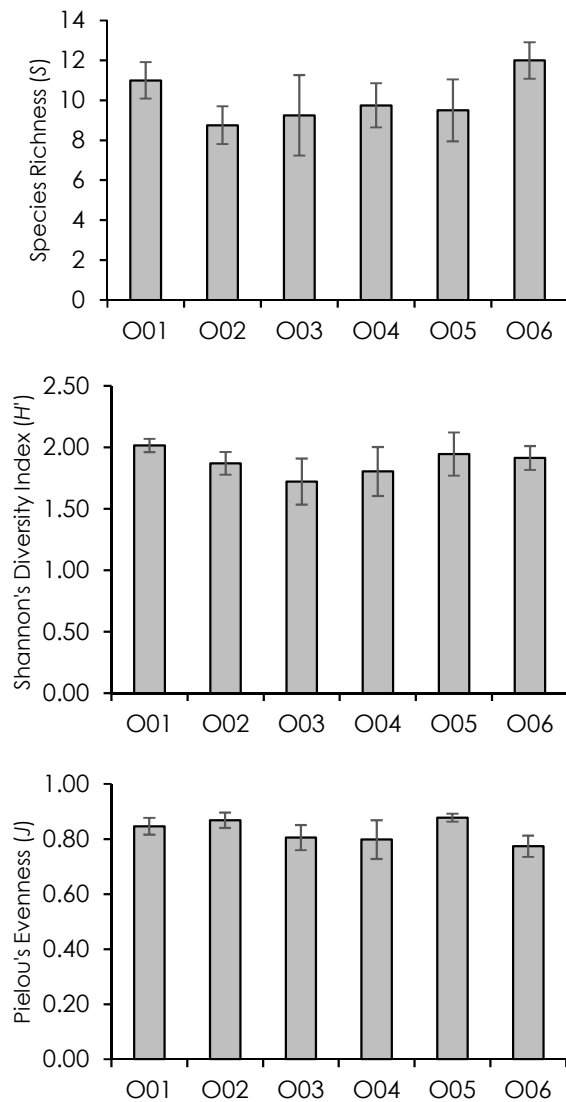


Figure 14. Butterflyfish Species Richness (S), diversity (Shannon's Diversity H' Index), and evenness (Pielou's J' Evenness) with standard error (SE) across transects in Dinahugan, Southern Leyte, the Philippines.

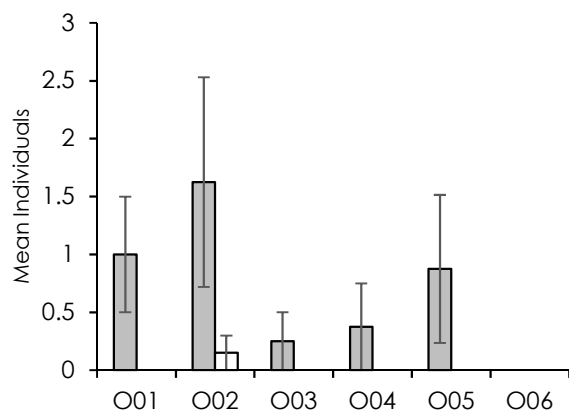


Figure 15. Mean obligate corallivore and facultative corallivore butterflyfish abundances with standard error (SE) per 500m³ across transects in Dinahugan, Southern Leyte, the Philippines. Grey = Obligate corallivore, White = Facultative corallivore.

3.4 Invertebrates

Mean invertebrate abundance across all transects was $N = 174.75 \pm 20.66$ per 100m² (Fig. 16), and no significant differences were found between any of the transects. More specifically, feather stars ($N = 104.71 \pm 12.69$), brittle stars ($N = 32.71 \pm 5.63$), feather duster worms ($N = 16.46 \pm 2.59$) and long spine sea urchins ($N = 12.13 \pm 6.60$) dominated the transects having a higher abundance than the rest of the invertebrates (Fig. C2).

Mean invertebrate species richness was $S' = 7.88 \pm 0.56$ per 100m² (Fig. 17) and transect O02 showed a significantly higher species richness than transect O06 ($p = <0.05$) (Fig. B9a). Mean Shannon's diversity index was $H' = 1.06 \pm 0.07$ per 100m² (Fig. 17). H' was significantly higher ($p = <0.05$) on transect O01 and O02 than transect O04 and O06; moreover, transect O03 H' was also significantly higher ($p = <0.05$) than transect O06 (Fig. B9b). Lastly, mean Pielou's J' evenness was $J' = 0.53 \pm 0.02$ per 100 m² (Fig. 17) and transects O01, O02 and O03 showed a significantly higher ($p = <0.05$) mean than transect O06 (Fig. B9c).

Commercially important invertebrate species including lobster (*Nephropidae*), triton's trumpet (*Charonia tritonis*), squid (*Teuthida*), prickly redfish sea cucumber (*Thelenota ananas*), greenfish sea cucumber (*Stichopus chloronotus*) and pinkfish sea cucumber (*Holothuria edulis*) were entirely absent from the survey. Four giant clams were recorded in total, with no individuals larger than 20 cm; more

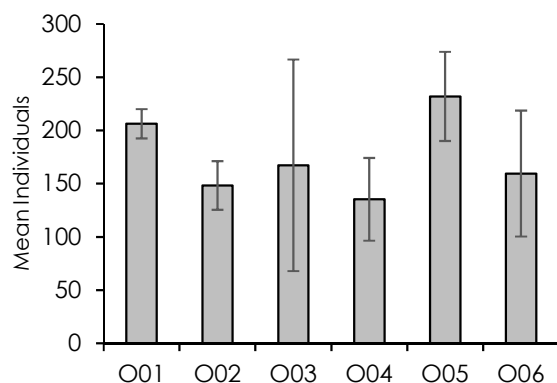


Figure 16. Mean invertebrate abundance at each transect per 100m² with standard error (SE) across transects inside (grey) and outside (white) the Napantao marine protected area (MPA), Southern Leyte, Municipality San Francisco, the Philippines.

specifically, 3 individuals were smaller than 10 cm and just one individual was between 10 and 20 cm. 9 Crown-of-Thorns-Starfish (CoTs, *Acanthaster planci*) were recorded during the survey in Dinahugan proposed area.

3.5 Benthic Substratum Composition

During the survey, the most prevalent substrate was sand with a mean coverage of $66 \pm 3.45\%$, followed by hard coral ($9.38 \pm 1.57\%$), rock ($8.33 \pm 1.41\%$), rubble ($8.33 \pm 1.48\%$) and nutrient indicator algae ($4.17 \pm 0.91\%$) (Fig. 18).

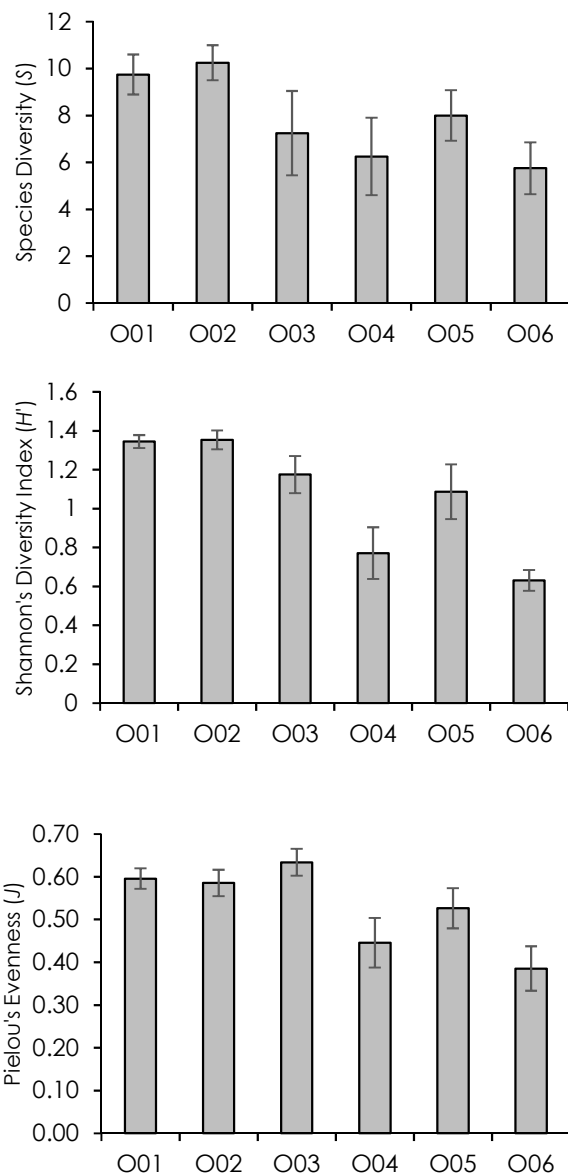


Figure 17. Invertebrate Species Richness (S), diversity (Shannon's Diversity H' Index), and evenness (Pielou's J' Evenness) per 100m² with standard error (SE) across transects in Dinahugan, Southern Leyte, Municipality San Francisco, the Philippines.

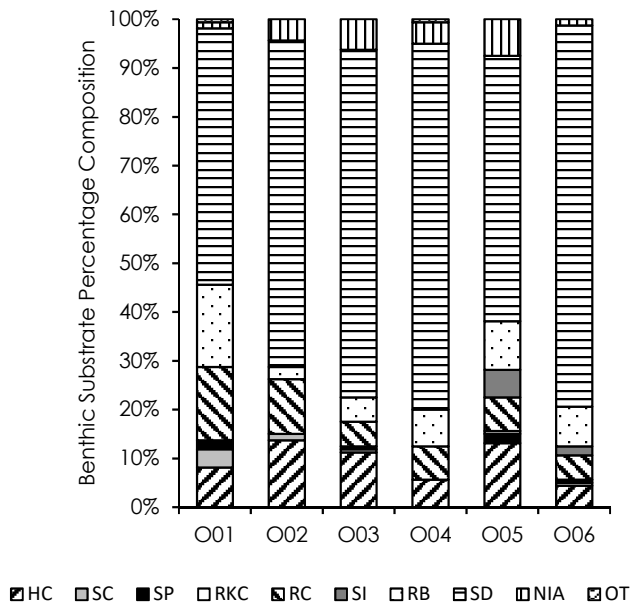


Figure 18. Mean substrate percentage cover at each transect in Dinahugan, Southern Leyte, the Philippines. HC –Hard coral; SC –Soft coral; SP –Sponge; RKC –Recently killed coral; RC –Rock; RB –Rubble; SD –Sand; SI –Silt; NIA –Nutrient indicator algae; OT –Other living organisms.

Sand cover was significantly higher ($p < 0.05$) on transect O04 and O06 than on transect O01 (Fig. B10a). Furthermore, nutrient indicator algae cover was significantly greater ($p < 0.05$) on transect O05 than on transects O01 and O06 (Fig. B10b). There were no significant differences across transects for the other substrates categories.

From all the hard corals observed during the survey, non-Acropora Sub-Massive corals were the most abundant, covering $19.22 \pm 5.39\%$ of the proposed area; followed by *Acropora* tabulate corals ($16.18 \pm 4.55\%$), *Acropora* branching corals ($15.94 \pm 4.70\%$), non-Acropora branching corals ($15.38 \pm 5.88\%$) and non-Acropora massive corals ($12.24 \pm 5.48\%$) (Fig. 19).

Fast growing corals were more abundant during the survey ($41.11 \pm 0.32\%$) than competitor corals ($33.33 \pm 0.32\%$) and stress tolerant corals ($25.56 \pm 0.20\%$). Fast growing corals dominated transect O02, O03, O04 and O06, while stress tolerant corals dominated on transect O01 and competitor corals heavily dominated transect O05 covering 66.10% (Fig. 20).

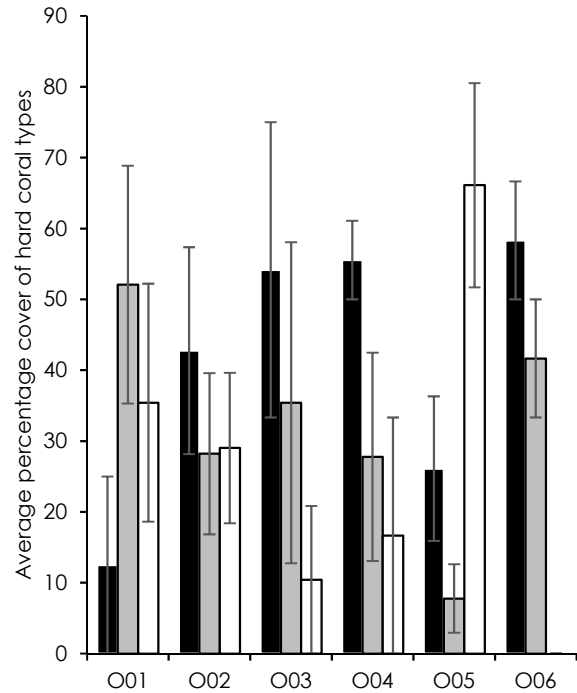


Figure 20. Mean percentage cover of coral types per 20m with standard error (SE) across transects in Dinahugan, Southern Leyte, the Philippines. Black = Disturbance adapted fast growing corals (i.e. *Acropora* sp., Fire coral (*Millepora* sp.), Blue coral (*Heliopora* sp.)); White = Competitor corals (i.e. branching, foliose, encrusting, mushroom non-*Acropora* sp.); Grey = Stress tolerant corals (i.e. massive, submassive, organ pipe (*Tubipora* sp.)) (Edinger and Risk 2000).

3.2 Anthropogenic Impacts

The surveyed area was reported to have a low overall anthropogenic impact; no blast or poison fishing and no harvesting of inverts for curio sales. However, the harvest of invertebrates for food occurs in the area together with reported commercial fishing activities, as well as artisanal/recreational fishing for personal consumption. Tourism was reported by Barangay officials as low within the area, with no recreational diving reported. Although the area is normally sheltered, in 1984 typhoon Nitang caused a tidal wave causing great damage to the reef; during heavy rainfall, siltation can be a problem with a river inside the proposed area.

During the survey, general trash was recorded 38 times. Overall, 62.5% of the area showed high impact, 12.5% moderate impact, 20.83% low impact and 4.17% showed no impact. Fishing related trash was recorded a total of 16 times during the

survey, with 20.83% of the area showing high impact, 16.67% showing moderate impact, 16.67% showing low impact and 45.83% showing no impact.

There were no obvious signs of boat, anchor, or dynamite damage. Undetermined coral damage was recorded to be high in 8.33% of the surveyed area, 4.17% showing moderate impact, 33.33% of the area showing low impact and 54.17% of the area without impact.

Coral bleaching was recorded on 11 replicates in total. On average, less than 1% of the population, within the proposed area, expressed signs of coral bleaching, with a mean of $12.37 \pm 3.93\%$ bleaching on those individual colonies. White band disease was recorded on one replicate and no other incidents of black band or other coral diseases were recorded.



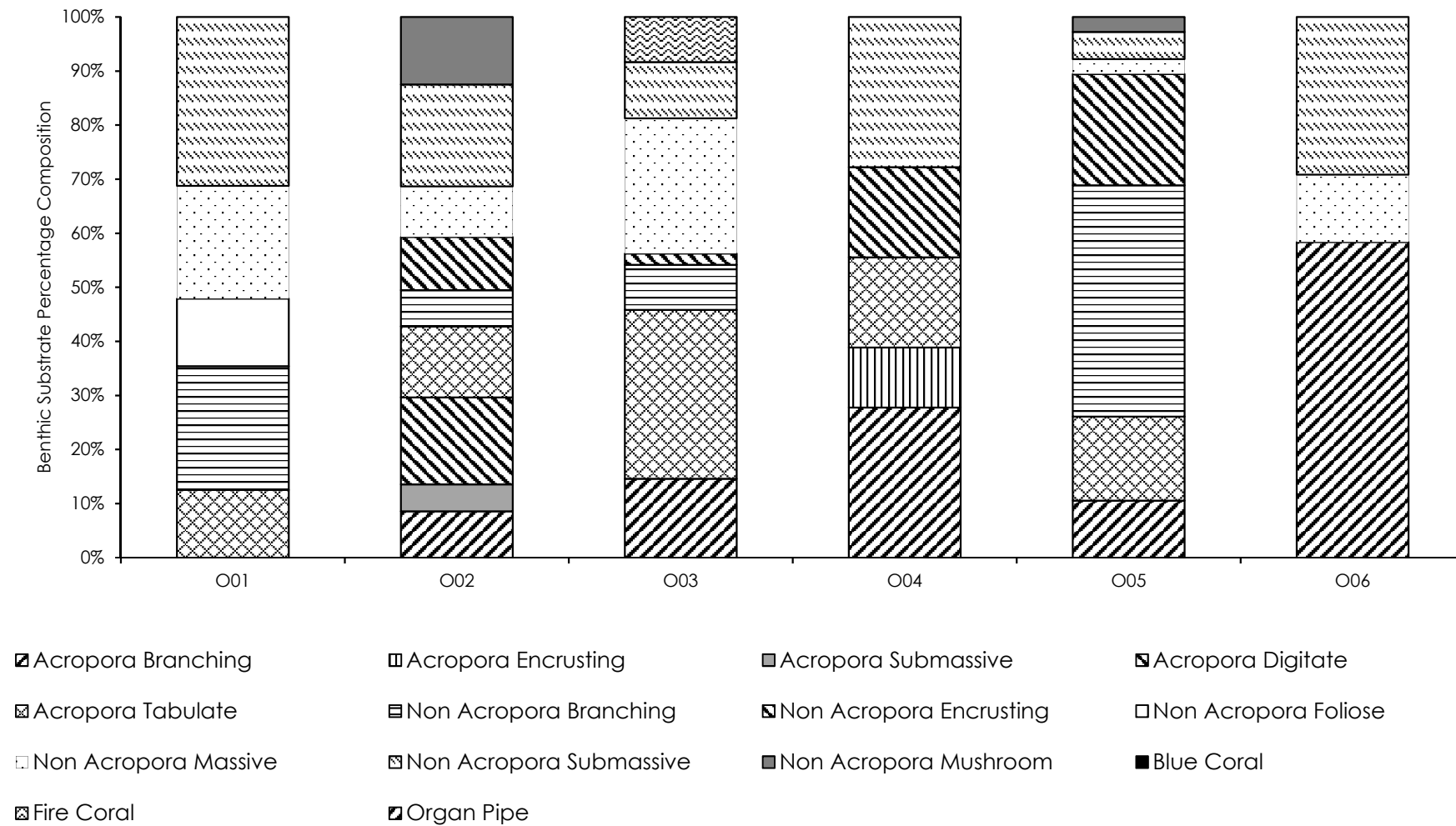


Figure 19. Mean percentage hard coral cover per 20m by classification across transects in Dinahugan, Southern Leyte, the Philippines.

4. Discussion

The assessment of the proposed MPA area in Dinahugan gave the overall impression that currently, the reef, whilst exhibiting clear signs of detrimental impacts, holds the ability to recover over a long-period of time. There are indications that the reef has been negatively impacted by environmental and human activity. Clear signs of overfishing, human waste and pollution should be considered and addressed to ensure the preservation and restoration of the ecosystem in the area. In this section, the results observed are discussed.

5.1. Fish

Overall, the surveyed area had moderate levels of fish abundance when compared to the Napantao MPA, San Francisco municipality ($N = 93.33 \pm 19.03$ in 2015 (Lancaster *et al.*, 2016) and $N = 106.04 \pm 10.06$ in 2016 (Parker *et al.*, 2017).

Napantao Fish Sanctuary is known by its high fish biodiversity, and is one of the most popular dive sites in Sogod Bay. Furthermore, the protected area has been in place for more than twenty years, which may contribute to its greater fish abundances (Edgar *et al.*, 2014). Therefore, the modest fish abundance in Dinahugan proposed area is an indicator that the area would benefit from the establishment of an MPA and proper enforcement, with various studies highlighting the benefit of the establishment of an MPA to coral reef communities (Russ and Alcala, 2004).

Fish diversity, mean species richness (S) and mean Shannon's diversity (H') in the Dinahugan proposed area was lower than on Napantao MPA. However, mean Pielou's evenness (J) was greater, meaning the communities recorded were limited in dominant species.

Greater H' values are often associated with healthier reef systems as high diversity typically increases a reef's resilience to anthropogenic and non-anthropogenic stressors (Chapin *et al.*, 2002).

Commercially important fishes such as Grouper, Snapper and Parrotfish had low abundance in Dinahugan and, when present, were small in size. This low abundance of commercially important species is indicative of a highly-overfished area.

Grouper, along with other commercially important reef fish families such as Snappers, are often long lived and slow growing, with life spans often ranging from 25 to 40 years (Coleman, *et al.*, 2000), with most species taking a long time to reach sexual maturity. Not only does it take these slower growing species a long time to recover when their populations are decreased, but preferential selection of larger individuals by fishermen also reduces the fecundity of the population and can disrupt sex ratios as well as population dynamics.

Therefore, continuous overfishing, together with the small size of the individuals increases population recovery time-scales, due to the high proportion of sexually immature individuals. It is evident that any recovery of these species would require site protection, reducing fishing pressure.

There were no observations of other commercially important species including *Bolbometapon muricatum* (Bumphead Parrotfish), *Cromileptes altivelis* (Barramundi Cod) or *Plectorhincus* sp. (Sweetlips). This supports the suggestion that these desirable food-fish species have been overfished in the area.

Butterflyfish are often used as indicators of reef health and resilience through their presence on reefs (Kulbicki and Bozec 2005). Butterflyfish species richness is highly correlated with both, total fish species richness and coral cover (Pratchett *et al.*, 2006).

The abundance, species richness, and diversity of Butterflyfish recorded, again

indicate that, although the proposed area exhibits positive signs of the area's ecological status, there is a clear need for improvement through adequate protection. Furthermore, the dominance of the obligate corallivorous species *C. baronessa* (Eastern Triangle) and *C. lunulatus* (Redfin) may suggest there is enough scleractinian hard coral to support fish communities that hold a dietary dependence upon hard coral (Stella *et al.*, 2011). This is supported by the absence of Butterflyfishes on transect O06; an area of low hard coral presence. However, it was surprising to see no Butterflyfish as there was a presence of fast-growing corals, a category including *Acropora* spp., a preference-prey by *C. baronessa*.

These findings could be expected due to the reef's lack of protection and indicates further that with an appropriately implemented MPA, the reef health at Dinahugan could improve markedly over time. Monitoring of these Butterflyfish and hard coral species should be continued to measure any population declines or increases, which could indicate failing or improving reef health.

5.2. Invertebrates

The mean abundance of Invertebrates was found to be higher when compared to Napantao MPA. However, in terms of *S*, *H'* and *J'*, Dinahugan exhibited lower values. The high mean abundance of invertebrates could be due to the high number of feather stars, with a higher mean abundance than all the remaining target organisms combined.

Many invertebrates feed preferentially upon hard coral species, particularly *Pocillopora* sp., *Acropora* sp. and *Stylophora* sp. (Stella *et al.*, 2011). *Pocillopora* sp. and *Stylophora* sp. are typically grouped into the lifeform non-Acropora Sub-Massive, which was the most common lifeform found during the survey. *Acropora* sp. in this region of the Philippines typically belong to the lifeform Acropora branching, accounting for 19% of the lifeforms recorded. Therefore, an increase

in the cover of those species may improve invertebrate abundance and diversity in the region.

Commercially important invertebrate species such as Triton's Trumpet (*Charonia* spp.), Prickly redfish (*Thelenota ananas*), Greenfish (*Stichopus chloronotus*) and Pinkfish (*Holothuria edulis*), Squid and other species of Sea Cucumber were all absent during the survey. These species, which in many cases are slow growing and slow moving, are particularly vulnerable to over exploitation. Giant Clams (*Tridacna gigas*), another important commercial species, were observed but in low numbers. Furthermore, all the individuals observed were <20cm in length. These results indicate that extraction pressure may be, historically and currently high in the area.

The presence of 9 Crown of Thorns Seastar (CoTs, *Acanthaster planci*) is of serious concern with various sources (e.g. GBRMPA 2014) stating an outbreak is considered when CoTs reach a density of 15 per ha (1 CoTs per approximately 666m²) or 5-9 are recorded within 2,500m² (CSREO 2012). This outbreak could be linked to the absence of their top predators, Triton's Trumpet at the site. This seastar is a voracious predator of corals and at high levels of abundance can cause catastrophic damage to reef communities. At low abundances CoTs are a natural component of reef systems and play a vital role in maintaining healthy, diverse coral communities. By feeding on diseased coral and preferentially predating fast-growing species such as *Acropora* sp. (Pratchett 2005), they can facilitate the control of disease and increase competition between coral species leading to higher diversity.

5.3. Substrates

The survey area was dominated by sand, which is not ideal for hard coral recruitment that requires hard surfaces to attach and grow. However, the second most prevalent substrate was hard coral, followed by rock and rubble, which is a positive sign for future coral recruitment in the area. Furthermore, bleaching and coral disease

were not recorded in high numbers and were relatively rare, which is a good sign for future coral growth. Similarly, the amount of recently killed coral recorded was low during the survey, which may be a positive indicator considering possible 'outbreak' levels of CoTs.

Research implemented by Reef Check between 1997 and 2001 shows that coral reef systems throughout the Indo-Pacific meand ~40% hard coral cover (Hodgson and Liebeler, 2002), exhibiting a decrease of 3-5% year⁻¹ (Tun *et al.* 2004). Compared to this Indo-Pacific mean, the ~10% hard coral cover at Dinahugan is very low. However, with the presence of hard substrates on the area that allow coral growth, and a pre-established coral reef to provide new recruits, the establishment of an MPA will have a positive impact on the ecosystem and its restoration.

The even presence of all three coral classifications throughout the transects: disturbance adapted fast growing; competitor; and stress tolerant, suggests a diverse reef ecosystem with a high conservation class (Edinger and Risk, 2000), although with low abundances. The slightly higher abundance of fast growing coral within the area, highlights that conservation strategies should afford maximum protection with activities such as diving and destructive fishing practices limited and prevented due to the fragility of the substrate (Edinger and Risk, 2000). These results, match with the data provided by the Barangay Officials, where they found no or little illegal fishing activities on the area, and the main stressors encountered were siltation and sedimentation during heavy rainfall.

Although the feedback from Dinahugan community was positive about the amount of anthropogenic impact, the amount of trash found and fish traps may suggest the contrary. Residents may be unaware of the magnitude of such anthropogenic impacts within their coastal waters, equally, their predictions may be accurate for this time period, with the reef showing the effects of

anthropogenic influence over many generations. Therefore, it is encouraging to see a high percentage of the different lifeforms types in the region, and highlights the importance of preserving Dinahugan's coastal region.

Overall, the proposed MPA exhibits a high hard coral diversity, capable of supporting a myriad of marine organisms, but still shows a low percentage of hard corals cover and potential for improvement. Importantly, it has been shown that a greater diversity in coral populations is ideal, as there is a link between greater coral diversity and increased fish and invertebrate diversity (Edinger and Risk, 2000).

5.4. Impacts

The overall anthropogenic impact in Dinahugan proposed area was reported as low by the community. Coral damage, coral disease and damages by anchor were low or absent during the survey, however, the high amount of trash recorded in the area throughout all the transects could be having a negative impact on the environment, smothering corals and potentially poisoning or choking marine life that ingest these items.

Additionally, if the proposed MPA is approved and established, these levels will diminish or disappear over time. The presence of trash tends to deter divers from visiting or returning to a site, therefore to improve the site for recreational diving trash levels should be reduced. Education about the consequences of improper waste disposal is extremely important and local communities require the right facilities to safely dispose of their waste.

Furthermore, low abundances and small fish sizes suggest historic overfishing has impacted the reef environment. Subsistence fishing is a necessity for the local fisher folk who rely on the fishing grounds for food and income. However, unsustainable exploitation methods will continue to place pressure on the fishery and associated reef and therefore, efforts

must be taken to develop sustainable gear-types and extraction methods.

As discussed before, the overall abundance of all commercially important species of both, fish and invertebrates was low in the proposed area. Furthermore, those individuals observed were all generally small indicating a population structure dominated by juveniles and small adults. This trend may indicate that pressure from fishing is removing large individual keystone species; vital for the control of species diversity and maintaining a balanced ecosystem.

The removal of important species of herbivorous fish such as Parrotfish (Scaridae), Rabbitfish (Siganidae) and Surgeonfish (Acanthuridae) through overfishing, can cause additional impacts to an ecosystem, such as phase shifts from coral dominated ecosystems to ones dominated by fleshy algae (Bellwood *et al.*, 2003). Herbivorous fish help control the abundance of algae in reef systems by constantly grazing new growth. When grazing fishes are removed, algae cover increases. Hard coral species are easily outcompeted by algae, which can lead to a reduction in coral cover and a shift to an algal dominated ecosystem which cannot support the same diversity of species (McClanahan *et al.*, 1996). Even if herbivore numbers were to increase again at a later stage, reversing this phase shift i.e. going back to a coral dominated reef, is extremely difficult (Lotze *et al.*, 2006).

Nevertheless, indirectly or directly, the effects of over fishing can be extremely serious. The relationships between organisms of different trophic levels are very complex and scientific understanding is limited. However, cases of both, trophic cascade and phase shift, have been recorded on reefs around the world where overfishing has played a critical role in the reduction of fish stocks (Bellwood *et al.*, 2004).

We believe that the establishment of Dinahugan proposed MPA will promote reef improvement, improving coral cover and fish diversity and abundances in the area if adequate protection, enforcement and management is in place. The implementation of an MPA could help to reverse these negative trends discussed and allow the reef to recover, with lasting benefits for the community of Dinahugan.



6. Recommendations

Due to the results highlighted in this report, CCC strongly recommend creating an MPA in Barangay Dinahugan, Padre Burgos. Considering the levels of overfishing suggested from the survey; an NTA that prohibits all fishing on at least some of the reef is the recommended course of action. Ideally this would be buffered by a designated 50m MR zone allowing some restricted (hook and line only) fishing in the area (Fig. 21). The no-take area (NTA) created, would provide a sanctuary for commercially important fish species to begin to repopulate the area. By allowing fish and invertebrates to grow to larger sizes within MPA they would produce more offspring and replenish fish stocks faster than an MR. Demarcation buoys should be established to clearly indicate the MPA's boundaries (Table 3).

Through further analysis of spatial data and survey location (Fig. 21), it is plausible to assume that some or all of transects were undertaken outside of the Barangay's official waters, possibly within the official coastal boundary of Barangay Lungsodan. As such, it is recommended that CCC establish a meeting with Dinahugan Barangay Officials to seek clarification on these official boundaries before an MPA is considered. Once clarification has been obtained, following proceedings can be undertaken. However, if it confirmed that surveys were undertaken outside of Barangay Dinahugan's boundaries then contact must be made with Barangay Lungsodan immediately.

Due to the results obtained for CoTs densities, it is highly recommended that CCC return to the surveyed area and conduct further surveys focusing on the abundance of CoTs and the composition of hard coral. If further data indicate an outbreak then immediate action must be taken to remove the CoTs from the reef.

A recent study by Edgar et al. (2014) argues that the effectiveness of MPAs relies on five criteria: that they should be no-take zones and well enforced, that they should be both large and old (>10 years), and that they should be isolated by deep water or sand. This is an ideal, but something that should be considered in the process of setting up an MPA within the waters of Barangay Dinahugan. MPAs throughout the Philippines are characteristically small and this size restriction will dictate the length of time it takes stocks to recover. Local fishers must be considered and it is unreasonable to suggest the designation of large MPAs restricting a substantial, if not all, of the local user group's fishing grounds. By zoning the area, allowing some restricted level of fishing in buffer zones surrounding the MPA local fishers can continue to benefit from subsistence fishing whilst allowing their reef to recover for future generations.

Edgar et al. (2014) further state that successful MPAs should be old and is something that needs to be considered

Table 3. Boundary coordinates for the proposed Marine Protected Area (MPA) in Barangay Dinahugan given in Universal Transverse Mercator (UTM). The boundary points indicate specific locations of recommended demarcation buoys and highlight specific areas within the MPA; No-Take Area (NTA); and Marine Reserve (MR).

Buoy	Easting (UTM)	Northing (UTM)	MPA component
A	721762.378	1113821.292	NTA
B	721810.910	1113816.266	NTA
C	721827.136	1114067.687	NTA
D	721809.618	1114315.376	NTA
E	721741.791	1114313.563	NTA
a	721747.463	1113773.513	MR
b	721857.092	1113758.077	MR
c	721877.194	1114069.949	MR
d	721857.522	1114366.313	MR
e	721741.073	1114364.877	MR
Total Area (ha)			7.11
NTA (ha)			3.40
MR (ha)			3.71



Figure 21. Proposed boundary locations for a No-Take Area (NTA) and Marine Reserve (MR) for the Barangay Dinahugan, Municipality Padre Burgos. The proposed constitutes to a Marine Protected Area (MPA). Pink/red area = 50m buffer zone (MR). Yellow/orange area = NTA. Demarcation buoy locations are highlighted by white squares and sequentially labelled. Lowercase labels refer to those that mark the boundary of the MR

when setting up this reserve. Response times can be slow and it may be a number of years before fishers see the benefits of a no-take zone. To ensure this is understood and realistic expectations are set, a consultation and presentation of data is recommended to inform the local barangay of the health of their reef and expected timeframe of results if an MPA is created. Engaging with the community and creating outreach events to disseminate data have proved to be key for the success of MPAs and to gain the support of the local community, which are the direct beneficiaries. Furthermore, education through these community events, can help address the anthropogenic impacts that put pressure on both, the marine environment and the terrestrial environment.

Perhaps the most important criterion ensuring the success of an MPA is that it is well enforced. If an MPA is designated

without full-compliance and support by stakeholders, the process becomes redundant and further degradation will occur. Even minimal instances of poaching (whether intentional or accidental) inside an MPA can destroy years of recovery in a relatively short period of time (McCook *et al.*, 2010). For this, CCC advise the creation of a management committee to oversee the effective running of the MPA. The committee would coordinate the collection of MPA fees for possible dive and snorkel sites, provide training and support to Bantay Dagats, oversee the enforcement of the MPA and be a link to the Municipal Government for matters concerning the MPA. It will be important for the management committee to establish goals and objectives for the MPA based on the criteria of species protection, fisheries and tourism. Reviewing these objectives will help inform management decisions. CCC can offer support throughout this process, and can assist in training local Bantay

Dagats at the request of Barangay Dinahugan.

All recommendations are flexible and the final designation will be the result of a collaboration of CCC with the Municipality of Padre Burgos and the local community of Dinahugan, in particular, the local fisherfolk. CCC provide suggestions on what is the ecological ideal, but understand that there are other factors to consider during the decision-making process. As such, the scenarios outlined here should be used as the initial step in opening a dialogue between all relevant stakeholders in order to come to the best possible conclusion for all parties. Combining an ecosystem approach to fisheries (EAF) and community-based management (CBM), empowering the local user group level and conferring high levels of transparency in a triangulated consortium, CCC aims to facilitate the local Barangay Dinahugan in achieving measurable levels of effectiveness from their designated MPA. By establishing clear, community driven objectives and goals during the formation of the Dinahugan MPA, CCC hopes to address the key challenge to successful MPAs by ensuring that the MPA's by-laws, policies and restrictions fit into the greater ecological, social and economic context, contextualising not only the needs for the fauna and flora present within its boundaries but the needs of the local stakeholders and that of the municipality under the Republic Act No. 8550.

Extensive consultation will be essential within the local community to enable compliance with the MPA. The livelihoods of many local fishers may be affected by the designation of an MPA so their agreement is essential to its success. Many studies (e.g. Pollnac *et al.*, 2001) from existing MPAs have shown that without the involvement of the local community the effectiveness of a MPA is greatly reduced. If individuals from the community are involved in the planning processes they will

have a vested interest in the effective running and management of the MPA. If an MPA is declared, an awareness campaign is essential to ensure that everyone is aware of the new MPA, its extent and the rules that they will be expected to follow. CCC can help at all levels of this process by providing educational support to the community with information on how and why MPA can be successful.

Support for the establishment of an MPA is available from both Municipal and Provincial government levels. It will be important to secure funding from the outset to aid in the establishment of the MPA. Demarcation buoys, signage and an easily decipherable MPA map are essential tools for raising awareness and promoting enforcement. Securing sustainable financing will help to secure the long-term future and success of an MPA.

If, after detailed consultation and evaluation, an MPA is designated in Dinahugan, it will be important to ensure that monitoring of the MPA is conducted on a regular basis. The MPA Management Effectiveness Assessment Tool (MPA MEAT) is a national government programme designed to enable MPA managers to assess the effectiveness of their MPA. It uses detailed questionnaires and documentation to highlight limitations of MPA management and also suggests ways to improve it. CCC can provide further support by conducting MPA assessments to provide the biophysical data required by the MPA MEAT. CCC can also provide training to allow the barangay to develop their own MPA monitoring team. Overall the future of a protected area in Dinahugan should be reviewed with consultation between all stakeholders involved. The site would greatly benefit from protection but this should only be established with the support of the local community and with management and monitoring coming from both Barangay and Municipal levels.

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Appendices

Appendix A

Table A1. List of target fish families, genera and species recorded during Coral Cay Conservation (CCC) surveys of the Barangay Dinahugan.

Common Name	Latin Name	Visayan Name
Angelfish	<i>Pomacanthidae</i>	Adlo
Barracuda	<i>Sphyrnaeidae</i>	
(Butterflyfish)	<i>Chaetodontidae</i>	Alibangbang
(Big) Longnose Butterflyfish	<i>Forcipiger flavissimus</i>	
Eastern Triangle Butterflyfish	<i>Chaetodon baronessa</i>	
Humphead Bannerfish	<i>Heniochus varius</i>	
Kleins Butterflyfish	<i>Chaetodon kleinii</i>	
Raccoon Butterflyfish	<i>Chaetodon lunula</i>	
Redfin Butterflyfish	<i>Chaetodon lunulatus</i>	
Vagabond Butterflyfish	<i>Chaetodon vagabundus</i>	
Cardinalfish	<i>Apogonidae</i>	
(Damsel fish)	<i>(Pomacentridae)</i>	
Anemonefish	<i>Amphiprion sp.</i>	
Sergeant Damsel fish	<i>Pomacentridae</i>	
Emperor	<i>Lethrinidae</i>	Katambak
Fusilier	<i>Caesionidae</i>	Dalagangbukid
Goatfish	<i>Mullidae</i>	Timbongan
Groupers	<i>Serranidae</i>	Lapu-lapu
Jack/Trevally	<i>Carangidae</i>	Talakitok
Lionfish	<i>Scorpaenidae</i>	
Lizardfish	<i>Synodontidae</i>	
Moorish Idol	<i>Zanclus cornutus</i>	Sanggowanding
Moray Eel	<i>Muraenidae</i>	
Parrotfish	<i>Scaridae</i>	Mulmul
Pufferfish	<i>Tetraodontidae</i>	
Rabbitfish	<i>Siganidae</i>	Kitong
Ray	<i>Rajiformes</i>	
Sandperch	<i>Pinguipedidae</i>	
Scorpionfish/Stonefish	<i>Scorpaenidae</i>	
Snapper	<i>Lutjanidae</i>	Maya-maya
Spinecheeks	<i>Nemipteridae</i>	Silay
Squirrelfish/Soldierfish	<i>Holocentridae</i>	
Surgeonfish	<i>Acanthuridae</i>	Indangan
Unicornfish	<i>Naso sp.</i>	
Sweetlips	<i>Haemulidae</i>	Lipti
Toby	<i>Tetraodontidae</i>	
Triggerfish	<i>Balistidae</i>	Pakol
(Wrasse)	<i>(Labridae)</i>	
Crescent Wrasse	<i>Thalassoma lunare</i>	
Humphead Wrasse	<i>Cheilinus undulatus</i>	
Red Breasted Wrasse	<i>Cheilinus fasciatus</i>	

Table A2. List of target Invertebrate families, Genera and species recorded during Coral Cay Conservation (CCC) surveys of the Barangay Dinahugan.

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
Other sea cucumber		

Table A3. List of target substrates recorded during Coral Cay Conservation (CCC) surveys of the Barangay Dinahugan.

Substrate		
Soft Coral (SC)	Sponge (SP)	Recently killed coral (RKC)
Rock (RC)	Silt/mud (SI)	Rubble (RB)
Sand (SD)	Nutrient indicator algae (NIA)	Other* (OT)
Hard Coral (HC)		
Hard Coral (HC) 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		

Appendix B

	O01	O02	O03	O04	O05	O06
O01						-
O02						
O03						
O04						
O05						-
O06	+				+	

Figure B1. Matrix showing significant differences in mean fish abundance per 500m³ across the survey site in Dinahugan. A green '+' indicates abundance was significantly higher at the surveyed transect on the left compared to transect at the top ($p < 0.05$). A blue '-' indicates that abundance was significantly lower at the transect on the left compared to transect at the top ($p < 0.05$). Blank cells indicate no significant difference.

	O01	O02	O03	O04	O05	O06
O01						
O02						
O03						
O04						
O05						+
O06					-	

Figure B2. Matrix showing significant differences in Pielou's evenness (J) per 500m³ across the survey site in Dinahugan. A green '+' indicates abundance was significantly higher at the surveyed transect on the left compared to transect at the top ($p < 0.05$). A blue '-' indicates that abundance was significantly lower at the transect on the left compared to transect at the top ($p < 0.05$). Blank cells indicate no significant difference.

	O01	O02	O03	O04	O05	O06
O01						-
O02						-
O03						
O04						
O05						
O06	+	+				

Figure B3. Matrix showing significant differences in Mean total commercial fish abundance per 500m³ across the survey site in Dinahugan. A green '+' indicates abundance was significantly higher at the surveyed transect on the left compared to transect at the top ($p < 0.05$). A blue '-' indicates that abundance was significantly lower at the transect on the left compared to transect at the top ($p < 0.05$). Blank cells indicate no significant difference.

	O01	O02	O03	O04	O05	O06
O01						
O02						-
O03						
O04						
O05						
O06		+				

Figure B4. Matrix showing significant differences in Parrotfish abundance per 500m³ across survey sites in Dinahugan. Grouper and Snappers didn't show any significant differences. A green '+' indicates abundance was significantly higher at the surveyed transect on the left compared to transect at the top ($p = <0.05$). A blue '-' indicates that abundance was significantly lower at the transect on the left compared to transect at the top ($p = <0.05$). Blank cells indicate no significant difference.

	O01	O02	O03	O04	O05	O06
O01						-
O02						-
O03						-
O04						
O05						-
O06	+	+	+		+	

Figure B5. Matrix showing significant differences in Parrotfish mean biomass per 500m³ across survey sites in Dinahugan. Grouper and Snappers didn't show any significant differences. A green '+' indicates abundance was significantly higher at the surveyed transect on the left compared to transect at the top ($p = <0.05$). A blue '-' indicates that abundance was significantly lower at the transect on the left compared to transect at the top ($p = <0.05$). Blank cells indicate no significant difference.

	O01	O02	O03	O04	O05	O06
O01						+
O02						
O03						
O04						
O05						
O06	-					

Figure B6. Matrix showing significant differences in mean total butterflyfish abundance per 500m³ across all survey sites, in Dinahugan. A green '+' indicates abundance was significantly higher at the surveyed transect on the left compared to transect at the top ($p = <0.05$). A blue '-' indicates that abundance was significantly lower at the transect on the left compared to transect at the top ($p = <0.05$). Blank cells indicate no significant difference.

	O01	O02	O03	O04	O05	O06
O01			+			+
O02						
O03	-					
O04						
O05						
O06	-					

Figure B7. Matrix showing significant differences in butterflyfish species richness per 500m³ across survey sites in Dinahagan proposed area. Pielou's evenness and Shannon's Diversity Index are not pictured as they showed no significant differences. A green '+' indicates abundance was significantly higher at the surveyed transect on the left compared to transect at the top ($p < 0.05$). A blue '-' indicates that abundance was significantly lower at the transect on the left compared to transect at the top ($p < 0.05$). Blank cells indicate no significant difference.

	O01	O02	O03	O04	O05	O06
O01						+
O02						
O03	-					
O04						
O05						
O06						

Figure B8. Matrix showing significant differences on mean obligate corallivore butterflyfish per 500m³ across survey sites in Dinahagan proposed area. A green '+' indicates abundance was significantly higher at the surveyed transect on the left compared to transect at the top ($p < 0.05$). A blue '-' indicates that abundance was significantly lower at the transect on the left compared to transect at the top ($p < 0.05$). Blank cells indicate no significant difference.

a)

	O01	O02	O03	O04	O05	O06
O01						
O02						+
O03						
O04						
O05						
O06		-				

b)

	O01	O02	O03	O04	O05	O06
O01				+		+
O02				+		+
O03						+
O04	-	-				
O05						
O06	-	-	-			

c)

	O01	O02	O03	O04	O05	O06
O01						+
O02						+
O03						+
O04						
O05						
O06	-	-	-			

Figure B9. Matrix showing significant differences in invertebrate species richness (a), Shannon's Diversity Index (b) and Pielou's evenness (c) per 100m² across all transects in Dinahagan. A green '+' indicates abundance was significantly higher at the surveyed transect on the left compared to transect at the top ($p < 0.05$). A blue '-' indicates that abundance was significantly lower at the transect on the left compared to transect at the top ($p < 0.05$). Blank cells indicate no significant difference.

a)

	O01	O02	O03	O04	O05	O06
O01				-		-
O02						
O03						
O04	+					
O05						
O06	+					

b)

	O01	O02	O03	O04	O05	O06
O01					-	
O02						
O03						
O04						
O05	+					+
O06					-	

Figure B10. Matrix showing significant differences in substrate abundance per 20m across all transects in Dinahugan. Substrate category: a) Sand, b) Nutrient Indicator Algae. Substrate categories not listed showed no significant differences across transects. A green '+' indicates abundance was significantly higher at the surveyed transect on the left compared to transect at the top ($p < 0.05$). A blue '-' indicates that abundance was significantly lower at the transect on the left compared to transect at the top ($p < 0.05$). Blank cells indicate no significant difference.

Appendix C

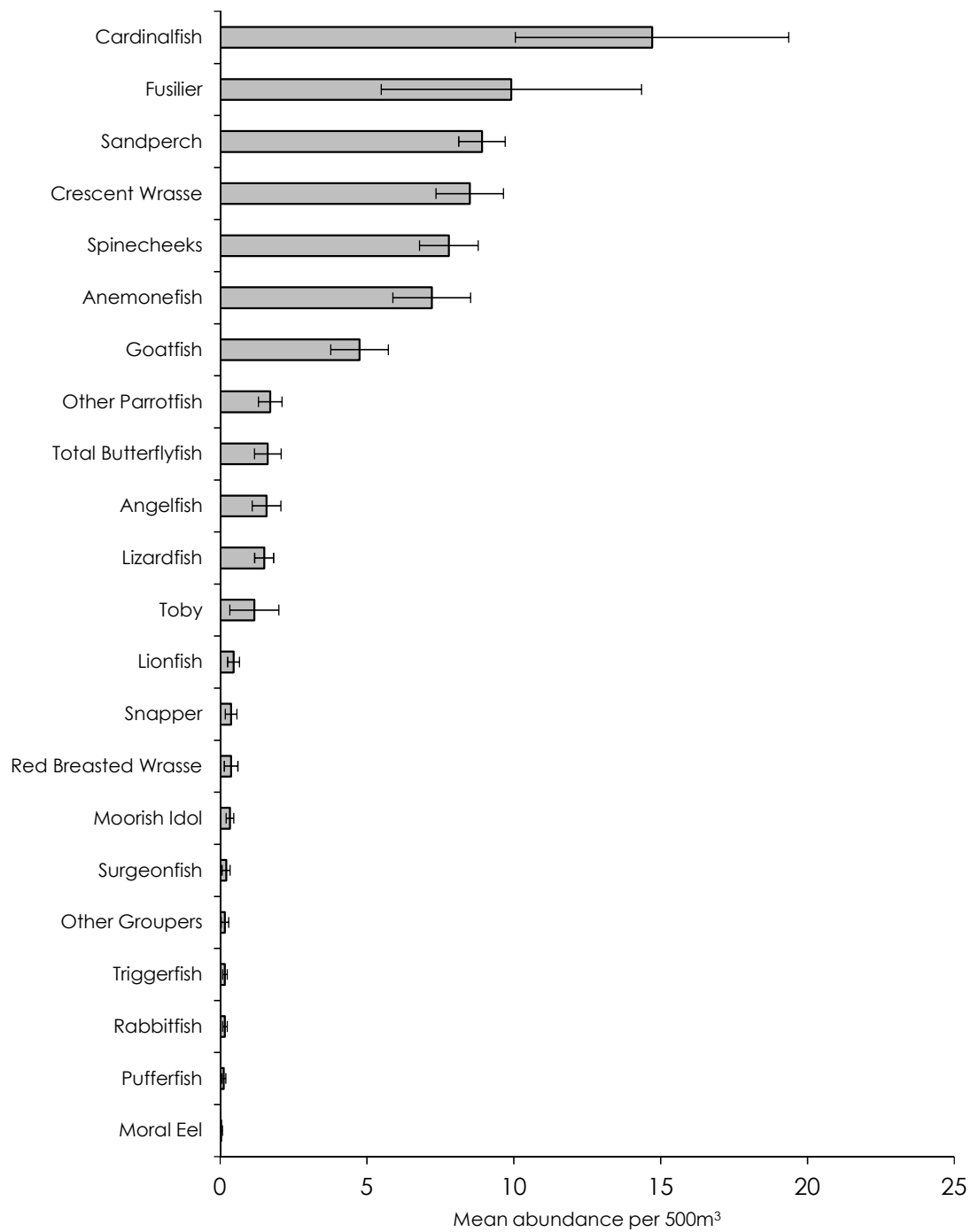


Figure C1. Mean abundance of target fish species and families with standard error (SE) for Dinahugan, Southern Leyte, the Philippines. Grey = inside MPA transects, White = outside MPA transects.



Figure C2. Mean abundance of target invertebrate species and families with standard error (SE) for Dinahugan Proposed area, Southern Leyte, the Philippines.

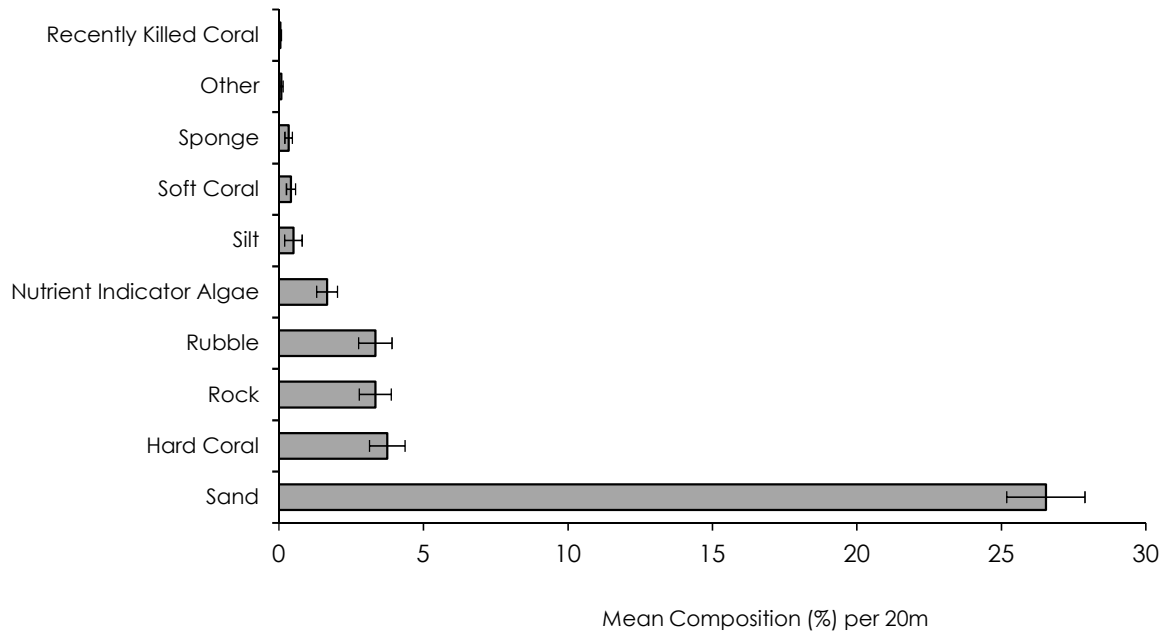


Figure C3. Mean composition (%) substrates per 20m with standard error (SE) for Dinahugan, Southern Leyte, Philippines.

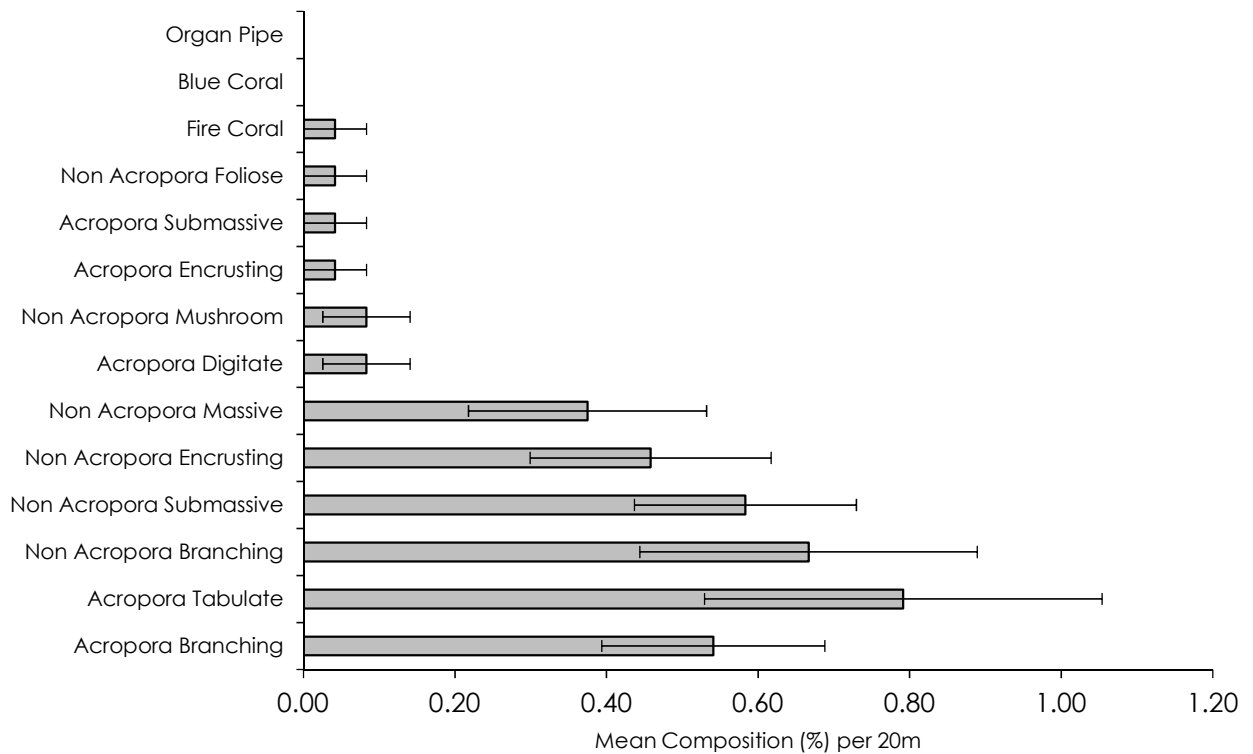


Figure C4. Mean composition (%) of coral lifeforms with standard error (SE) across transects in Dinahugan, Southern Leyte, the Philippines.