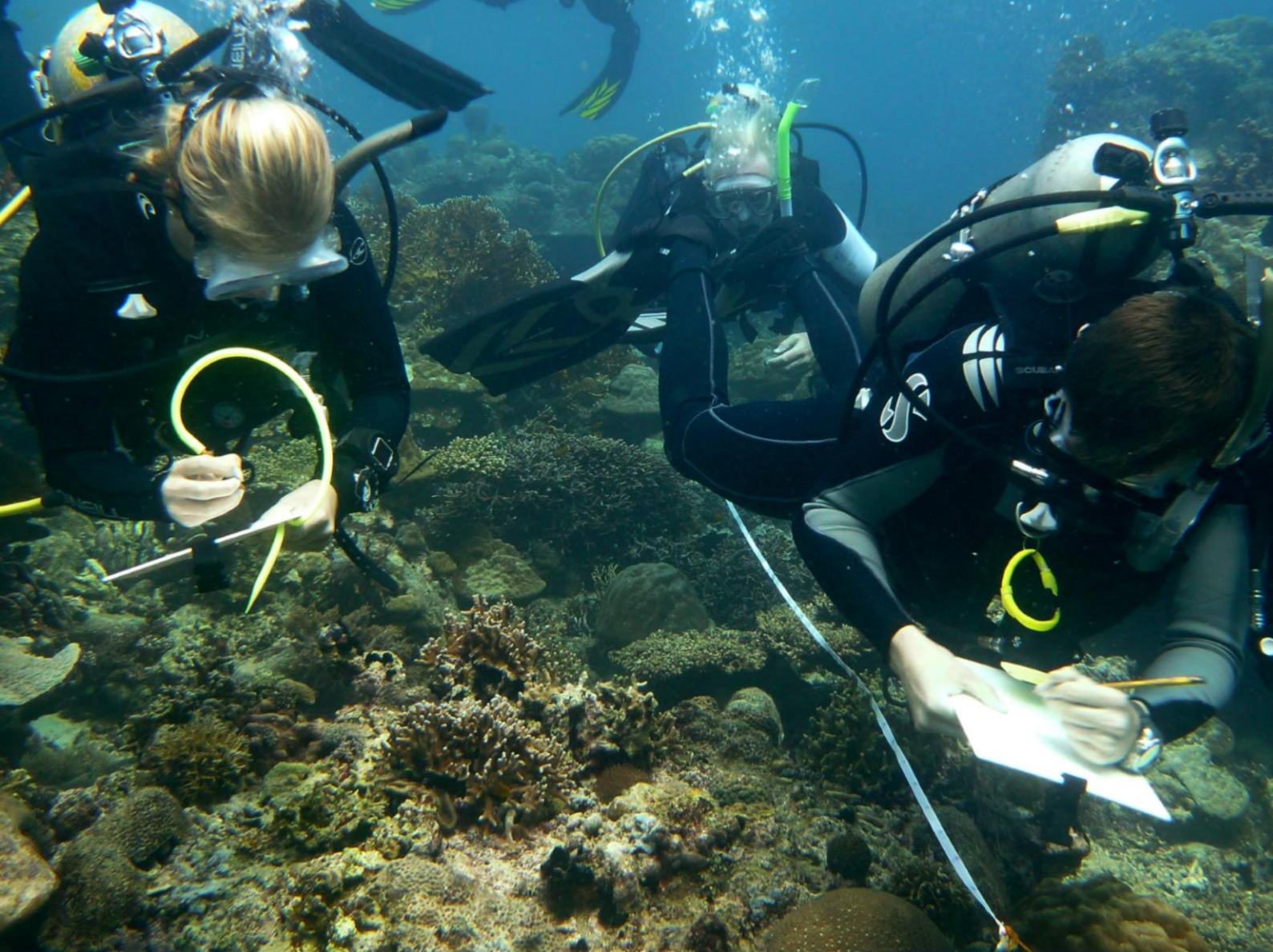




LRCRP
Southern Leyte Coral Reef Conservation Project

Coral Cay Conservation Proposed Marine Protected Area Report: Barangay Cabulihan 2017

Report Date: October 2018



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In partnership with the Southern Leyte
Provincial Government, Philippines





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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 Barangay Cabulihan, Limasawa in February and March 2017.
- At the request of Armando Gaviola of PENRMO, and after consulting the Barangay Captain in Cabulihan, CCC conducted Underwater Visual Census (UVC) protocols. An enhanced Reef Check methodology was used to survey six 100m transects each containing four 20m replicates.
- Average fish abundance was $N = 48.96 \pm 5.12$ per 500m³ with transect O01 obtaining the greatest average abundance. Significance was seen in both Shannon's Diversity Index (H') and Pielou's Evenness (J'), with transect O02 displaying a lower Species Richness over transects O04 and O05 and transect O04 displaying more evenness over transects O01 and O02.
- Low abundance ($N = 2.46 \pm 0.89$ per 500m³) and small size (<30cm) of commercially important fishes, as well as the absence of both Snappers and commercially important invertebrates, 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.
- Average Butterflyfish abundance was greater ($N = 2.63 \pm 0.47$ per 500m³) in comparison to Limasawa Triana (surveyed in 2016), however lower when considering San Augustin (2013) (where an MPA is established), suggesting that the coral cover is sufficient to support populations of Butterflyfish though could be significantly improved through protection. Obligate corallivorous butterflyfish were more abundant ($N = 1.46 \pm 0.17$ per 500m³) in comparison to their facultative counterparts ($N = 1.04 \pm 0.06$ per 500m³).
- The average abundance of invertebrates ($N = 67.67 \pm 6.89$ per 100m²) was found to be lower in comparison to other surveyed reefs located on Limasawa (Triana and Sa Augustin). Many commercially important species of invertebrates were absent from surveys suggesting intensive historic harvesting.
- The dominating substrate was rock ($37.08 \pm 3.10\%$) followed by hard coral ($23.54 \pm 3.57\%$) and sand ($18.33 \pm 5.17\%$). The presence of exposed rocky substrate shows potential future coral recruitment in the area. Overall bleaching, recently killed coral and coral diseases were low.
- Results from the Barangay Cabulihan, Limasawa proposed Marine Protected Area (MPA) site indicates that the surveyed reef is in a capable position of supporting more diverse reef structure and community assemblages if assigned a MPA status. Its location will largely assist in creating a connective network between other established MPAs within Sogod Bay, allowing the protection and recovery of species with large dispersal and geographic ranges.

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List of Acronyms and Abbreviations

CBM	: Community-based Management
CC	: Competitor Corals
CCC	: Coral Cay Conservation
CoTs	: Crown of Thorns Seastars (<i>Acanthaster planci</i>)
EAF	: Ecosystem Approach to Fisheries
FGC	: Fast Growing Corals
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
SE	: Standard Error ($\pm$)
SST	: Sea Surface Temperature ($^{\circ}\text{C}$)
STC	: Stress Tolerant Corals
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 Provincial Government of Southern Leyte (PGSL) invited CCC 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 *et al.*, 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 (TWB, 2005).

To assess the beneficial impact of an MPA, resource managers often seek to measure its respective effectiveness. Effectiveness can be measured by assessing a range of factors, most commonly addressing 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), 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 *et al.* (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 occur 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. Levels of exploitation of the fauna within the MR considering various species, size, biomass and life-stage classes are all at the discretion of the by-laws set during the planning stage of the MR. 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 that 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 (Poltnac *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 the 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).

1.2 Coral Reefs and Marine Conservation in the Philippines

The Philippines lie 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 most biodiverse 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, Burke *et al.*, 2012). The same extraordinary diversity is also found in other types of marine organisms; with over 3,000 species of fish recorded and even higher figures for molluscs, with new species still being discovered (Allen, 2008).

The waters of the Philippines contain roughly 26,000 km² of coral reefs (Burke *et al.* 2012). In 2012, it was estimated that 60% of the 98 million citizens lived within proximity to coral reefs, and fish accounted for 70% of the consumed animal protein (ADB, 2014). 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

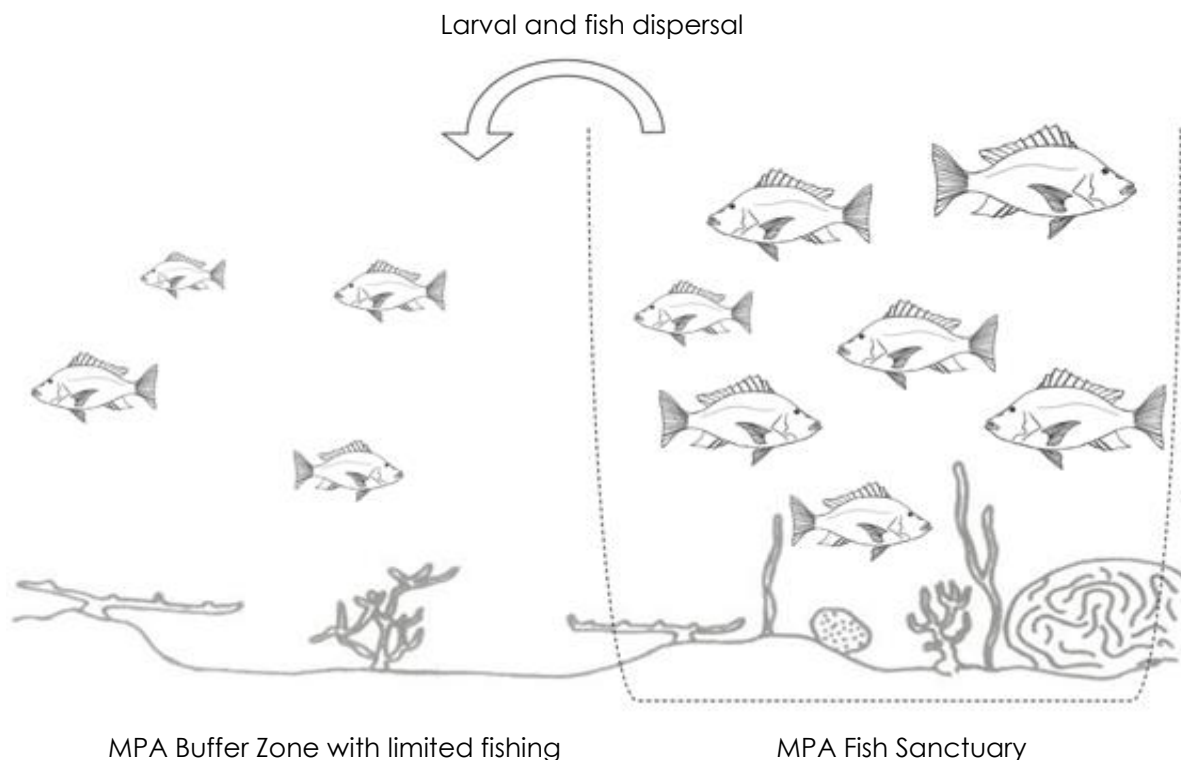


Figure 1. Schematic diagram of MPA functioning. Protected fish within the MPA fish sanctuary grow and produce offspring. This leads to 'overspill', increasing fish numbers inside and outside of the MPA. In addition, the corals inside the MPA are not disturbed by destructive fishing methods.

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 surveying 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 an average 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 Cabulihan

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 Cabulihan located on Limasawa Municipality, on the western side of Limasawa Island. The Barangay has a population of approximately 810 people, all of which live within close proximity to the coastline.

Due to its geographical location, the reefs of Cabulihan are sheltered from the prevailing trade winds coming across the pacific. However, during the monsoon season of Habagat (June-October), southwest winds leave the western coast of Limasawa exposed to moderate to high wave action. The site was also heavily impacted by the recent typhoons, Yolanda and Queenie.

2.0 Methodology and Data Collection

2.1 Survey Sites

CCC's assessment of the proposed MPA site at Cabulihan was conducted between February 24th and March 16th, 2017, by trained volunteer survey teams (Fig. 2). The weather was sunny during this time with no major weather systems moving through the region. Average air temperature during surveys was 26.8°C and Sea Surface Temperature (SST) was 25.8°C. The average water temperature at 3m and at survey depth did not vary from SST with both having an average

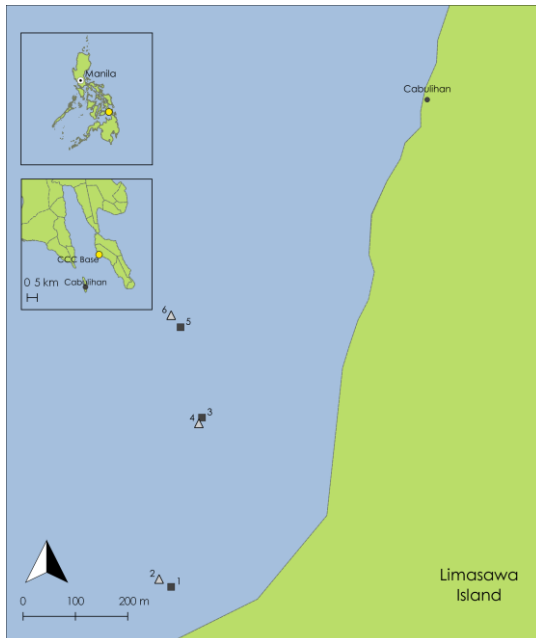


Figure 2. The Philippines (top), Southern Leyte (bottom) in relation to Coral Cay Conservation (CCC) base (yellow) within Barangay Napantao. Six transects were completed within the coastal waters of Barangay Cabulihan (black) at depths of 6m (purple) and 12m (pink). Each transect is sequentially labelled.

temperature of 25.8°C. The average estimated horizontal visibility throughout the survey was 17.5m.

From discussion with the Barangay Officials, although the site does not have a close proximity to a river mouth, siltation can occasionally be an issue during periods of heavy rainfall. Suspended sediments in the water can inhibit the

ability for sunlight to penetrate through coral tissue, restricting coral growth.

As the proposed area is within close proximity to the Barangay, human activities are observed within the area. The main form of this anthropogenic impact is the harvest of invertebrates for food which is classed as 'medium' and artisanal/recreational fishing alongside the harvest of invertebrate for curio sales which are 'low'. In addition, the area is frequented by tourists for diving and snorkelling. However, this impact is classed as 'low', while the overall anthropogenic impact at the site is also 'low'.

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 Liebel 2002). It was developed in 1996 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. 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 Cabulihan (Limasawa), Southern Leyte, the Philippines.

Transect Number	Depth (m)	Easting (UTM)	Northing (UTM)
O01	12	726793	1096211
O02	6	726770	1096226
O03	12	726852	1096535
O04	6	726846	1096524
O05	6	726811	1096708
O06	12	726273	1096731

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 was 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):

(1)

$$W = aL^b$$

Equation 1. Length-weight relationships were used to determine the biomass (kg) of each individual recorded on BarangayCabulihan 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 average 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 average determined for the allometric LWR coefficients. To establish the overall allometric coefficient values for the family, the geometric average 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 averages 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 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

Table 2. The calculated Length-Weight allometric coefficients to determine the biomass (kg) of sized Grouper, Snapper and Parrotfish within Cabulihan 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

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).

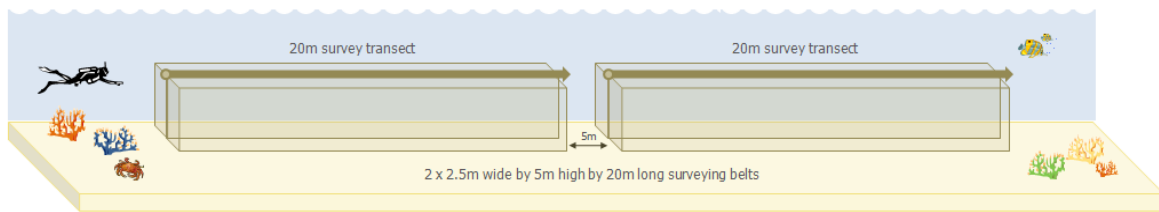


Figure 3. The augmented Reef Check methodology conducted for the assessment of the diversity and abundance of fishes within Barangay Cabulihan. Each conducted transect is separated into 4 x 20m replicates segmented by 5m inter-replicate gaps.

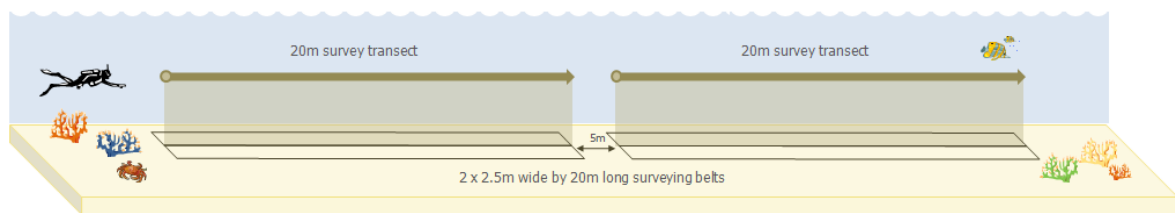


Figure 4. The augmented Reef Check methodology conducted for the assessment of the diversity and abundance of invertebrates within Barangay Cabulihan. Each conducted transect is separated into 4 x 20m replicates segmented by 5m inter-replicate gaps.

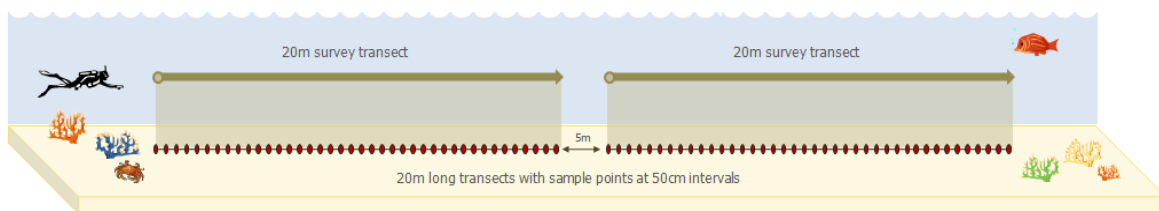


Figure 5. The undertaken point intercept methodology conducted for the assessment of benthic composition within Barangay Cabulihan. Each conducted transect is separated into 4 x 20m replicates segmented by 5m inter-replicate gaps with the respective benthic substrate recorded at 0.5m intervals. The presented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

3.0 Results

3.1 Fishes

The average fish abundance was $N = 48.96 \pm 5.12$ per 500m³ with transect O01 obtaining the greatest total abundance ($N = 120$) and average abundance of $N = 30 \pm 8.82$ per 500m³ replicate (Fig. 6). Transect O01 had a significantly greater ($p = <0.05$) average fish abundance than both transects O03 and O04 (Fig. B1). Fish species richness (S'), Shannon's Index (H') and Pielou's Evenness (J') were calculated for all transects (Fig. 7).

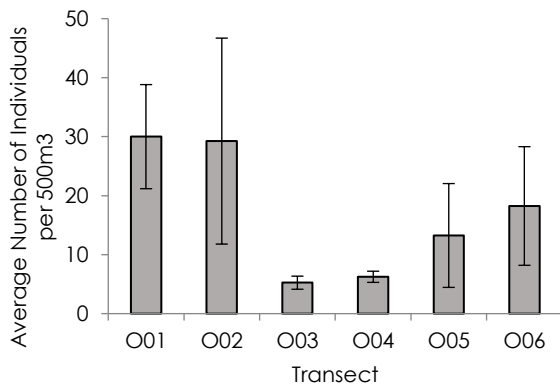


Figure 6. Average fish abundance per 500m³ with standard error ($\pm$ SE) across transects in Cabulihan, Limasawa, the Philippines

The average fish S between all transects was $S' = 10.25 \pm 0.49$ per 500m³ with no significant differences found between transects. Average H' between all transects was $H' = 1.88 \pm 0.07$ per 500m³, with transect O02 having a significantly lower ($p = <0.05$) H' than transects O04 and O06 (Fig. B2a). With regards to evenness, the average between all transects was $J' = 0.82 \pm 0.02$ per 500m³ with transect O04 having a significantly greater ($p = <0.05$) J' than transects O01 and O02 (Fig B2b).

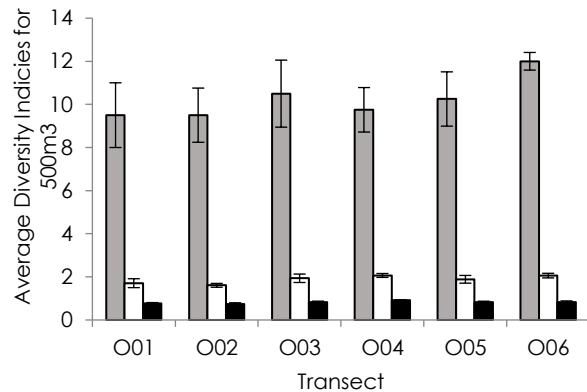


Figure 7. Average fish Species Richness (S , grey), diversity (Shannon's H' Diversity Index, white), and evenness (Pielou's evenness J' , black) per 500m³ with standard error ($\pm$ SE) between transects in Cabulihan, Limasawa, the Philippines.

3.1.1 Commercially important Fishes

Snapper, Parrotfish and Groupers are classed as commercially important fishes. The average commercial fish abundance was $N = 2.46 \pm 0.89$ per 500m³, with transect O02 showing the highest average abundance of commercially important species ($N = 5.25 \pm 4.92$ per 500m³), likely influenced by a large school of 20 Parrotfish (Fig 8). Parrotfish were the most abundant with 50 individuals recorded compared to the 9 Groupers and null Snappers throughout the survey.

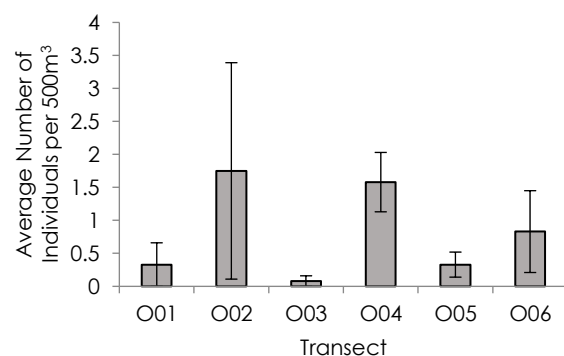


Figure 8. Average total abundance of commercially important fish species observed per 500m³ with standard error ($\pm$ SE) across all transects in Cabulihan, Limasawa, the Philippines.

The average Parrotfish and Grouper abundances per 500m³ were $N = 2.08 \pm 0.88$ and $N = 0.38 \pm 0.18$ respectively. Parrotfish were the dominant species recorded in all transects with the exception of transect O01 where groupers were in greater abundance (Fig. 9).

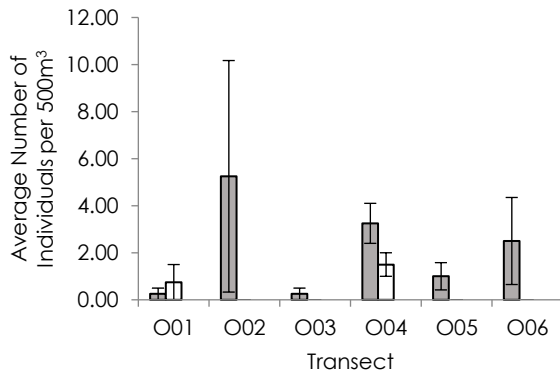


Figure 9. Average abundance of Parrotfish (grey), Grouper (white) and Snapper (null) observed per 500m³ with standard error ($\pm$ SE) across all transects in Cabulihan, Limasawa, the Philippines.

The average amalgamated abundance of Parrotfish, Snapper and Grouper observed in the Cabulihan proposed protected area, with regards to size, demonstrated that 85% of the individuals were less than 10cm, 15% were 10-20cm and no individuals were recorded greater than 20cm (Fig. 10).

Of the 50 Parrotfish recorded, 43 were less than 10cm. Within this size category there was a significant difference between transects with significantly more ($p = <0.05$) parrotfish in transect O04 than in transects O01, O03 and O05 (Fig B3). With regards to Groupers, 7 of the 9 individuals recorded measured less than 10cm. Within this size category there were significantly more ($p = <0.05$) Groupers in transect O04 than in transects O02, O03, O05 and O06 (Fig B4). There was no significant difference ($p = >0.05$) in either Parrotfish or Grouper abundance between transects in the 10-20cm size category.

A total 0.69kg of standing biomass was recorded between all transects. Parrotfish

accounted for 81% and Grouper 19% (Fig. 11). The average total commercial fish biomass per 500m³ was 0.03 ± 0.01 (Fig. 12). There was a significant difference for both Parrotfish and Grouper biomass found between the transects. For Parrotfish, transect O04 had a significantly higher ($p = <0.05$) biomass than transects O01 and O03 (Fig. B5). Similarly, with regards to Groupers, transect O04 had a significantly higher ($p = <0.05$) biomass than transects O02, O03 and O05 (Fig. B6).

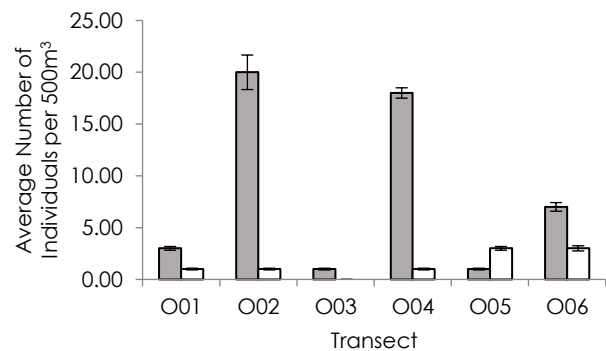


Figure 10. Average abundance of Parrotfish, Grouper and Snapper in the categories 0-10cm (grey), and 11-20cm (white) per 500m³ with standard error ($\pm$ SE) between transects in Cabulihan, Limasawa, the Philippines.

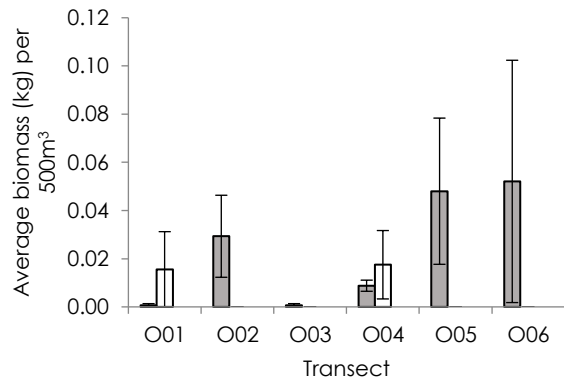


Figure 11. Average commercial fish biomass of Parrotfish, Grouper and Snapper per 500m³ with standard error ($\pm$ SE) between transects in Cabulihan, Limasawa, the Philippines.

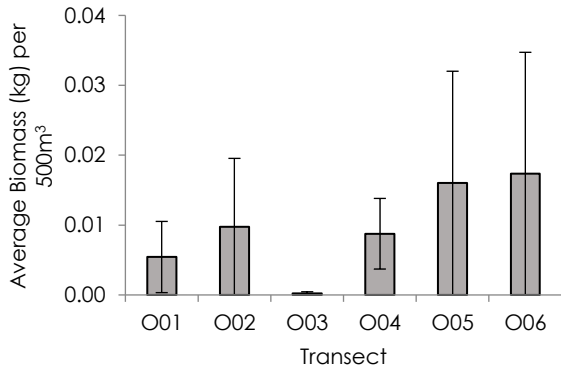


Figure 12. Average total commercial fish biomass per 500m³ with standard error ($\pm$ SE) between transects in Cabulihan, Limasawa, the Philippines.

Other commercially important fish species including *Bolbometapon muricatum* (Bumphead Parrotfish) and *Cromileptes altivelis* (Barrmundi Cod) were completely absent from the survey.

3.1.2 Butterflyfish Diversity and Abundance

The average Butterflyfish abundance per transect was $N = 2.63 \pm 0.47$ per 500m³ (Fig. 13), with transect O06 displaying a significantly higher ($p = <0.05$) abundance of Butterflyfish than transects O01, O02, O03 and O04 (Fig B7) with a total of 21 individuals.

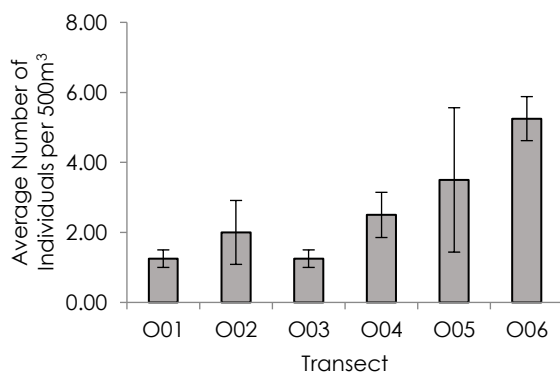


Figure 13. Average total Butterflyfish abundance per 500m³ with standard error ($\pm$ SE) across transects in Cabulihan, Limasawa, the Philippines.

Species richness (S'), Shannon's Diversity Index (H') and Pielou's Evenness (J') were calculated for all transects (Fig 14). The average S' was $S' = 1.33 \pm 0.18$ per 500m³ with transect O06 having a significantly greater ($p = <0.05$) S' than transects O01, O02, O03 and O04 (Fig B8a). The average H' and J' were $H' = 0.27 \pm 0.08$ per 500m³ and $J' = 0.32 \pm 0.09$ per 500m³ respectively. For both H' and J' , transect O06 displayed a significantly greater ($p = <0.05$) value than transects O01, O02 and O03 (Fig B8b and c).

A total of 63 Butterflyfish were recorded, 56% of which were obligate corallivores. The average abundance of obligate corallivore Butterflyfish was $N = 1.46 \pm 0.17$ per 500m³ (Fig. 15) and transect O06 displayed a significantly higher ($p = <0.05$) abundance than transects O01, O03 and O04 (Fig B9a). The average abundance of facultative corallivore Butterflyfish was $N = 1.04 \pm 0.06$ per 500m³ (Fig. 15) with transect O04 having a significantly greater ($p = <0.05$) abundance than transects O01 and O03. Transect O06 also had a significantly higher ($p = <0.05$) abundance than transect O01 (Fig B9b).

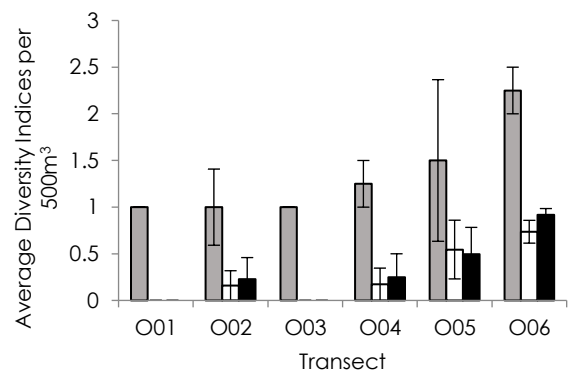


Figure 14. Average butterflyfish Species Richness (S' , grey), diversity (Shannon's H' Diversity Index, white), and evenness (Pielou's evenness J' , black) per 500m³ with standard error ($\pm$ SE) between transects in Cabulihan, Limasawa, the Philippines.

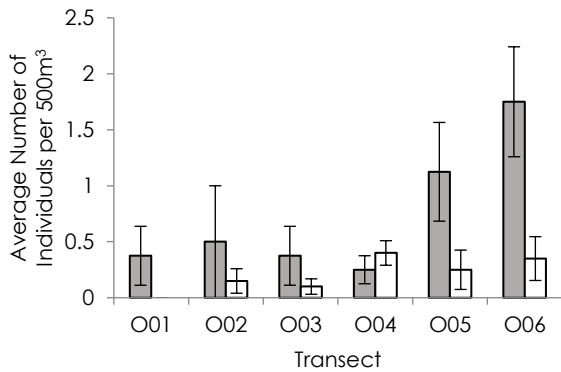


Figure 15. Average obligate (grey) and facultative (white) corallivore Butterflyfish abundances per 500m³ with standard error ($\pm$ SE) across transects in Cabulihan, Limasawa, the Philippines

3.2 Invertebrates

The average invertebrate abundance across all transects was $N = 67.67 \pm 6.89$ per 100m² (Fig. 16) with transect O03 having the highest average per 100m² ($N = 82.5 \pm 24.83$). Significant differences were observed between transects. Transect O02 had a significantly lower ($p = <0.05$) total invertebrate abundance than transects O01, O03, O05 and O06. Additionally, transect O04 had a significantly lower ($p = <0.05$) total invertebrate abundance than transect O06 (Fig B10).

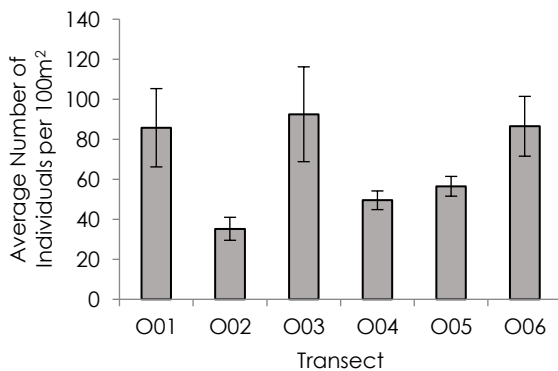


Figure 16. Average invertebrate abundance per 100m² with standard error ($\pm$ SE) across all transects in Cabulihan, Limasawa, the Philippines.

Those invertebrates with the highest abundance were long spine sea urchins ($N = 897$), *Linkia laevigata* ($N = 176$) and feather stars ($N = 114$).

Species richness (S'), Shannon's Diversity Index (H') and Pielou's Evenness (J') were calculated for all transects (Fig. 17). The average S' between all transects was $S' = 8.13 \pm 0.43$ per 100m² with transect O03 having a significantly lower ($p = <0.05$) S' than transect O01 and O02, in addition to transect O05 having a significantly lower S' than transect O02 (Fig B11a). The average H' and J' were $H' = 1.41 \pm 0.11$ per 100m² and $J' = 0.67 \pm 0.04$ per 100m², respectively. For both H' and J' , transect O03 had a significantly lower ($p = <0.05$) value than all other transects (Fig B11b and c). In addition, transect O02 had a significantly higher ($p = <0.05$) value for both H' and J' when compared to other transects. For H' transect O02 had a significantly higher ($p = <0.05$) H' than transect O05 and for J' transect O02 had a significantly higher ($p = <0.05$) J' than transects O04, O05 and O06.

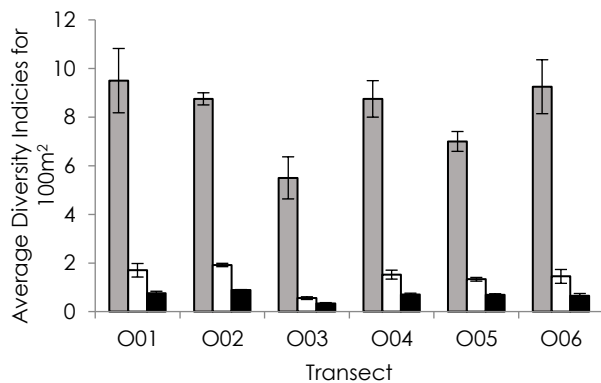


Figure 17. Average invertebrate Species Richness (S' , grey), diversity (Shannon's Diversity H' Index, white) and evenness (Pielou's Evenness J' , black) per 100m² with standard error ($\pm$ SE) across transects in Cabulihan, Limasawa, the Philippines.

Commercially important invertebrate species including lobster (*Nephropidae*), squid (*Teuthida*), prickly redfish sea cucumber (*Thelonota ananas*), greenfish sea cucumber (*Stichopus chloronotus*), pinkfish sea cucumber (*Holothuria edulis*) and triton trumpet (*Charonia tritonis*) were absent from the survey.

19 giant clams were recorded in total, 12 of which measured under 10cm. The remaining individuals measured between 11-20cm ($N = 4$) and 21-30cm ($N = 3$), no giant clams of 31cm and above were recorded. 3 Crown-of-Thorns Seastars (*Acanthaster planci*) were recorded within the survey area.

3.3 Benthic Substratum Composition

The most common substrate recorded was rock, with an average percentage cover of $37.08 \pm 3.10\%$. This was followed by hard coral ($23.54 \pm 3.57\%$) and sand ($18.33 \pm 5.17\%$) (Fig. 18).

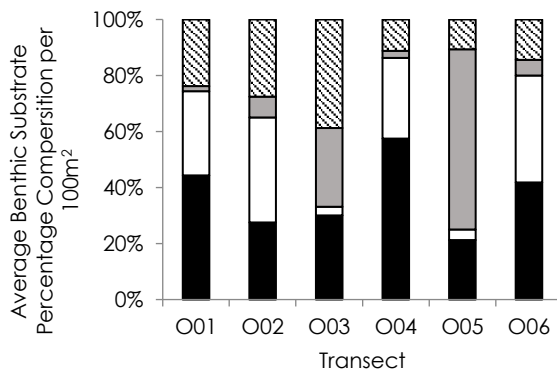


Figure 18. Average percentage cover (%) per 20m for rock (black), hard coral (white), sand (grey) and other substrates (diagonal lines) across transects in Cabulihan, Limasawa, the Philippines.

Within these substrate categories there was a significant difference between transects. With regards to rock, there was a significantly higher ($p = <0.05$) abundance in transect O04 than in transects O02, O03, O05 and O06. Transect O06 also showed a significantly higher ($p = <0.05$) occurrence of rock than transects O02 and O05 (Fig. B12a). Looking at hard coral, transect O03 and O05 have a significantly lower ($p = <0.05$) occurrence than all other transects (Fig. B12b). With regards to sand, transect O05 had a significantly higher ($p = <0.05$) occurrence of sand than all other transects. Additionally, transect O03 had a significantly higher ($p = <0.05$) occurrence than transects O04 and O06. (Fig. B12c). When considering hard coral lifeforms, Non-Acropora sub-massive (CS) had the greatest coverage at $24.98 \pm 5.08\%$, followed by Non-Acropora massive (CM) ($22.10 \pm 5.68\%$) and Non-Acropora encrusting (CE) ($18.07 \pm$

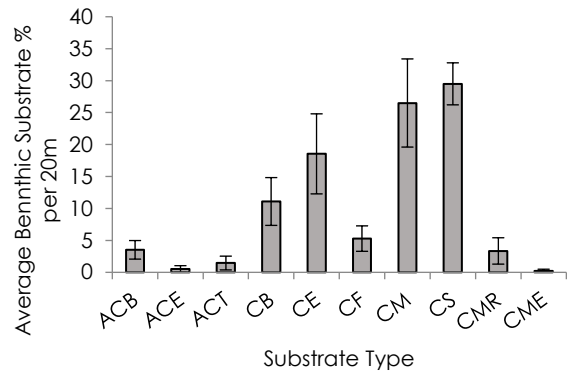


Figure 19. Average percentage substrate type per 20m with standard error ($\pm SE$) by classification across transects in Cabulihan, Limasawa, the Philippines

4.07%) (Fig. 19). Both Non-Acropora massive and Non-Acropora sub-massive are classed as stress tolerant corals (STC). STC had the greatest percentage of coral cover at $47.09 \pm 5.93\%$. This was followed by competitor corals (CC) ($34.67 \pm 5.02\%$) which includes Non-Acropora encrusting and fast-growing corals (FGC) ($5.75 \pm 1.63\%$) (Fig. 20). Transects O03 and O05 had a significantly lower ($p = <0.05$) occurrence of STC than all remaining transects (Fig. B13a). With regards to CC, transects O03 and O05 had a significantly lower ($p = <0.05$) occurrence than transects O02, O04 and O06. (Fig. B13b).

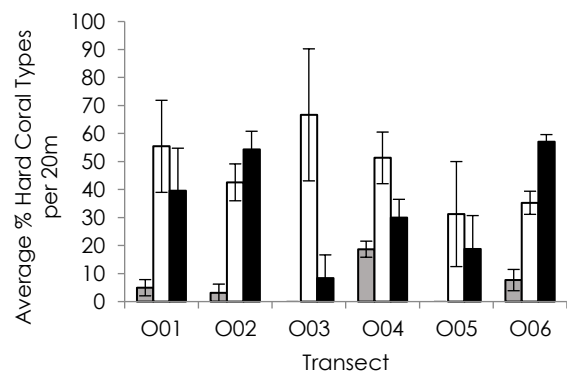


Figure 20. Average percentage cover (%) of coral types per 20m with standard error ($\pm SE$) across transects in Cabulihan, Limasawa, the Philippines. Disturbance adapted fast growing corals (FGC, grey) include *Acropora* species, Fire coral (*Millepora* sp.) and Blue coral (*Heliopora* sp.). Stress tolerant corals (STC, white) include non-*Acropora* massive and sub-massive lifeforms alongside organ pipe coral (*Tubipora* species). (Endiger and Risk, 2000). Competitor corals (CC, black) comprise of branching, encrusting, foliose and mushroom non-*Acropora* species.

3.4 Anthropogenic Impacts

No direct anthropogenic reef damage was observed (boat, anchor, or dynamite damage), however, indirect damage in the form of both fishing and general trash was recorded. There was a much higher prevalence for general trash compared to fishing trash. This has resulted in a high overall impact rating with regards to indirect anthropogenic reef damage.

Coral-specific damage was recorded only twice throughout the survey. This is likely due to the presence of the corallivorous gastropod *Drupella cornus*, 31 of which were recorded throughout the survey and *Acanthaster planci* (CoTs) which were recorded 3 times. No signs of coral bleaching or disease were recorded across the survey.

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4.0 Discussion

This study assessed the suitability and capacity for a Marine Protected Area (MPA) to be established in Barangay Cabulihan's coastal waters. To ensure the selected site would be improved by an MPA status, factors including current community status, connectivity, larval supply, resilience capacity, and community resistance to environmental stressors must all be taken into consideration. This study focuses on the current community structure (species richness, diversity, abundance and distribution) of target survey species within the Cabulihan proposed MPA. Results indicated a low abundance and species diversity of coral-reliant fish species, with a considerably low presence of commercially important fish and invertebrate species. These results suggest that overall community assemblages, combined with the lack of specific commercially important species, have been affected by current and historic "top-down" reef community impacts from anthropogenic and local environmental stressors. Whilst "top-down" impacts have severe effects on reef community structure, it does have the capacity to recover and provide the Cabulihan reef with a greater chance of survival and longevity by achieving MPA status.

4.1 Fish

Overall the fish abundance within the Cabulihan survey site was low in comparison to Triana, a survey site north of Cabulihan previously surveyed by CCC. Likewise, the average species richness (S') and Shannon's diversity (H') were also low in comparison, while in contrast, the average Pielou's evenness (J') was high within the proposed site. A low species richness and high evenness indicates that large populations exist of only a few select species. In the Cabulihan site, the species that showed the greatest abundance were cardinalfish, wrasse and

anemonefish, all of which had significantly higher populations than all other target species. The greater abundance of fish in transect O01 and lower species diversity in transect O02 compared to other transects, can be attributed to the particularly high abundance of cardinal fish within them. A greater diversity is associated with healthier reef systems as a high diversity typically increases a reef's resilience to both anthropogenic and non-anthropogenic stressors (Chapin *et al.*, 2002). The low diversity displayed at this site indicates that the reef system is struggling to deal with these aforementioned stressors with only select species being able to thrive in the current conditions. It is likely that a combination of overfishing and a lack of suitable habitats due to reduced structural complexity on the reef have reduced the settlement potential and refuge available for specific target reef fishes. The reef fish population within this site would benefit from the establishment of an MPA due to the associated preservation of live coral cover and removal of fishing pressures.

4.1.1 Commercially Important Fish

Overall there was a low abundance of commercially important fish (Parrotfish, Grouper and Snapper) recorded within the proposed Cabulihan site. Herbivorous Parrotfish had the highest abundance; however this was poorly distributed over the study site with 21 of the 50 located as a school in transect O02, accounting for O02's high abundance of commercially important fish. The presence of schooling parrotfish was however very promising and indicates that the reef is healthy enough to support a large schooling population. Parrotfish and other herbivorous fish play a key role in exposing reef substrates for coral settlement and limiting macroalgal growth (Bellwood *et al.* 2004). This is a highly specialised role and hence it is important that herbivore populations are

maintained and protected from unsustainable fishing practises (Mouillot *et al.*, 2014).

The low abundance of groupers and null snappers is of concern. The removal of apex predators such as groupers and snappers cause decreasing predation of species such as wrasse, resulting in an increase of their population. The impact of this is already being observed within the Cabulihan site as wrasse had the second highest overall abundance of all target fish species. As many wrasse species feed on benthic invertebrates, the population of invertebrates in turn decreases. This clearly illustrates how the indirect top-down effects from the depletion of apex predators can have wide-spread impacts on the reef (Myers *et al.*, 2007).

The low biomass values for Parrotfish and Grouper and null values for Snapper species, in addition to their low average length of less than 10cm, indicates that commercially important fish are being fished out of this area. The life history of Groupers, Snappers and Parrotfish is that they are slow growing, long lived and undertake many changes in sex as they grow (Sadovy *et al.*, 1994). Fishing of these species can lead to skewed sex ratios within the population as larger males are sought by fishermen, leaving a population highly saturated with females (Domeier and Colin, 1997). Furthermore, the small size of commercially important fish potentially indicates that many individuals are sexually immature. This will make recovery a long-term process which cannot be undertaken in the presence of continued fishing pressure.

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

4.1.2 Butterflyfish

The abundance and diversity of Butterflyfish were recorded during the surveys undertaken at Cabulihan. The presence of Butterflyfish is often used as indicators of reef health and resilience (Hourigan *et al.*, 1998) as their energetic demands are so closely linked to the existence and overall health of coral substrate (Crosby and Reese, 1996). There are two general types of feeding regimes that Butterflyfish employ, obligate and facultative corallivores. Obligate corallivore Butterflyfish depend entirely on the live tissue of corals for their food, in contrast to facultative corallivore Butterflyfish who have broader dietary requirements, a portion of which is live coral tissue (Pratchett and Berumen, 2008). Because the diet of facultative corallivore Butterflyfish is broader; they are more resistant to reductions in live coral cover. Overall Butterflyfish abundance within the Cabulihan survey site was low with 56% being obligate corallivores, indicator species of which show strong feeding preferences for FGC *Acropora* species. FGC only accounted for 5.75% of the hard-coral cover, suggesting that this percentage is too low to support a large population of obligate corallivores.

Looking at the diversity indices in regard to Butterflyfish, S' and H' were lower than those found at Triana. This suggests that in comparison to the Triana site, coral cover is not sufficient to support large and diverse populations of Butterflyfish. Facultative Butterflyfish in particular displayed a distinct lack of diversity with only 2 of the 5-target species, Klein's (*Chaetodon kleinii*) and Vagabond (*Chaetodon vagabundus*), being present. Klein's Butterflyfish accounted for 96% of all facultative Butterflyfish observed. This is likely due to Klein's Butterflyfish having a wide diet breadth in comparison to the other target facultative species (Nagerlkerken *et al.*, 2009) and hence having greater food availability on the reef.

A low value of J' however, does indicate that there is balanced distribution of species through each transect within the Canulihan site. This suggests that there is sufficient coral cover within each transect area that a small Butterflyfish population can be supported. With the formation of an MPA and the removal of top-down stressors on the reef, it is likely that hard coral abundance would increase, and this would in turn increase the population of Butterflyfish within the area.

4.1.3 Fish Summary

As the overall target fish abundance was low, it is clear that the Cabulihan survey area would benefit from the establishment of an MPA. An MPA would increase fish abundance within the protected coastal waters by restricting fishing activities and hence allowing the potential recovery of a population that has been subjected to fishing pressures. In the long term, it is likely that the establishment of an MPA would increase fishing potential outside of its protected areas due to the emigration of fish and increased larval production in the area. It should be noted however, that the size of the reserve relative to the mobility of the fish will influence the degree to which reserve population recovery is undermined by emigration to fished areas. Species with low dispersal will significantly benefit from the establishment of an MPA within Barangay Cabulihan's coastal waters.

4.2 Invertebrates

The overall abundance of invertebrates in Cabulihan was low, being half of the abundance found in the waters of Triana. Likewise, S' and H' were lower than those calculated for Triana whereas J' was higher. This low species richness, low diversity and high evenness indicate a system that is not biologically diverse and where several key species are dominant in select locations on the reef. For Cabulihan, these results are primarily caused by the large abundance of long spine sea urchins throughout the site. Transect O03 in particular had a significantly higher abundance of long spine sea urchins than

all other transects, with it containing over a third of the total urchin abundance. This is likely due to the significantly higher abundance of nutrient indicator algae in transect O03 compared to all other transects, as algae is the primary component of long spine sea urchins' diet (Lewis, 1964). Following on from long spine sea urchins, *Linkia laevigata* and feather stars had the highest abundances. However, unlike long spine sea urchins, both were spread evenly across transects with no transect having a significantly higher abundance than another. The abundance of these invertebrates can be attributed to the level of structural complexity and conditions within the Cabulihan survey site. As hard coral was the second most dominant substrate within the site it is expected that the site as a whole has a high level of structural complexity. Generally, the more structurally complex a habitat, the greater the breadth of organisms it can support (Huston, 1979), as structural complexity provides key physical functions such as providing refuge from predation and the modification of the local hydrodynamic environment (Jones *et al.*, 2004). The invertebrate abundance within Cabulihan however, is lower than other survey sites within the near vicinity. One of the reasons for this may be due to the fact that although hard coral was the second most dominant substrate within the survey site, the most prevalent coral lifeforms were Non-Acropora sub-massive and Non-Acropora massive. A study by Edinger and Risk (2000) established that sites dominated by these lifeforms have a lower structural complexity than sites dominated by other lifeforms, such as Acropora branching, and hence generally exhibit lower species richness and abundance. In addition, the low invertebrate abundance with the Cabulihan site, may also be a direct impact of the high wrasse abundance observed within the survey area. Both target wrasse species, crescent wrasse (*Thalassoma lunare*) and red breasted wrasse (*Cheilinus fasciatus*), are benthic invertebrate feeders (Pratchett *et*

al., 2001; Breder and Rosen, 1966) and hence are likely to impact the invertebrate population due to predation.

4.2.1 Commercially Important Species

Commercially important invertebrate species including lobster (*Nephropidae*), squid (*Teuthida*), prickly redfish sea cucumber (*Thelonata ananas*), greenfish sea cucumber (*Stichopus chloronotus*), pinkfish sea cucumber (*Holothuria edulis*), and Triton's Trumpet (*Charonia tritonis*) were absent from the survey. These species, which in many cases are slow growing and slow moving, are particularly vulnerable to over exploitation, with results from Cabulihan suggestive that exploitive pressures remain. h

19 giant clams were recorded in total, 12 of which were under 10cm and with no individuals larger than 21cm. This lack of large and mature giant clams was also observed in Triana and suggests that the populations within these sites have faced historic fishing pressures of extraction. Giant clams play various ecological roles in coral reef ecosystems, by potentially counteracting eutrophication via water filtering, as well as producing large quantities of calcium carbonate (CaCO_3) shell material that is eventually incorporated into the reef framework (Neo *et al.* 2015). Due to these ecological roles it is vital that the population of giant clams is monitored via scientific and social surveys to establish whether the current population are re-establishing from past or current fishing pressures. Indeed, the presence of giant clams within the smaller size categories may indicate the slow by continued recruitment of new individuals within the area. Establishing an MPA would enable these individuals to be protected and reach sexual maturity.

4.2.2 Crown of Thorns Seastar

The low abundance of Crown of Thorns (CoTs) seastars recorded throughout the survey is a promising finding as many reefs within Sogod bay are experiencing elevated numbers and population outbreaks (Waters and Dallison, 2018). These outbreaks are likely due to both the

lack of CoTs primary predator, Triton's Trumpet, in addition to the change in the oligotrophic balance of the water to a more nutrient rich state, which in turn supports the reproductive success of CoTs larvae (Wolfe *et al.*, 2015). As no Triton's Trumpets were recorded within the Cabulihan survey site, the lack of outbreak is likely due to the lowered circulation between the western side of Limasawa where Cabulihan lies and the remainder Sogod bay. This isolation occurs particularly during Habagat season when nutrient influxes within Sogod Bay increase due to increased terrestrial anthropogenic input which in turn causes the aforementioned increase in CoTs larvae survival rate. At this time, the prevailing wind from the West means that there is little circulation between the two and hence CoTs larvae are unlikely to be present in in Cabulihans waters at in increased density, limiting their recruitment to the area.

4.2.3 Invertebrates Summary

As the overall invertebrate abundance is low, it is clear that the Cabulihan survey area would benefit from the establishment of an MPA. The formation of an MPA and the associated restriction of fishing practices within the area would allow the abundance of commercially important species to increase and recover. Furthermore, the establishment of an MPA would remove multiple top-down stressors facing the reef ecosystem and potentially allow increased hard coral settlement and growth. This would in turn enhance the structural complexity of the environment and allow it to support a high abundance and diversity of invertebrates.

4.3 Substrates

The most prevalent substrate within the Cabulihan survey site was rock with only transects O02 and O05 not dominated by this substrate. This was followed by high abundances in both hard coral and sand. Overall over 60% of the substrate within the survey site was either rock or hard coral which is a promising indication of the reefs current and future health. The relatively

high abundance of hard coral indicates that the reef is currently in good health and is able to support the populations of fish and invertebrates discussed above. In terms of future health, rock is essential for the settlement of coral larvae (Fadlallah, 1983) and hence if anthropogenic stressors are removed by the establishment of an MPA then there is the possibility of an increase in hard coral cover within the area. As hard coral is the second most dominant substrate at the site, there is already a pre-established coral base to provide new recruits which will be able to attach on the abundant rock available and increase hard coral cover. This increase in coral cover would in turn cause an increase in fish and invertebrate species richness and total abundance (Komyakova *et al.*, 2013) due to an increase in food and habitat availability. The high abundance of sand is of concern as in these areas corals will die after settlement due to abrasion and smothering (Edwards *et al.*, 2010). However as over half of this sand is located in transect O05, high sand coverage will not have a detrimental impact on hard coral growth for the majority of the reef.

4.3.1 Hard Coral Cover

Looking at coral classification, STC had the greatest percentage cover with nearly half of all corals being within the category. This high abundance indicates that the site is under persistent stress which is likely to be from both anthropogenic and natural sources. During the social survey of Cabulihan the overall anthropogenic impact of the area was listed as low. This means that either the population is unaware of the magnitude of anthropogenic impacts currently on the reef, or that historical impacts are still affecting the reef to this day. In terms of the natural impacts seen within the area, the site is exposed to medium to high wave action during the monsoon season of Habagat (June-October). This is likely to have a large impact on the coral population as it is exposed to significant physical stress for several months of the

year. Siltation is also occasionally a problem during periods of heavy rainfall which has been shown to promote the growth of STC (Edinger and Risk, 2000). STCs are slow growing corals and typically provide limited structural complexity due to their lifeforms. This can result in limited fauna community structure as there are not enough habitats available in order to support extensive species assemblages (Edinger and Risk, 2000). By establishing an MPA and removing several anthropogenic pressures, it is likely that the coral assemblage will shift away from being STC dominated and become more structurally complex. This would allow the fish and invertebrate species assemblages to diversify within the site and improve the overall health of the reef. If an MPA is established, it is essential that the percentage cover of hard coral coverage is monitored to determine if there are any changes over time.

4.3.2 Substrate Summary

The substrate community assemblage has the potential to exhibit the structural complexity necessary to support a higher diversity of reef fish and invertebrates if disturbances are removed. Natural impacts such as the monsoon season do have a significant impact on coral settlement and growth. However, the removal or top-down stressors such as over fishing and removing anthropogenic impacts by establishing an MPA will take a degree of stress away from the reef and will promote a higher chance of survival from these major bottom-up disturbances.

4.4 Impacts

Whilst direct anthropogenic impacts were recorded as low within the Cabulihan site, indirect impacts were high. This is mainly due to the high occurrence of trash within the survey area, over 80% of which was within the general category. Close proximity of the site to shore and the barangay of Cabulihan, in addition to the monsoon season of Habagat causing trash from outside the local vicinity to be washed in due to the prevailing currents, are the likely the causes of this result.

General waste can negatively affect corals directly by smothering them; blocking out essential sunlight and preventing polyps from feeding within the water column (Sheavly and Register, 2007). Furthermore, as these plastics degrade via mechanical action and photodegradation they form microplastics within the water. As non-selective feeders, corals have been recorded ingesting these microplastics, which can cause significant damage to their health (Andrady, 2011). Alongside corals, fish and invertebrate populations are negatively affected by trash and microplastics within the water column as their presence can provide a potential choking and poisoning hazard (Setälä *et al.*, 2014). In order to target this problem waste management schemes will need to be put in place with communities educated about the consequences of improper waste disposal and provided with the facilities in order to safely dispose of their waste.

With regards to the occurrence of fishing trash on the reef, this suggests that the site is still being used as a fishing ground more frequently than described within the social survey. This is supported by the low number and small size of commercially important fish and invertebrate species observed. There are numerous socio-economic drivers causing this influx of overfishing by

local communities on the reef such as poverty and population growth (Teh *et al.*, 2013). The decision to implement an MPA should therefore consider the balance between protecting coral reef ecosystems and allowing people to use them for social and economic purposes (Teh *et al.*, 2013).

4.4.1 Impacts Summary

The waters of Cabulihan are clearly negatively affected by several anthropogenic impacts. The establishment of an MPA would allow several of these top-down stressors such as fishing pressures to be removed. In order to alleviate these top down stressors on the reef system, adequate protection and enforcement within the MPA boundary, as well as controlling coastal threats originating from outside the boundary will be essential. If these threats are alleviated then this will potentially improve the reef ecosystems resilience and adaptation to future bottom up disturbances, such as those associated with storms and climate change. The implementation of an MPA could also help reverse the reduction in commercially important fish and invertebrates within the area and provide lasting benefits for the community of Cabulihan.

5.0 Recommendations

The results from the Cabulihan proposed Marine Protected Area (MPA) site assessment indicate that the surveyed reef has the potential to support a more diverse reef structure, in addition to a higher assemblage of reef invertebrates and fish, if assigned MPA status and associated top-down reef stressors are removed. Whilst the site is under threat from bottom-up disturbances such as Habagat and threats associated with climate change, the removal of top-down stressors would provide the area with a greater chance of survival and longevity against these issues. In addition, the location of this MPA would assist in creating a connective network between other established MPAs within Sogod Bay, allowing the protection of species with large dispersal and geographic ranges. To ensure effectiveness of the Cabulihan proposed MPA is reached, a series of recommendations have been detailed.

1. The marked Marine Protected Area boundary should include a NTA, with a 50m Marine Reserve buffer

Due to the small size or complete absence of select commercially important invertebrate and fish species found with the Cabulihan reef, it is recommended that the MPA should become a No-Take Area (NTA). NTA guidelines prohibit all methods of fishing, as well as the removal of all life within the NTA. Within Sogod Bay, a 50m Marine Reserve (MR) typically buffers these NTAs allowing restricted fishing practices (hook and line only). These MR buffers are typically not marked by any buoys and instead are observed as an invisible barrier around the MPA. Due to this lack of obvious demarcation, restricted fishing practises often take place within the MR and void its purpose. By adding additional buoys of a different colour than those marking the NTA the MR will be clearly marked out. This would decrease fisherman misunderstanding

whilst increasing the level of protection within the NTA itself.

2. High MPA Enforcement

Current research indicates that the permanent closure of fishing grounds prevents marine resources from becoming depleted, as well as maintaining or even enhancing yields from the areas adjacent to them. In order for the proposed Cabulihan site to obtain these ecological benefits, it is essential that there is high MPA enforcement in place to prevent illegal fishing or poaching. The incentive for this enforcement lies in the economic benefits that the local fishing community could gain due to the enhanced yields of fish in the MPAs neighbouring waters due to spill-over processes (Di Franco *et al.*, 2016).

Table 3. Boundary coordinates for the proposed Marine Protected Area (MPA) in Barangay Cabulihan 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	727147.108	1096712.068	NTA
B	726744.823	1096792.126	NTA
C	726716.549	1096210.671	NTA
D	726794.302	1096106.795	NTA
a	727168.621	1096758.935	MR
b	726697.494	1096853.437	MR
c	726664.611	1096191.924	MR
d	726745.744	1096092.351	MR
Total Area (ha)		13.88	
NTA (ha)		9.10	
MR (ha)		4.78	

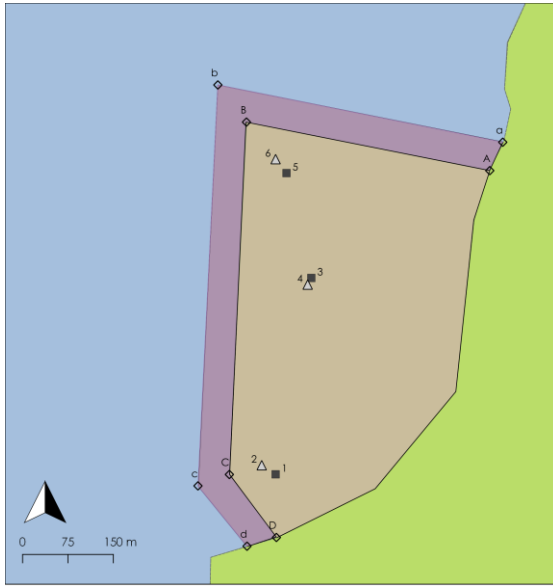


Figure 20. Proposed boundary locations for a No-Take Area (NTA) and Marine Reserve (MR) for the Barangay Cabulihan, Limasawa, the Philippines. The proposed constitutes to a Marine Protected Area (MPA). Pink/red area = 50m buffer zone (MR). Yellow/orange area = NTA. Demarcation buoy locations are highlighted and sequentially labelled. Lowercase labels refer to those that mark the boundary of the MR.

CCC advises the implementation of a management board to oversee the effective running of the MPA which includes members of the local fishing community. This committee would facilitate the collection of MPA fees from associated dive charters entering the site, provide both 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 Cabulihan.

3. Fisherman Engagement

MPAs that actively engage fisherman in MPA management have proved to display a higher level of commitment to the protection of the MPA, than fisherman

that have a marginal or passive role (Di Franco *et al.* 2016). Furthermore, this engagement it also likely to increase compliance towards MPA guidelines which is a necessary step towards long-term sustainability. If the fishing community and other stakeholders are not engaged in the management process, then increased surveillance and enforcements are generally required to control this lack of compliance. This could potentially lead to a negative attitude of stakeholders towards the MPA (Di Franco *et al.*, 2016; Pollnac *et al.*, 2001) and cause friction between MPA managers and stakeholders, potentially resulting in law infringements by local fisherman. Ensuring fisherman participate in either formal or informal rulemaking on the MPA management board safeguards their rights, resulting in informal commitment to the protection of the MPA.

4. Create coastal management regimes to control threats originating outside of the MPA

Survey results indicate that the Cabulihan proposed MPA has a high occurrence of trash, the majority of which recorded was single-use plastic items. If full protection and recovery is to be obtained within the MPA then coastal management regimes to control these anthropogenic-induced threats originating outside of the MPA must be established. CCC recommends an initial site clean-up with an associated marine debris survey, alongside the establishment of the MPA. This marine debris survey can follow the methodology of Dive Against Debris which is an effective way to determine if policies or legislative bodies can be established to create strategies to overcome poor waste management. CCC is willing to assist in conducting marine debris surveys and training, as well as education days focussing on thinking beyond plastic.

5. Develop alternative livelihoods and skills

Previously, CCC have conducted a Management Effectiveness Assessment Tool (MEAT) on established MPAs within Sogod Bay. These results have indicated

that communities that are failing in MPA enforcement and user compliance are a result of the false expectation that MPA establishment alone will lead to increased livelihood opportunities. It should be made clear to the local community of Cabulihan that MPAs do not directly equate to increased tourism, nor does it necessarily equate to increased local incomes of those stakeholders directly affected by the MPA. This is not to say that the community cannot benefit economically from the establishment of an MPA, but rather that the community must develop a tourism plan which takes into account the needs, talents and interests of its people. This tourism plan can be used to establish local businesses which will provide an income source for the local community.

If livelihood expectations are not met, it will have impacts on the management of the MPA. One way to combat this is to consider non-tourism business opportunities related to MPA establishment such as employing a member of the local community as law enforcement personnel. It will also be integral that the MPA management committee discusses plans and commitments towards ensuring equitable distribution of benefits and MPA user fees. When managed carefully, this has the capacity to cover some of the management costs.

All recommendations and suggestions provided by CCC are based on what is ecologically ideal, however there are numerous social and economic factors to consider in the decision-making process. Therefore, the recommendations listed above should be used as the initial step in opening a dialogue between stakeholders in order to come to the best possible solution for all parties involved. By combining an ecosystem approach to

fisheries (EAF) and community-based management (CBM) to empower the local community, CCC aims to assist Cabulihan in achieving measurable levels of effectiveness from their MPA. By establishing these clear, community driven objectives and goals during the initial formation of the Cabulihan MPA, CCC hopes to reduce the risk of forming an MPA that is solely ecologically focussed and is unlikely to have long-term success. In order to do this, MPA by-laws, policies and restrictions must fit into the greater ecological, social and economic context; taking into consideration 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.

If after detailed consultation and evaluation, an MPA is designated in Barangay Cabulihan, 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 assessment 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 Cabulihan should be reviewed with consultation between all stakeholders involved. Whilst the site would benefit greatly from protection, support of the local community, and with management and monitoring 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 Cabulihan.

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 (Wrasse)	<i>Balistidae</i> (<i>Labridae</i>)	Pakol
Crescent Wrasse Humphead Wrasse	<i>Thalassoma lunare</i> <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 Cabulihan

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>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 Cabulihan.

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> sub-massive
<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> sub-massive
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		

* Hard coral colonies are placed into categories to allow for greater resolution whilst removing the risk of identification errors when attempting to consider colonies to the Genus or Species resolution. Lifeforms are defined by the growth structure exhibited by each colony.

** The category "Other" is defined as any substrate that is encountered within the substrate surveys that does not conform to the criteria of the other categories. For succinctness, the "Other" categories are limited to the most common encountered.

Appendix B

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

Figure B1. Matrix showing significant differences in average fish abundance per 500m³ across the survey site in Cabulihan, Limasawa, the Philippines. 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 B2. Matrix showing significant differences in a) Pielou's evenness (H') and b) Shannon's Diversity Index (J') per 500m³ across the survey site in Cabulihan, Limasawa, the Philippines. 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 Parrotfish abundance per 500m³ across the survey site in Cabulihan, Limasawa, the Philippines. 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 Grouper abundance per 500m³ across the survey site in Cabulihan, Limasawa, the Philippines. 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 biomass per 500m³ across the survey site in Cabulihan, Limasawa, the Philippines. 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 Grouper biomass per 500m³ across the survey site in Cabulihan, Limasawa, the Philippines. 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 abundance per 500m³ across the survey site in Cabulihan, Limasawa, the Philippines. 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 B8. Matrix showing significant differences in Butterflyfish a) Species Richness (S') b) Shannon's Diversity Index (H') and c) Pielou's Evenness (J') per 500m³ across the survey site in Cabulihan, Limasawa, the Philippines. 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 B9. Matrix showing significant differences in a) obligate and b) facilitative Butterflyfish abundance per 500m³ across the survey site in Cabulihan, Limasawa, the Philippines. 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 B10. Matrix showing significant differences in average invertebrate abundance per 100m² across the survey site in Cabulihan, Limasawa, the Philippines. 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 B11. Matrix showing significant differences in invertebrate a) Species Richness (S') b) Shannon's Diversity Index (H') and c) Pielou's Evenness (J') per 100m² across the survey site in Cabulihan, Limasawa, the Philippines. 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 B12. Matrix showing significant differences in average percentage cover of a) rock b) hard coral and c) sand per 20m across the survey site in Cabulihan, Limasawa, the Philippines. 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			+	conserv	+	2018
O03		-		-		-
O04			+		+	-
O05		-		-		-
O06			+	+	+	

Figure B13. Matrix showing significant differences in average percentage cover of a) stress tolerant corals and b) competitor corals per 20m across the survey site in Cabulihan, Limasawa, the Philippines. 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

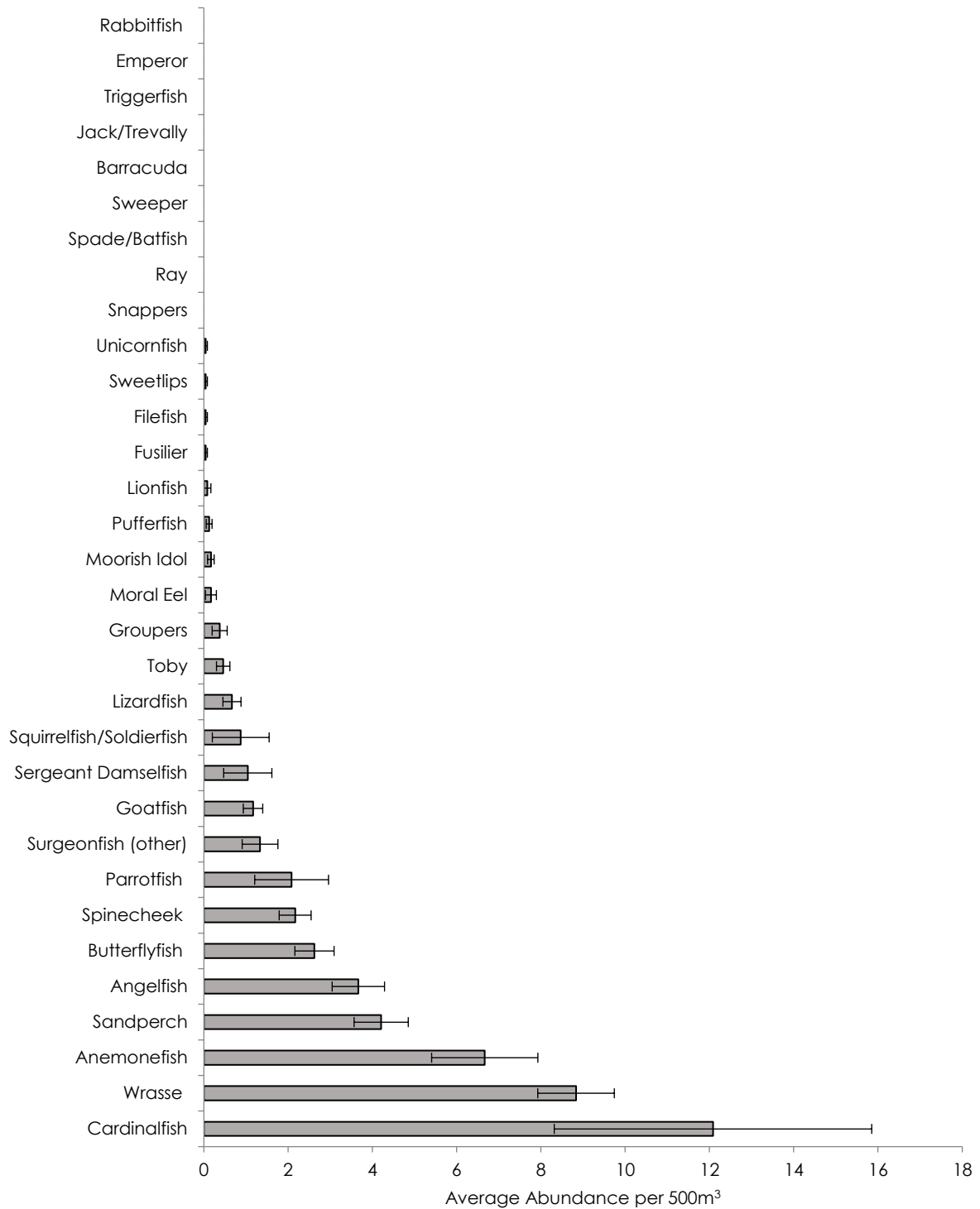


Figure C1. Average abundance of target fish species and families per 500m³ with standard error ($\pm$ SE) for Cabulihan, Limasawa, the Philippines.

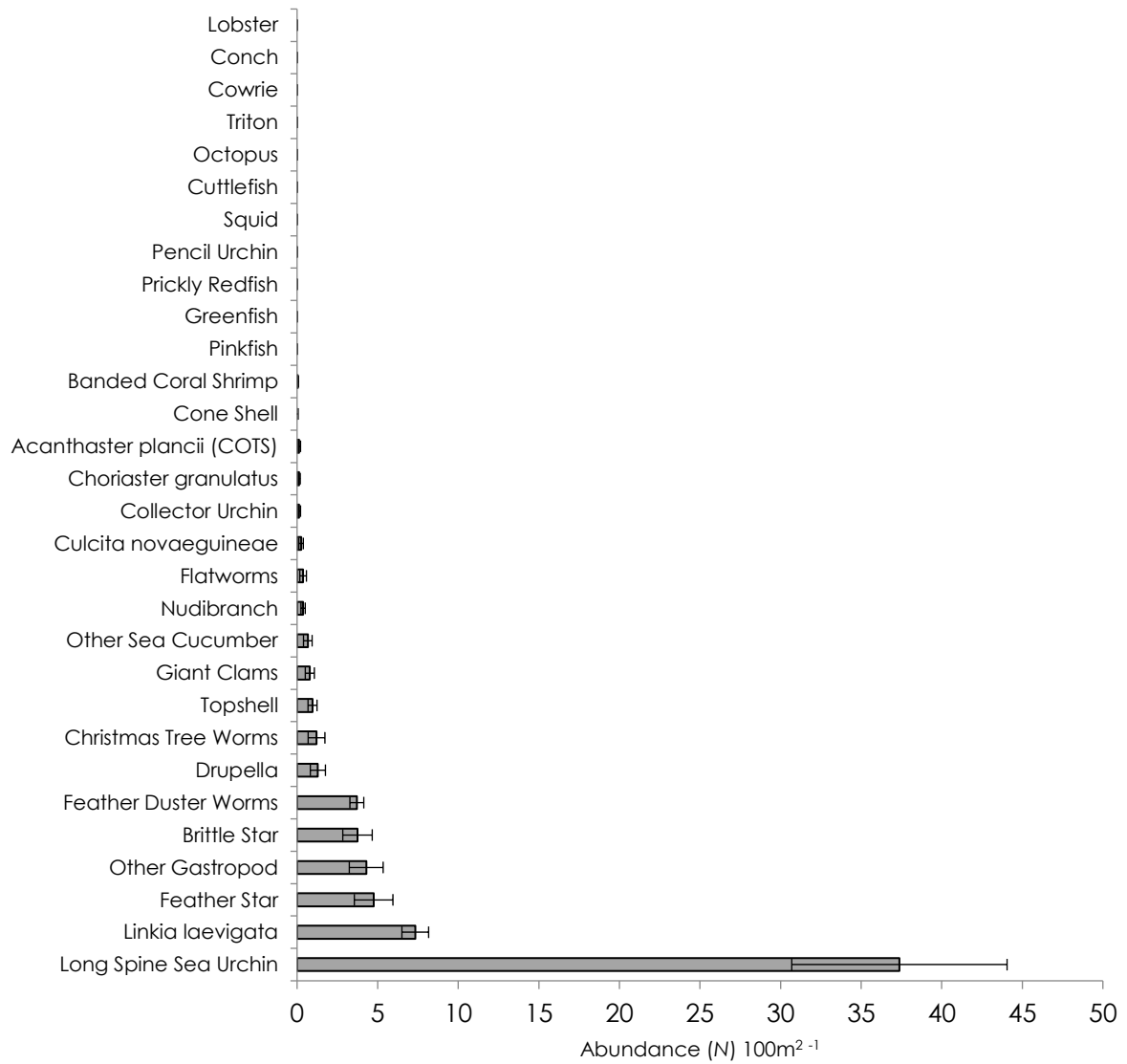


Figure C2. Average abundance of target invertebrate species and families per 100m² with standard error ($\pm$ SE) for Cabulihan, Limasawa, the Philippines.

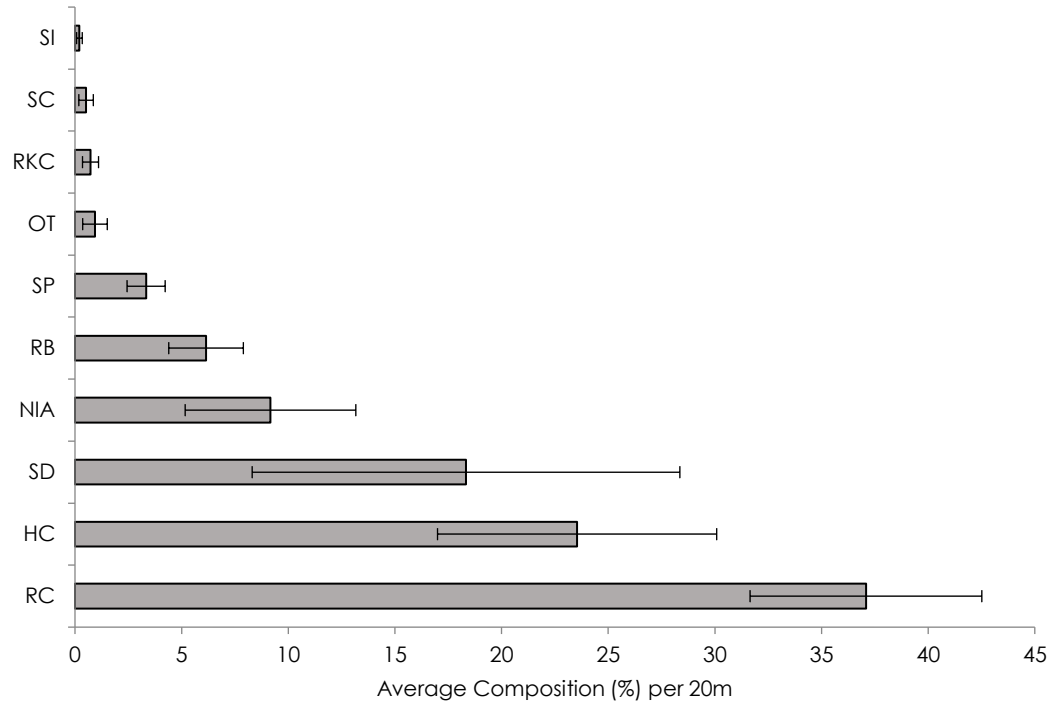


Figure C3. Average composition (%) of substrates per 20m with standard error ($\pm$ SE) for Cabulihan, Limasawa, the Philippines.

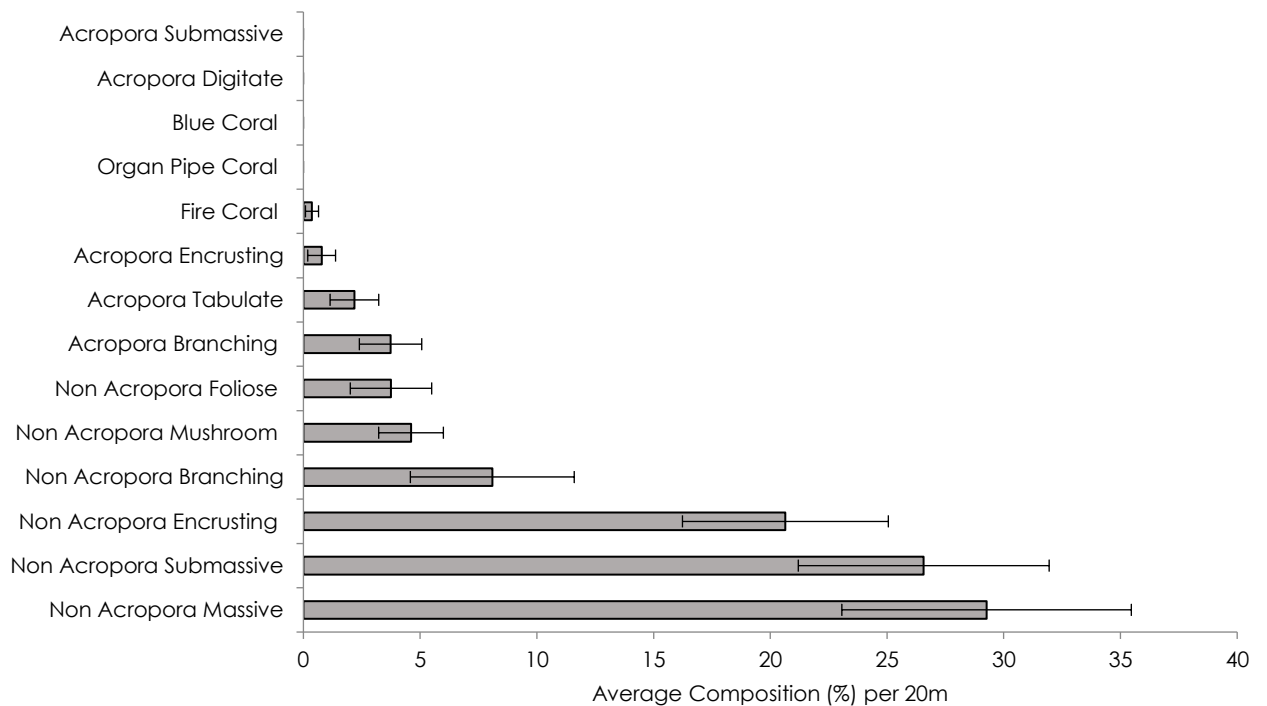


Figure C4. Average composition (%) of coral lifeforms per 20m with standard error ($\pm$ SE) for Cabulihan, Limasawa, the Philippines.