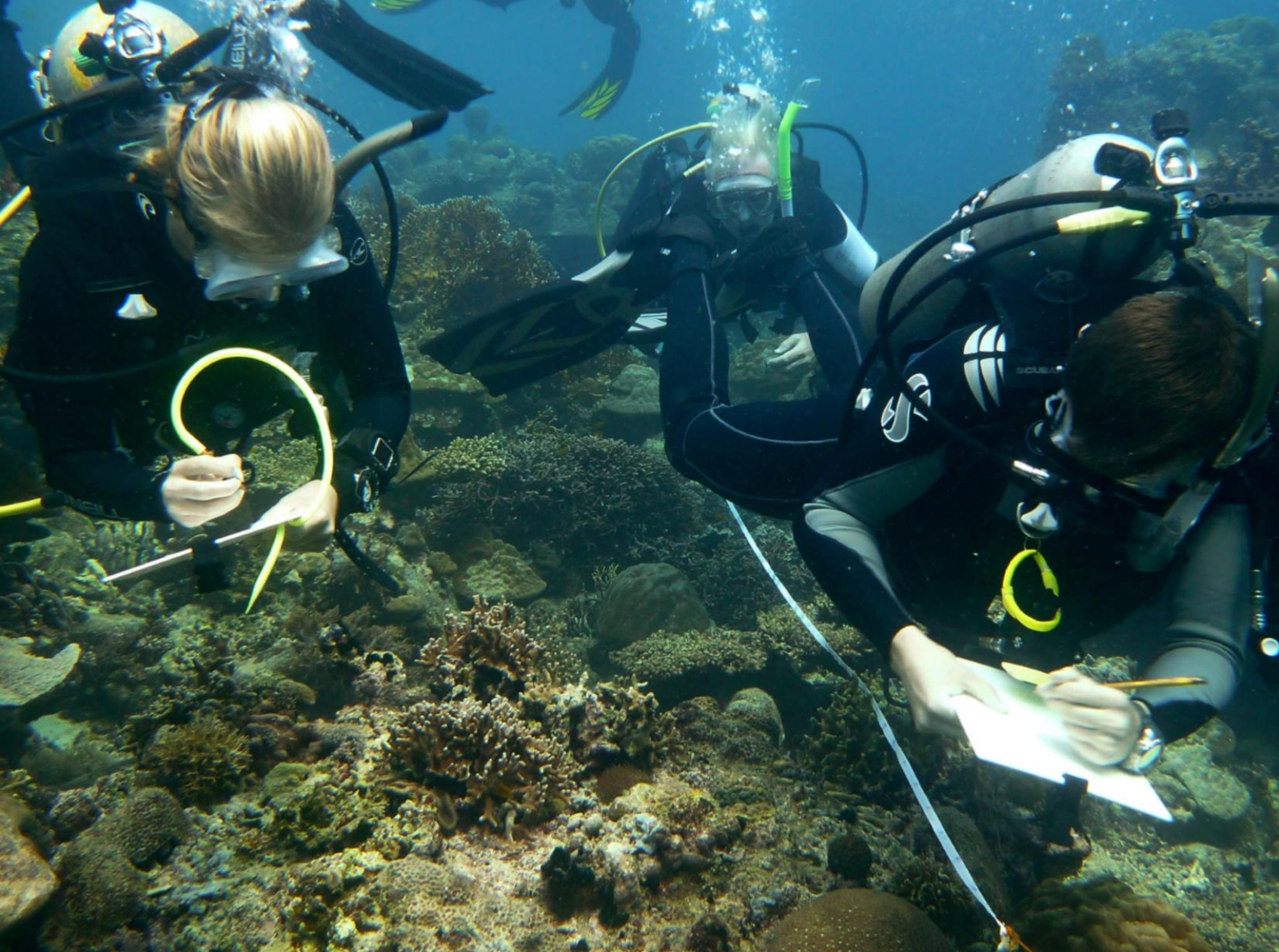




LRCP
Southern Leyte Coral Reef Conservation Project

Coral Cay Conservation Proposed Marine Protected Area Report: Barangay San Bernardo 2017

Report Date: January 2019



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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 San Bernardo (Municipality Limasawa) through the months of April to June 2017.
- At the request of Armando Gaviola of PENRMO, and after consulting the Barangay Captain in San Bernardo, CCC conducted Underwater Visual Census (UVC) protocols. An enhanced Reef Check methodology was used to survey twelve 100m transects each containing four 20m replicates.
- Mean fish abundance was $N = 102.12 \pm 10.77$ per 500m³ with transect O10 obtaining the greatest mean abundance. Although transect O09 showed the highest species richness (S), transect O01 had the highest calculated Shannon-Wiener Diversity index (H') and associated high Pielou's evenness (J'). Moderately high results of S' and H' were obtained, with related associations of J' within the proposed site.
- Average abundance of Obligate corallivorous butterflyfish exceeded that of their Facultative counterparts ($N = 2.00 \pm 0.29$ and $N = 0.71 \pm 0.15$ per 500m³, respectively). This suggests that the scleractinian coral cover in San Bernardo is sufficient to support Obligate Butterflyfish feeding preferences, though could be significantly improved through protection.
- Low abundance ($N = 7.75 \pm 1.07$ per 500m³) and small size (<30cm) of commercially important fishes, as well as the absence of most 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.
- Invertebrate populations displayed a moderate mean abundance ($N = 101.48 \pm 11.77$ per 100m²), with additional measures of species richness (S), Shannon's diversity (H') and Pielou's evenness (J) suggest a diverse invertebrate population.
- The dominating substrate was Hard Coral ($32.29 \pm 2.55\%$); followed by Rock ($30.26 \pm 2.02\%$) and Sand ($15.05 \pm 2.20\%$). Whilst bleaching and coral disease was recorded as low within the survey, predation from *Acanthaster planci* (CoTS) and *Drupella* sp. accounted for the majority of the Recently Killed Corals recorded in the site.
- Results from the Barangay San Bernardo, Limasawa Municipality proposed Marine Protected Area (MPA) site indicates that the surveyed reef is in a capable position of supporting a more diverse reef structure and community assemblage if assigned an MPA status. Its location will also 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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Acknowledgements

Coral Cay Conservation would like to extend its heartfelt gratitude to the following people and organisations, without whom this project would not have been possible:

- The Previous Provincial Governors of Southern Leyte, Hon. Roger G. Mercado (now the current Congressman) and Hon. Damian G. Mercado, for their valued support and guidance throughout CCC's efforts.
- Previous Vice-Governor Hon. Christopherson 'Coco' M. Yap and Provincial Board members.
- Sir. Nedgar V. Garves and the staff of the Provincial Tourism Office.
- Ma'am Eva Abad, Sir. Armando Gaviola and the staff of the Provincial Environmental and Natural Resource Management Office (PENRMO).
- Dr. Arturo Isip, Department of Education Superintendent, Southern Leyte Division.
- Members of the Sogod Bay Sustainable Marine Management Alliance (SBSMMA).
- Hon. Samson Gumutan Jr., Municipal Mayor of San Francisco.
- Barangay Captain Sally M. Oro and the Barangay Council of San Bernardo.
- Our Filipino staff: Bok Bok, Dudong and Ricky whose loyalty, trust, and dedication are highly valued.
- All the dedicated international volunteers and staff who gathered the data and made this project possible: Felipe Lei, Andrea Gaurana, Sarah Mynott, Joaquin Lacson, Carm Novila, Gizelle Lim, Philippa Roe, Connor Reynolds, Ellie Corne, Tyler Goebel, Jerome Napala, Victor Villero, Ryan Palacol and Jesus Fetil.

List of Acronyms and Abbreviations

CC	: Competitor Corals
CCC	: Coral Cay Conservation
CoTS	: Crown of Thorns Seastar (<i>Acanthaster planci</i>)
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
SST	: Sea Surface Temperature (°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 sustenance of livelihoods and poverty alleviation are facilitated through the restoration and protection of valuable socio-economic ecosystems, accompanied by the promotion of sustainable resource exploitation and local capacity building.

1.0 Introduction

1.1 Marine Protected Areas

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

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

MPAs have become vital tools in protective management for the conservation of marine resources. MPAs in the Philippines encompass No-Take Areas (NTAs), within which no form of extraction is permitted. These NTAs are surrounded by 50m "buffer zones" where only non-destructive fishing methods, such as single hook and line fishing, are permitted. These large areas of no extraction combat resource exploitation by providing local communities with a sustainable supply of goods; such as fish and invertebrates; and services, such as shoreline protection and tourism (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; McDaniel 2007), as well as meeting the stakeholder-defined parameters of success (Dahl-Tacconi 2005), can often satisfy the quantifiable conclusion of effectiveness. The definition of effectiveness was given by Pajaro *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 can lead to 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 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 habitats.

"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 (Pollnac *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).

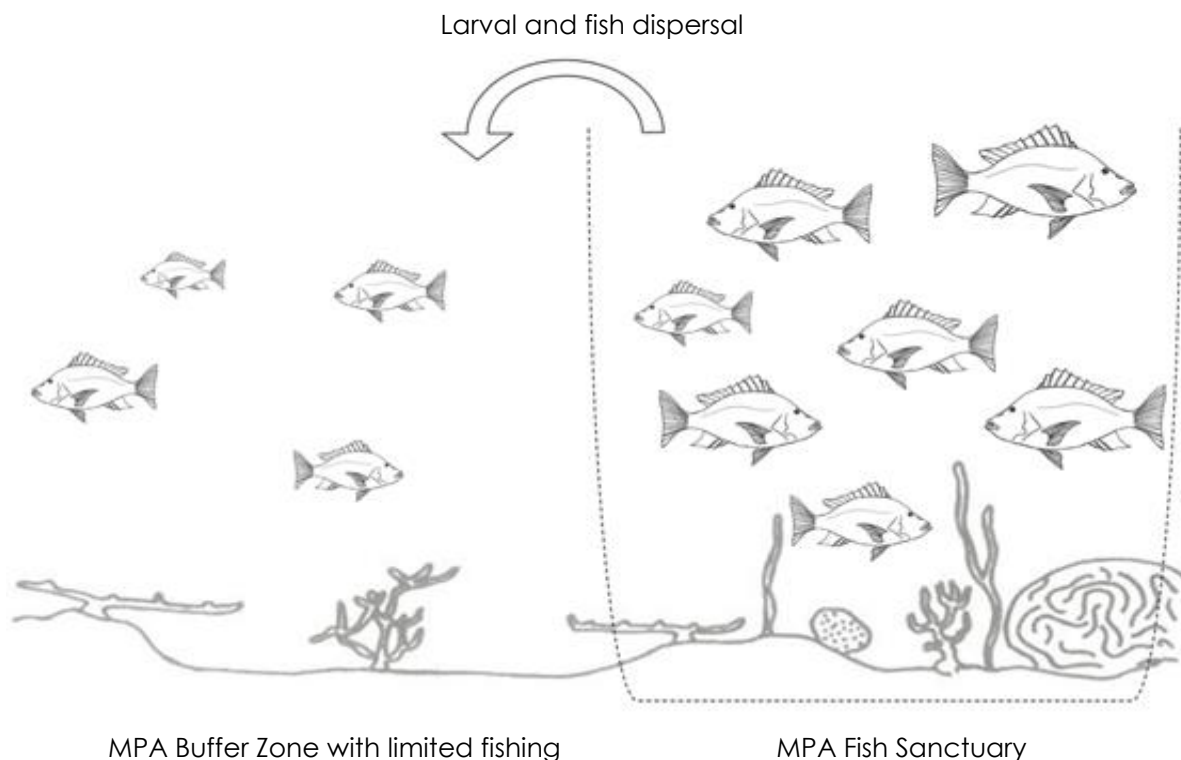


Figure 1. Schematic diagram of MPA functioning. Protected fish within the MPA fish sanctuary grow and produce offspring. This leads to 'overspill', increasing fish numbers inside and outside of the MPA. In addition, the corals inside the MPA are not disturbed by destructive fishing methods.

1.2 Coral Reefs and Marine Conservation in the Philippines

The Philippines 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.* 2002). In 2012, it was estimated that 60% of the country's 98 million citizens live proximity to coral reefs and that fish accounts for nearly 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 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 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 1,226 hectares. Utilising Reef Check's 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 a mean size of 11.7 hectares (± 2.2 SE) and a median of 7.9 hectares (PENRMO-CFRU, 2014). The sizes for several MPAs are not known, as accurate GPS coordinates are not available.

1.3.2 San Bernardo

The survey was requested by Sir Armando Gaviola of PENRMO on behalf of the Protected Area Management Enhancement (PAME) Project, which aims to establish MPAs within the LGUs of San

Francisco, Liloan, Padre Burgos and Limasawa, 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 San Bernardo located in the Limasawa Municipality, an Island located south of Sogod Bay. The proposed location for the MPA is located to the south of the barangay, while the nearest population centre is approximately 0.6km to the proposed area with an estimated population size of 500 (June 2017). The location of Barangay San Bernardo being outside the shelter of Sogod Bay results in its associated reef being exposed annually to the damaging northeast trade winds throughout the months of June to September (Habagat). The last major storm in the area which may have caused significant coral reef damage was recorded in 2013.

2.0 Methodology and Data Collection

2.1 Survey Sites

CCC's assessment of the proposed MPA site at Barangay San Bernardo was conducted between 4th April and 17th June 2017, by trained volunteer survey teams. The weather was sunny during this time with no major weather systems moving through the region. Mean air temperature and Sea Surface Temperature (SST) were 29.3°C during surveys, while the mean temperature was 29.0°C at a depth of 3m and 27.9°C at 10m. The mean estimated horizontal visibility throughout the survey was 14.2m.

From discussions with the Barangay Officials, whilst heavy rains, especially during monsoon (Habagat), occasionally results in siltation, the exposed location of the reef has allowed these particles to remain in suspension for only a short period of time. Suspended sediments in the water can inhibit the ability for sunlight to

penetrate through to the coral tissue, restricting coral growth. The proposed area is parallel to the Barangay, situated on the shoreline. This results in a high use of the reef for fishing in addition to the collection of invertebrates for personal consumption.

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 Liebler 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

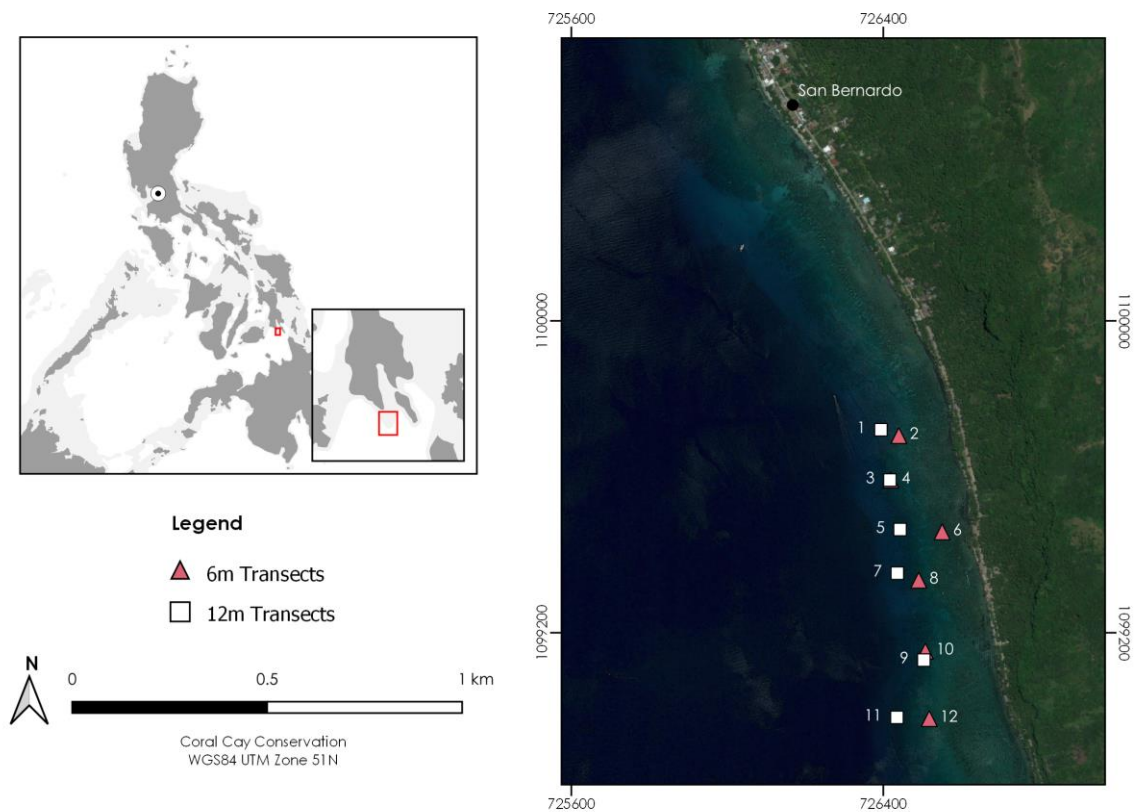


Figure 2. The Philippines (left) and San Bernardo, Limasawa (right). 12 transects were completed within the coastal waters of Barangay San Bernardo (black) at depths of 6m (triangle) and 11m (square). Each transect is sequentially labelled.

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

Table 1. Depths (m) and coordinates (UTM) of 100m transects surveyed along the coast of San Bernardo, Limasawa, Southern Leyte.

Transect Number	Depth (m)	Easting (UTM)	Northing (UTM)
O01	11	726419	1099723
O02	6	726465	1099708
O03	11	726442	1099594
O04	6	726444	1099594
O05	11	726468	1099467
O06	6	726576	1099461
O07	11	726461	1099355
O08	6	726516	1099337
O09	11	726529	1099132
O10	6	726533	1099155
O11	11	726460	1098985
O12	6	726543	1098982

Transects were laid along the reef, parallel to the shore, on a north to south bearing (Fig. 2). Six transects were situated at a depth of approximately 6m, and six transects were situated at a depth of approximately 11m (Table 1). Each 100m transect was divided into four 20m replicates, separated by 5m inter-replicate gaps in which no data were collected. This produced a total surveyed length of 80m per transect. A distance of approximately 100m was left between each whole transect. This survey design allowed for robust statistical analysis of collected data.

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 trade 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 compared among 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 for one minute at 5m intervals along each replicate, to allow 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 mass ((W) g) and biomass (kg) of each individual. The individual weight of species in each sample can vary considerably. Therefore, specific

steps were taken within this study 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 Barangay San Bernardo coral reef, Sogod Bay, Southern Leyte, Philippines. W = mass (g), *a* = the condition factor (Hilborn and Walters 1992), *b* = species specific growth parameter (Quinn and Deriso, 1999), L = the total length (TL) (cm) measured of the individual fish.

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

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

cm) studies and where FishBase listed the study as "doubtful" were excluded.

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

For genera that did not supply studies of values that complied with this report's selection criteria, a Bayesian approach was taken in accordance with Froese *et al.* (2013). If no Bayesian approach was readily available, the following geometric means were used for data deficient families of the three families: *a* = 0.0112 and *b* = 3.04. When a target species was categorised as a differing body-form to the status-quo of the family, such as Barramundi Cod (*Cromileptes altivelis*) which is 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).

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

Genera	Species	Common Name	Allometric Coefficients	
			<i>a</i>	<i>b</i>
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

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 include those 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 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). Thus, 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 (OT) 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 $n=24$ at 6 meters and $n=24$ at 11 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. All data were analysed with the assumption that the temporal difference in data collection would not significantly affect the results in diversity and distribution.

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).

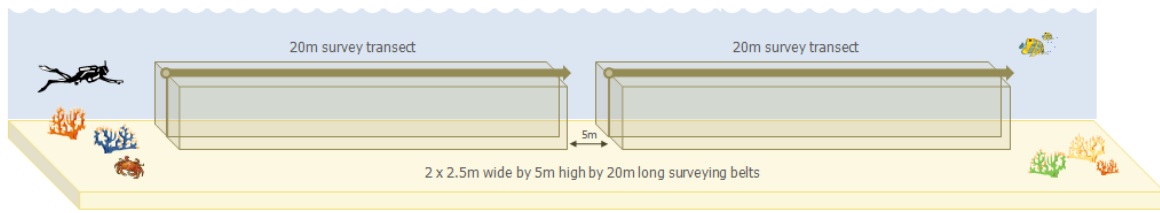


Figure 3. The augmented Reef Check methodology conducted for the assessment of the diversity and abundance of fishes within Barangay San Bernardo. Each conducted transect is separated into 4 x 20m replicates segmented by 5m inter-replicate gaps.

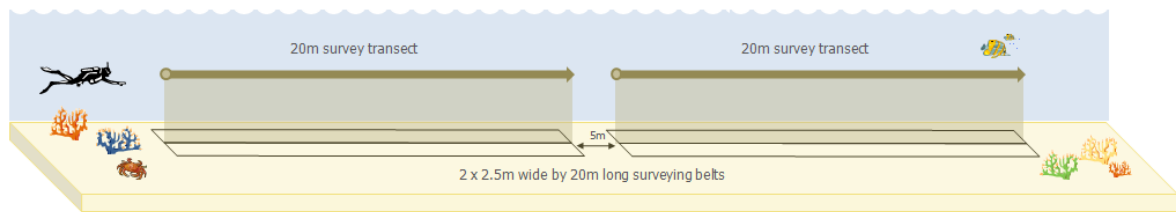


Figure 4. The augmented Reef Check methodology conducted for the assessment of the diversity and abundance of invertebrates within Barangay San Bernardo. Each conducted transect is separated into 4 x 20m replicates segmented by 5m inter-replicate gaps.

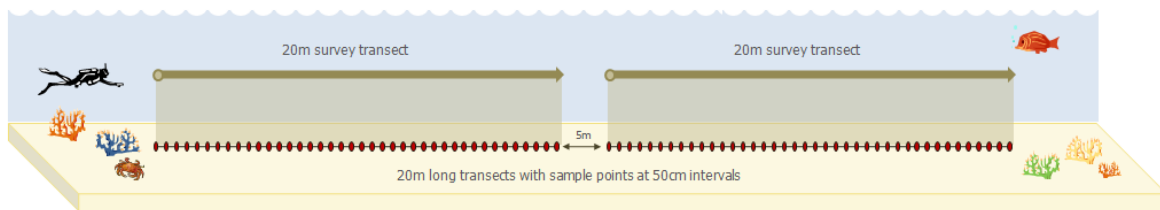


Figure 5. The undertaken point intercept methodology conducted for the assessment of benthic composition within Barangay San Bernardo. Each conducted transect is separated into 4 x 20m replicates segmented by 5m inter-replicate gaps with the respective benthic substrate recorded at 0.5m intervals. The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

3.0 Results

3.1 Fishes

In total, $N=5004$ individual fishes were recorded, representing 74.4% (32 of 43 target species) of all target organisms, with a mean abundance of $N= 102.12 \pm 10.77 \text{ } 500\text{m}^{-3-1}$, throughout the survey area. The most represented organisms were target Cardinalfish, Sergeant Damselfish and Damsel Anemonefish ($N= 39.19 \pm 8.09 \text{ } 500\text{m}^{-3-1}$, $N= 19.56 \pm 7.33 \text{ } 500\text{m}^{-3-1}$, and $N= 7.90 \pm 0.89 \text{ } 500\text{m}^{-3-1}$, respectively) (Fig. C1). At the transect resolution, transect O10 presented the greatest mean abundance of fishes ($N= 150.25 \pm 68.87 \text{ } 500\text{m}^{-3-1}$) followed by transect O02 and O08 ($N= 145.50 \pm 34.41 \text{ } 500\text{m}^{-3-1}$ and $N= 136.75 \pm 77.10 \text{ } 500\text{m}^{-3-1}$, respectively) (Fig. 6, Fig D1a). Transect O01 presented the lowest mean abundance ($N= 52.00 \pm 15.90 \text{ } 500\text{m}^{-3-1}$) followed by transect O11 and O12 ($N= 54.25 \pm 7.15 \text{ } 500\text{m}^{-3-1}$ and $N= 68.25 \pm 18.76 \text{ } 500\text{m}^{-3-1}$, respectively). When compared, transects O02 and O04 showed significantly greater abundances than transects O01 and O11, while transect O04 was also significant over transect O12 ($p= <0.05$) (Fig. B1).

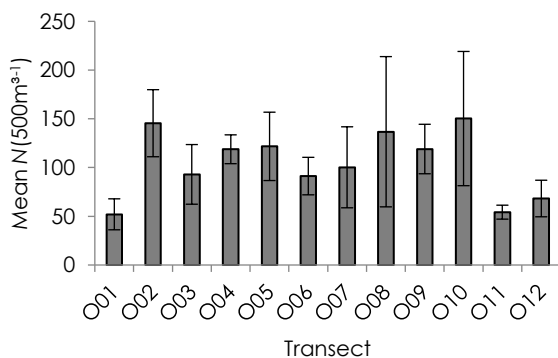


Figure 6. Mean target fish abundance per 500m^3 with standard error ($\pm\text{SE}$) between transects in San Bernardo, Limasawa, Southern Leyte.

Mean species Richness (S) throughout the sample area was recorded as $S= 12.73 \pm 0.5 \text{ } 500\text{m}^{-3-1}$ while mean Shannon-Weiner Diversity (H') was recorded as $H'= 1.74 \pm 0.07 \text{ } 500\text{m}^{-3-1}$. Mean S was not found to differ between transects ($p= >0.05$). Transect O01 showed a significantly higher H' over transect O04 ($p= <0.05$), with a high degree of evenness ($J'= 0.80 \pm 0.07 \text{ } 500\text{m}^{-3-1}$) (Table 3, Fig. B2 and D1b).

No significant differences ($p= >0.05$) were found between transects for J' .

Table 3. Mean Diversity indices for target fish Species Richness (S) and Shannon-Weiner Diversity (H') and Pielou's Evenness (J) per 500m^3 , with standard error ($\pm\text{SE}$) across transects in San Bernardo, Limasawa, Southern Leyte. Due to the multi-variate nature of analysis in determining significant ($p= <0.05$) variance, values that are significant have not been highlighted (see Fig. AX).

Transect	$S(500\text{m}^{-3-1})$		$H'(500\text{m}^{-3-1})$		$J'(500\text{m}^{-3-1})$	
	S	$\pm$	H'	$\pm$	J'	$\pm$
O01	12.00	1.47	1.94	0.10	0.80	0.07
O02	13.25	0.63	1.71	0.16	0.67	0.07
O03	10.75	1.49	1.69	0.36	0.70	0.13
O04	14.00	1.08	1.59	0.08	0.61	0.03
O05	14.00	2.92	1.65	0.27	0.64	0.10
O06	11.50	1.85	1.65	0.22	0.68	0.07
O07	14.00	2.68	1.93	0.13	0.76	0.07
O08	13.50	1.19	1.71	0.13	0.66	0.12
O09	15.25	1.11	1.93	0.31	0.71	0.09
O10	12.75	1.55	1.43	0.39	0.56	0.15
O11	10.50	2.10	1.78	0.26	0.77	0.05
O12	11.25	2.21	1.81	0.21	0.77	0.07

3.2 Butterflyfish Diversity and Abundance

Throughout the survey period, a total of $N= 157$ butterflyfish were recorded, representing 5 of 7 target Butterflyfish species (71.4%), with a mean abundance of $N= 3.27 \pm 0.42 \text{ } 500\text{m}^{-3-1}$. At the transect resolution, transect O08 presented the highest mean abundance ($N= 6.00 \pm 1.08 \text{ } 500\text{m}^{-3-1}$) of target butterflyfish, followed by transect O09 ($N= 5.50 \pm 0.96 \text{ } 500\text{m}^{-3-1}$) and transects O05 and O07 (both with $N= 4.25 \pm 2.50$) (Fig. 7). Transect O08 showed a significantly higher ($p= <0.05$) mean abundance over transects O01, O02 and O03, while transect O09 showed a significantly higher ($p= <0.05$) mean abundance over transects O01 and O04 (Fig. B3).

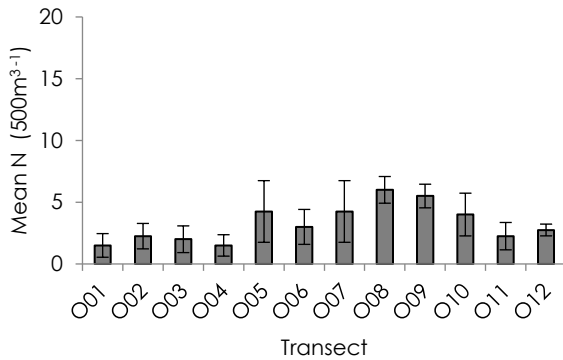


Figure 7. Mean target butterflyfish abundance per 500m³ with standard error ($\pm$ SE) between transects in San Bernardo, Limasawa, Southern Leyte.

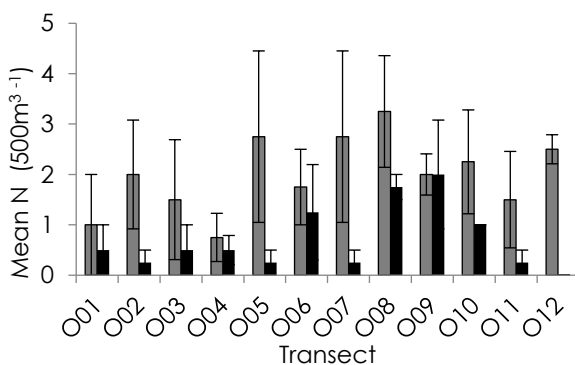


Figure 8. Mean abundance of Obligate (Grey) and Facultative (Black) corallivorous butterflyfish per 500m³ with standard error ($\pm$ SE) between transects in San Bernardo, Limasawa, Southern Leyte

When considering Obligate and Facultative butterflyfish, 130 of all recorded butterflyfish could be described between the two feeding habits. Mean Obligate butterflyfish abundance was $N = 2.00 \pm 0.29$ 500m³-1 and Facultative was $N = 0.71 \pm 0.15$ 500m³-1. Obligate corallivores were represented by 73.85% of the sightings while the remaining 26.15% were Facultative feeders. Transect O08 showed the highest mean abundance in Obligate feeders ($N = 3.25 \pm 1.11$ 500m³-1, Fig. 8). However, the only transect presenting a significantly greater ($p = <0.05$) mean abundance of Obligate butterflyfish was transect O12 ($N = 2.50 \pm 0.29$ 500m³-1) over transect O04 ($N = 0.75 \pm 0.48$ 500m³-1) (Fig. B4). In terms of Facultative butterflyfish, transect O09 showed the highest mean abundance ($N = 2.00 \pm 1.08$ 500m³-1) followed by transect O08 ($N = 1.75 \pm 0.25$ 500m³-1) (Fig. 8). Transect O09 showed a significantly higher ($p = <0.05$) mean abundance than transect O12.

Transect O08 showed a significantly higher ($p = <0.05$) abundance than all but transects O01, O03, O06, O08 and O02, while transect O10 showed a significantly greater ($p = <0.05$) mean abundance than all but transects O01, O03, O04, O06, O08 and O09 (Fig. B5).

3.3 Commercially Important Fishes

7.43% ($N = 372$) of all fishes recorded throughout the survey were considered as commercial species; Parrotfish, Grouper or Snapper. Of the overall commercial fish species count, Parrotfish contributed the greatest abundance (71.5%, $N = 266$) followed by Snapper (18.28%, $N = 68$) and Grouper (10.22%, $N = 38$). At the transect resolution, transect O09 presented the greatest mean abundance of Parrotfish ($N = 13.00 \pm 1.58$ 100m²-1), followed by transect O01 ($N = 8.00 \pm 3.58$ 500m³-1) and O03 ($N = 7.75 \pm 3.12$ 500m³-1) (Fig. 9). Transect O02 demonstrated a significantly greater ($p = <0.05$) Parrotfish abundance than transects O04 and O09; likewise transect O04 over O09 and O12, and transect O09 over transects O10, O11 and O12 (Fig. B7a). Additionally, transects O06 and O08 displayed a significantly greater abundance ($p = <0.05$) than transect O09.

Transect O09 also showed the highest mean abundance in Grouper ($N = 2.00 \pm 1.00$ 500m³-1) followed by transect O04 and O12 ($N = 1.25 \pm 0.48$ 500m³-1, $N = 1.25 \pm 1.25$ 500m³-1, respectively). Transects O02, O04, O05, O08 and O09 demonstrated a significantly greater ($p = <0.05$) Grouper abundance than transects O10 and O11, with transect O01 also showing greater abundance over transect O09 (Fig. B7b).

Finally, transects O05 and O07 showed the highest mean abundance in Snapper (both with $N = 5.00 \pm 2.92$ 500m³-1) followed by transect O01 ($N = 3.75 \pm 2.42$ 500m³-1) (Fig. 9). Transect O01 showed a significantly greater abundance ($p = <0.05$) in Snapper than transects O02, O03, O06, O08, O09, O11 and O12, whilst transects O02 and O03 displayed a greater abundance than transects O04 and O10 (Fig. B7c). Transect O04 showed a greater abundance than transects O06, O08, O09, O11 and O12. Finally, transects O06, O08 and O09 reflected a significantly greater

($p = <0.05$) Snapper abundance than transect O10.

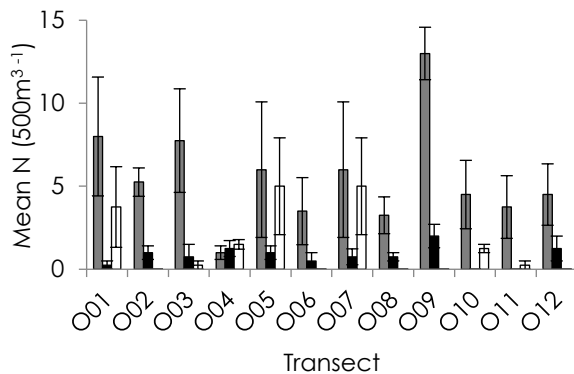


Figure 9. Mean abundance of Parrotfish (Grey), Grouper (Black) and Snapper (White) observed per 500m³ with standard error ($\pm$ SE) between transects in San Bernardo, Limasawa, Southern Leyte .

Recorded Parrotfish were dominated by small individuals (<10cm, $f = 122$), with the subsequent prevailing size class being 11-20cm ($f = 113$, Fig 10). The same size trend can be observed in Grouper and Snapper, which also consisted of smaller individuals. Only two individual Parrotfish measuring 31-40cm were sighted during the survey, while no individuals of any group measured more than this size class. The total standing biomass (kg) recorded throughout the sample period was 20.20 kg, with Parrotfish standing biomass (kg) being the greatest (17.35 kg), followed by Snapper and Grouper (1.68kg and 1.18kg, respectively) (Fig. D1e-h). Furthermore, Parrotfish contributed the greatest to overall mean biomass (kg) ($0.36 \pm 0.09 \text{ kg } 500\text{m}^3^{-1}$) (Fig. 11). The biomass (kg) recorded for each transect and respective commercially important fish family reflect similar significance to mean abundance, with transect O03 and O09 demonstrating the largest biomass of Parrotfish ($1.59 \text{ kg} \pm 0.63$ and $0.79 \text{ kg} \pm 0.36 \text{ } 500\text{m}^3^{-1}$, respectively, Fig. 11) which were significantly greater ($p = <0.05$) than transects O02, O04, O05, O07, O08, O10 and O11 (Fig. B8a). Transect O01 also demonstrated a higher significance over transect O02 ($p = <0.05$); likewise transect O12 over O04. Transects O02, O04 and O05 demonstrated a greater Grouper biomass than transects O10 and O11 ($p = <0.05$) (Fig. B8b), whilst transects O01, O04 and O10

demonstrated a greater Snapper biomass than transects O02, O06, O08, O09, O11 and O12 (Fig. B8c).

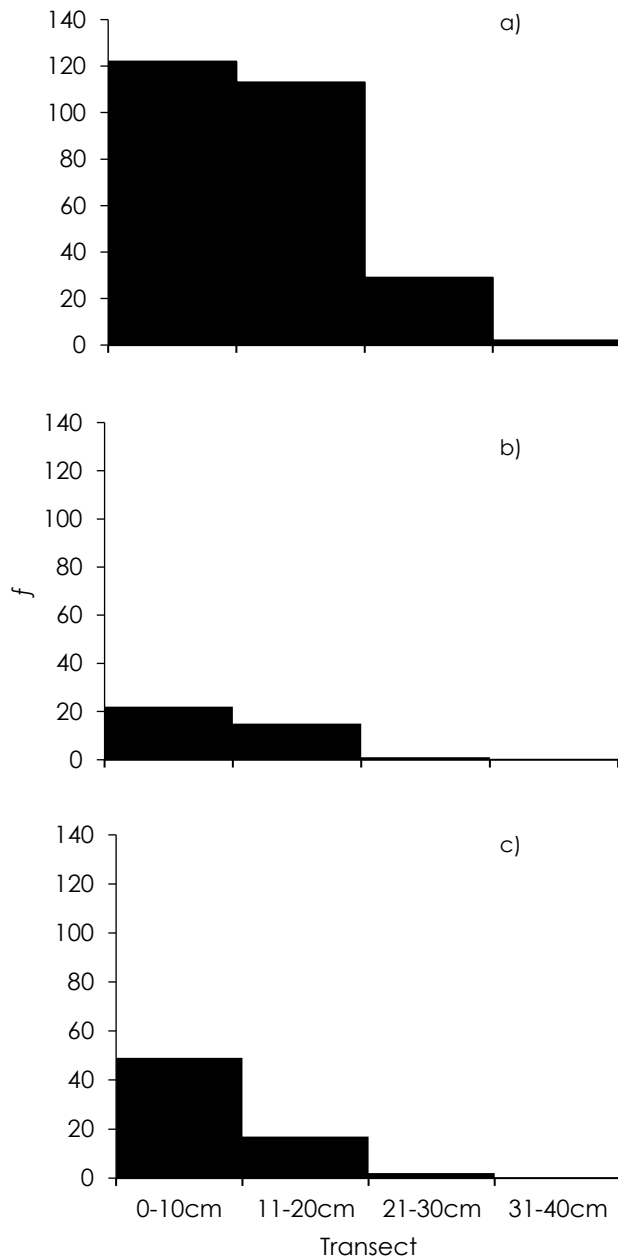


Figure 10. Total frequency (f) of Parrotfish (a), Grouper (b) and Snapper (c) by size class throughout transects in San Bernardo, Southern Leyte, the Philippines.

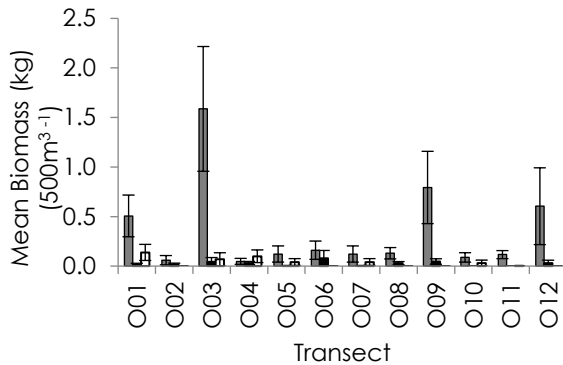


Figure 11. Mean commercial fish biomass by family (Parrotfish (Grey), Grouper (Black) and Snapper (White)) per 500m³ with standard error ($\pm$ SE) between transects in San Bernardo, Limasawa, Southern Leyte.

3.4 Invertebrates

In total, $N = 4871$ individual invertebrates were recorded, representing 64.5% (20 of 31) of all target organisms, with a mean abundance of $N = 101.48 \pm 11.77$ 100m⁻², throughout the survey period. The most represented organisms (mean 100m⁻²) were Long Spine Sea Urchins, Other Gastropods and Feather Duster Worms ($N = 32.52 \pm 5.21$, $N = 30.65 \pm 4.78$, and $N = 10.75 \pm 1.30$ 100m⁻² respectively). At the transect resolution, transect O08 presented the greatest mean abundance of invertebrates ($N = 156.50 \pm 39.77$ 100m⁻²) followed by transect O06 and O02 ($N = 155.75 \pm 15.35$ and $N = 130.75 \pm 13.74$ 100m⁻², respectively) (Fig. 12, Fig. D1c)). Transect O01 presented the lowest mean abundance ($N = 52.00 \pm 15.90$ 100m⁻²) followed by transect O11 and O12 ($N = 54.25 \pm 7.15$ and $N = 68.25 \pm 18.76$ 100m⁻², respectively). When compared, transects O05, O06, O07, O08, O09, O10 and O12 showed significantly greater abundances than transects O01 and O03 ($p = <0.05$) (Fig. B9). Transects O01, O03 and O04 showed significantly greater abundances over transect O02, O06, O08 ($p = <0.05$), likewise O12 over transect O04 ($p = <0.05$), and O02, O06, O12 over transect O11.

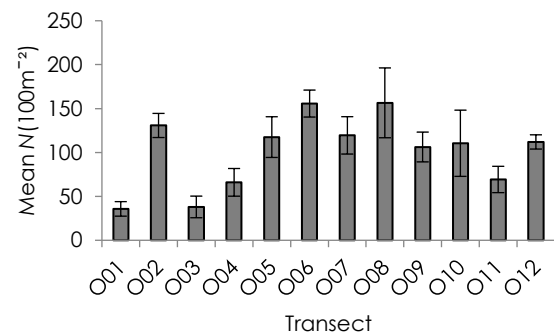


Figure 12. Mean invertebrate abundance per 100m² with standard error ($\pm$ SE) between transects in San Bernardo, Limasawa, Southern Leyte.

Mean Species Richness (S) throughout the sample area was recorded as $S = 9.52 \pm 0.28$ 100m⁻² (Table 4) with transect O04 holding a statistically significant ($p = <0.05$) species richness in comparison to transects O03 and O12 (Fig. B10a). Mean Shannon-Weiner Diversity (H') was recorded as $H' = 1.58 \pm 0.07$ 100m⁻². Transects O01, O02, O03, O04, O05, O07, O09 and O11 showed a significantly greater diversity over transect O06, which had an associated low evenness ($J = 0.48 \pm 0.05$) ($p = <0.05$) (Fig. B10b, Fig. D1d). Transect O01 showed a significantly higher H' over transect O02 ($p = <0.05$). Transects O04, O05, O07 and O11 showed a significantly higher H' over transects O08, O10 and O12 ($p = <0.05$). Transects O04 and O11 showed a significantly higher H' over transect O09 ($p = <0.05$). Mean Evenness (J') was recorded as $J' = 0.71 \pm 0.03$ 100m⁻². Transect O01 showed a significantly higher J' over transect O02 ($p = <0.05$). Transects O01, O02, O04, O05, O07, O09 and O11 showed a significantly higher J' over transect O06 ($p = <0.05$). Transects O01, O04, O07 and O11 showed a significantly higher J' over transect O08 ($p = <0.05$). Transects O01 and O11 showed a significantly higher J' over transect O09 ($p = <0.05$). Transects O01, O04, O05, O07 and O11 showed a significantly higher J' over transect O10 ($p = <0.05$).

Table 4. Mean diversity indices presented for invertebrates over each independent transect per 100m² surveyed in San Bernardo, Limasawa, Southern Leyte; Species Richness (S), Shannon-H-Diversity (H'), and Pielous J' Evenness (J) with standard error ($\pm$ SE).

Transect	S(100m ²)		H'(100m ²)		J'(100m ²)	
	S	$\pm$	H'	$\pm$	J'	$\pm$
O01	9.00	1.29	1.81	0.13	0.84	0.02
O02	9.25	0.48	1.60	0.09	0.72	0.05
O03	8.00	0.71	1.62	0.13	0.79	0.06
O04	10.50	0.65	1.80	0.11	0.76	0.03
O05	10.50	1.44	1.82	0.14	0.78	0.02
O06	10.25	1.38	1.12	0.17	0.48	0.05
O07	10.75	1.31	1.87	0.13	0.79	0.02
O08	10.50	0.87	1.41	0.09	0.61	0.05
O09	8.50	1.04	1.46	0.04	0.70	0.04
O10	9.50	0.87	1.34	0.15	0.61	0.08
O11	9.25	0.63	1.78	0.08	0.80	0.02
O12	8.25	0.48	1.32	0.11	0.84	0.02

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*) were absent from the survey. Six triton's trumpets (*Charonia tritonis*) were recorded within the survey area.

Giant clams were recorded a total of 27 times throughout the sample period but were dominated by those in size classes 11-20cm ($f=14$) and 21-30cm ($f=7$) (Fig. 13). Giant clams were recorded at a mean abundance of $N=0.56 \pm 0.10$ 100m²⁻¹, with transect O06 demonstrating the greatest abundance of giant clam ($N=1.25 \pm 0.63$ 100m²⁻¹). Giant clam abundances did not differ significantly ($p>0.05$) between transects.

When assessing the abundance of corallivorous invertebrates, 12 *Acanthaster Planci* (Crown-of-Thorns Seastar, COTs) and 131 *Drupella cornus* were recorded during the survey in the San Bernardo proposed area. Of the 12 COTs, one individual was recorded in each of transects O01, O04, O05,

O06, O07, O08 and O12. Two CoTs were recorded in transect O10, and three were recorded in transect O03 (Fig. 14).

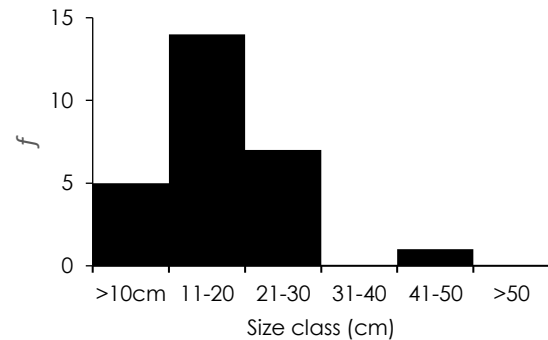


Figure 13. Total frequency (f) of Giant Clams by size class across all transects in San Bernardo, Limasawa, Southern Leyte.

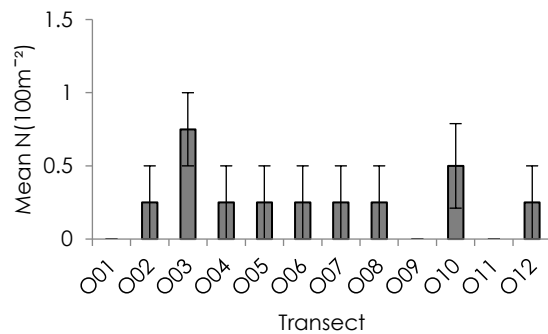


Figure 14. Mean *Acanthaster Planci* (Crown-of-Thorns Seastar, COTs) abundance per 100m² with standard error ($\pm$ SE) between transects in San Bernardo, Limasawa, Southern Leyte.

3.5 Benthic Substratum Composition

Hard Coral (HC) was recorded to be the dominant substrate throughout the sample area ($32.29 \pm 2.55\%$ 20m⁻¹), with Rock (RC) ($30.26 \pm 2.02\%$ 20m⁻¹) and Sand (SD) ($15.05 \pm 2.20\%$ 20m⁻¹) also proving to be abundant throughout the area (Fig. 15). HC and RC did not prove significant against each other ($p>0.05$), but were found to be greater than the remaining substrates (Fig. B11). SD also proved significant ($p<0.05$) against all substrates except for RB, and was significantly lesser than HC and RC.

HC was recorded as being the dominant substrate on transects O02, O04, O05, O07, O08 and O011 over transect O12, while transects O02, O04, O08 and O011 were also significant over transect O01 (Table 5, Fig.

B12, Fig. D1i). Furthermore, transect O08 proved significant over transects O03 and O09.

RC was significantly greater ($p = <0.05$) in abundance on transects O03, O08, O09 and O01 over transects O05 and O07 (Fig. B13). Transects O09 and O11 were also significant over transect O01, while O09 was also significant over transect O02.

SD showed the lowest composition on transect O04 in comparison to all but transects O02 and O08 ($p = <0.05$) (Fig. B14). Finally, transects O01 and O09 showed a significantly higher ($p = <0.05$) SD cover than transects O03, O08, O11 and O12.

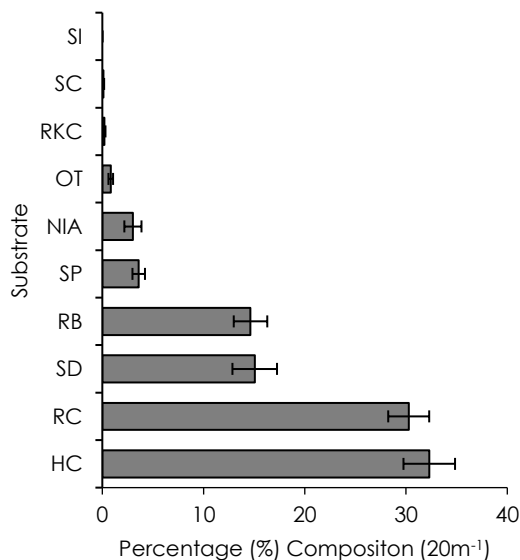


Figure 15. Mean percentage (%) cover of benthic substrate types (SI= Silt, SC= Soft Coral, RKC= Recently Killed Coral, OT= Other, NIA= Nutrient Indicator Algae, SP= Sponge, RB= Rubble, SD= Sand, RC=Rock, HC= Hard Coral) per 20m with standard error ($\pm$ SE) in all transects in San Bernardo, Limasawa, Southern Leyte.

Of the Hard-Coral Lifeforms, Non-acropora massive (CM) was recorded to be the dominant Hard Coral type throughout the sample area ($25.30 \pm 2.96\%$ $20m^{-1}$), with Non-acropora Branching (CB) ($22.20 \pm 3.05\%$ $20m^{-1}$) and Non-acropora Submassive (CS) ($19.07 \pm 2.79\%$ $20m^{-1}$) also proving to be abundant throughout the area (Fig. 16). CM, CS and CB did not prove significant against each other ($p = >0.05$) but were found to be greater than the remaining substrates, save CS and CB that were not greater than CE cover (Fig.

B15). CM was recorded as significantly higher ($p = <0.05$) on transects O09 and O12 when compared to transects O02, O03, O04 and O11, while having a significantly lesser cover on transect O12 than all but transects O03, O05, O07 and O11. CS was significantly greater ($p = <0.05$) on transect O01 than O08 (Fig. B17). CB was found to be significantly lesser ($p = <0.05$) on transect O01 than all but transects O06, O08, O09, O11 and O12, while transect O09 showed a higher abundance than transect O03 (Fig. B18).

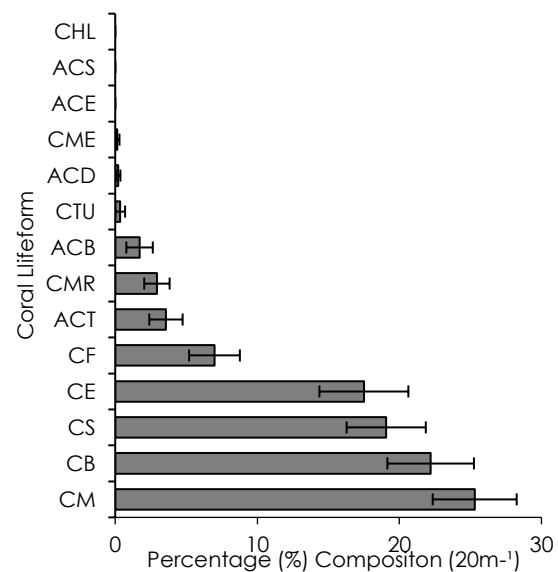


Figure 16. Mean percentage (%) cover of Hard Coral types per 20m with standard error ($\pm$ SE) in all transects in San Bernardo, Limasawa, Southern Leyte. CHL= *Heliopora* spp., ACS= Acropora Submassive, ACE= Acropora Encrusting, CME=, ACD= Acropora Digitate, CTU= *Tubipora* spp., ACB= Acropora Branching, CMR= Non-acropora Mushroom, ACT= Acropora Tabulate, CF= Non-acropora Foliose, CE= Non-acropora Encrusting, CS= Non-acropora Submassive, CB= Non-acropora Branching, CM= Non-acropora Massive.

Competitor (CC) were recorded in greatest abundance throughout the survey area ($49.63 \pm 3.86\%$ of all Hard Corals $20m^{-1}$) (Fig. 17). CC abundance was significantly lesser ($p = <0.05$) on transect O01 than all but transect O06 (Fig. B20, Fig. D1j). However, transect O06 showed a greater CC abundance ($p = <0.05$) than transects O03 and O10.

Stress Tolerant Corals (STC) were the second most prevalent of all Hard Corals ($44.72 \pm 3.83\%$). STC was significantly greater ($p =$

<0.05) on transect O01 than all but transects O02, O08 and O11, while greater on transect O06 than transects O10 and O12 (Fig. B21, Fig. D1k). Transect O11 also had a greater abundance of STC ($p = <0.05$) than transect O12.

Both CC and STC coral growth types were significantly greater than the presence of Fast-Growing Corals (FGC) ($5.65 \pm 1.51 \text{ } 20\text{m}^{-1}$, $p = <0.05$) (Fig. B19). FGC cover did not vary between transects ($p = >0.05$) (Fig. D1i).

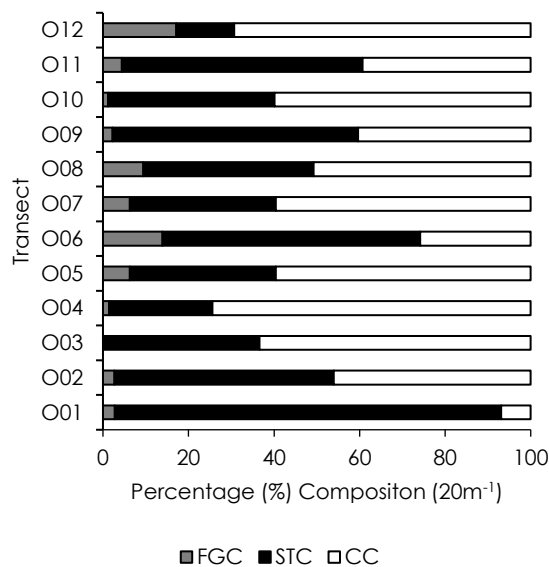


Figure 17. Percentage (%) cover of coral types per 20m with standard error ($\pm$ SE) between transects in San Bernardo, Limasawa, Southern Leyte. FGC= Fast growing Corals (Grey), CC= Competitor Corals (Black) and STC= Stress Tolerant Corals (White))

Table 5. Mean percentage (%) cover of benthic substrate types per 20m with standard error ($\pm$) between transects in San Bernardo, Limasawa, Southern Leyte. HC= Hard Coral, SC= Soft Coral, SP= Sponge, RKC= Recently Killed Coral, RC= Rock, SI= Silt, RB= Rubble, SD= Sand, NIA= Nutrient Indicator Algae, and OT= Other.

Transect	HC		SC		SP		RKC		RC		SI		RB		SD		NIA		OT	
	%	$\pm$	%	$\pm$	%	%	$\pm$	%	$\pm$	%	%	$\pm$	%	$\pm$	%	%	$\pm$	%	$\pm$	%
O01	15.00	2.70	0.00	0.00	4.38	2.13	0.63	0.63	26.25	2.60	0.00	0.00	21.88	5.34	30.00	4.68	0.63	0.63	1.25	1.25
O02	44.38	9.49	0.00	0.00	5.00	1.44	0.00	0.00	23.75	3.89	0.00	0.00	11.88	4.13	10.00	6.54	5.00	2.04	0.00	0.00
O03	21.88	4.00	0.00	0.00	6.88	1.88	0.63	0.63	43.13	5.72	0.00	0.00	18.13	6.72	8.75	1.61	0.00	0.00	0.63	0.63
O04	43.75	7.67	0.00	0.00	1.25	0.72	0.63	0.63	41.25	8.45	0.00	0.00	10.63	3.29	0.63	0.63	0.63	0.63	1.25	1.25
O05	45.63	9.38	0.00	0.00	1.88	1.20	0.00	0.00	15.63	5.04	0.00	0.00	19.38	5.34	14.38	5.24	0.63	0.63	2.50	1.02
O06	35.00	10.21	0.00	0.00	2.50	1.02	0.00	0.00	27.50	7.00	0.00	0.00	4.38	2.77	23.75	16.38	6.25	2.17	0.63	0.63
O07	45.63	9.38	0.00	0.00	1.88	1.20	0.00	0.00	15.63	5.04	0.00	0.00	20.00	5.86	14.38	5.24	0.00	0.00	2.50	1.02
O08	41.88	3.59	0.00	0.00	1.88	0.63	0.00	0.00	40.00	4.79	0.00	0.00	6.88	2.58	6.88	2.58	2.50	1.77	0.00	0.00
O09	16.88	4.83	0.00	0.00	0.63	0.63	0.00	0.00	40.00	3.68	0.00	0.00	13.13	2.37	29.38	6.24	0.00	0.00	0.00	0.00
O10	30.00	10.05	0.00	0.00	1.25	0.72	0.63	0.63	25.00	7.97	0.00	0.00	16.88	2.77	23.75	11.84	1.88	1.20	0.63	0.63
O11	35.63	4.38	1.25	0.72	8.75	2.60	0.00	0.00	40.00	1.02	0.00	0.00	5.63	1.88	7.50	1.44	1.25	1.25	0.00	0.00
O12	11.88	2.58	0.00	0.00	6.88	4.72	0.00	0.00	25.00	8.35	0.00	0.00	26.88	11.79	11.25	1.25	17.50	5.20	0.63	0.63

Table 6. Mean percentage (%) cover of Hard Coral types per 20m with standard error ($\pm$) between transects in San Bernardo, Limasawa, Southern Leyte. ACB= Acropora Branching, ACE= Acropora Encrusting, ACS= AcroporaSubmassive, ACD= Acropora Digitate, ACT= Acropora Tabulate, CB= Non-acropora Branching, CE= Non-acropora Encrusting, Ce= Non-acropora Encrusting, CF= Non-acropora Foliose, CM= Non-acropora Massive, CS= Non-acropora Submassive, CMR= Non-acropora Mushroom, CME= *Millepora* spp., CTU= *Tubipora* spp. CHL= *Helippora* spp. Were absent from the survey.

Transect	ACB		ACE		ACS		ACD		ACT		CB		CE		CF		CM		CS		CMR		CME		CTU	
	%	$\pm$	%	$\pm$	%	$\pm$	%	$\pm$	%	$\pm$	%	$\pm$	%	$\pm$	%	$\pm$	%	$\pm$	%	$\pm$	%	$\pm$	%	$\pm$	%	$\pm$
O01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.78	2.41	0.00	0.00	0.00	0.00	4.17	3.61	45	11.7	41.11	6.2	2.78	2.41	0.00	0.00	4.17	3.61
O02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.89	0.77	28.37	10.68	13.23	4	2.68	2.32	19.58	4.42	31.67	15.88	1.79	1.55	1.79	1.55	0.00	0.00
O03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.17	4.5	0.00	0.00	14.77	10.34	8.33	4.17	28.22	8.83	12.5	6.91	0.00	0.00	0.00	0.00
O04	1.39	1.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	38.38	11.25	4.39	2.47	30.26	9.57	12.72	2.22	11.47	8.32	1.39	1.2	0.00	0	0.00	0.00
O05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.3	2.26	21.72	2.72	30.61	13.26	4.78	1.79	26.11	11.13	7.98	5.56	2.5	2.17	0.00	0.00	0.00	0.00
O06	0.00	0.00	0.00	0.00	0.00	0.00	1.39	1.2	12.5	10.83	18.85	7.1	5.73	3.41	1.25	1.08	40.38	10.31	19.9	8.54	0.00	0.00	0.00	0.00	0.00	0.00
O07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.3	2.26	21.72	2.72	30.61	13.26	4.78	1.79	26.11	11.13	7.98	5.56	2.5	2.17	0.00	0.00	0.00	0.00
O08	3.33	2.89	0.00	0.00	0.00	0.00	1.19	1.03	4.9	2.75	28.08	12.84	14.69	6.35	6.43	3.89	28.74	11.14	11.09	3.04	1.56	1.35	0.00	0.00	0.00	0.00
O09	2.27	1.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.3	4.47	26.77	12.25	2.27	1.97	40.53	3.69	16.86	6.53	0.00	0.00	0.00	0.00	0.00	0.00
O10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.19	1.03	18.53	4.59	32.74	4.62	2.75	1.4	20.09	4.8	18.82	6.63	5.88	2.23	0.00	0.00	0.00	0.00
O11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.42	2.25	13.29	5.01	11.97	3.71	9.7	3.59	36.04	2.91	20.24	8.77	4.34	2.33	0.00	0.00	0.00	0.00
O12	13.5 7	8.17	0.00	0.00	0.00	0.00	0.00	0.00	3.57	3.09	30	20.62	39.29	15.6	0.00	0.00	0.00	0.00	13.57	8.17	0.00	0.00	0.00	0.00	0.00	0.00

3.6 Anthropogenic Impacts

The total survey area was mostly perceived as subject to no (rating '0') impacts, with 14.58 % perceived as "Low" (rating '1') impact, 10.42% as "Medium" impact and 0.83% as "High" (Fig. 18). 4.17% of the surveyed area was subjected to "High" levels of "Other" direct coral damage, with 14.58% and 18.75% subjected to "Medium" and "Low" levels, respectively (Fig. 18). This damage is heavily correlated with predation of both the corallivorous gastropod *Drupella cornus*, which was recorded 131 times across the survey, and *Acanthaster planci* (CoTS) which was recorded 12 times across the survey.

In regards to indirect anthropogenic impacts, "General Trash" was recorded as the greatest impact (in comparison to discarded fishing gear), with 37.50% of the surveyed area subjected to "Medium" levels of trash, and 31.25% subjected to "Low" levels (Fig. 18).

Of the total survey area, only two coral colonies were affected by bleaching, exposed to an average of 0.67% of bleaching. This represented a total of 0.31% of the overall coral population. One of the bleached colonies was also affected to 0.01% by each of Black Band and White Band Disease within the San Bernardo proposed MPA area.

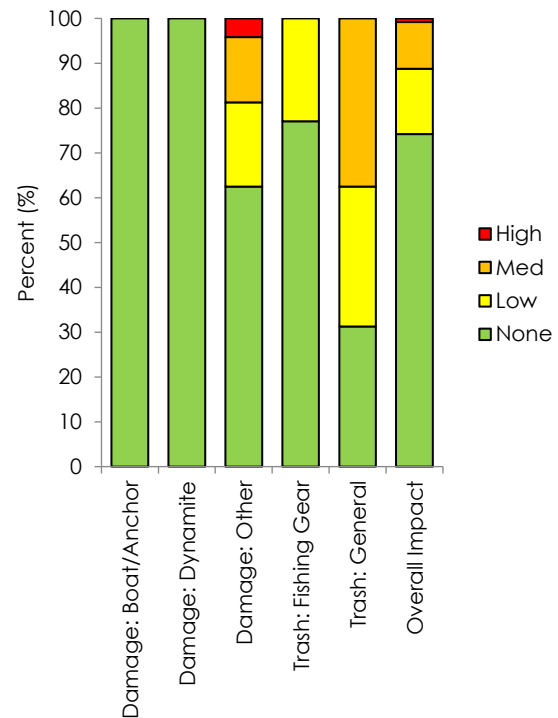


Figure 18. Total impact scale recorded over the complete survey area, Barangay San Bernardo, Limasawa, Southern Leyte. Counts of impacts are categorized to scale (0=none, 1=low, 2-4=medium and >5=high), which is applied to each recorded impact category as a percentage (%) of the surveyed area, split into two categories (coral damage and trash); Boat/Anchor Damage, Dynamite, Other, Fishing Gear, and General. Total overall impact count is also given that incorporates impact counts from the other 5 categories.

4. Discussion

This study assessed the suitability and capacity for a Marine Protected Area (MPA) to be established in the coastal waters of Barangay San Bernardo (Municipality Limasawa). To ensure the selected site will be improved by an MPA designation, 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 San Bernardo proposed MPA. Results indicated a stable and diverse abundance of coral-reliant fish species, with a considerably low presence of commercially important fish and invertebrate species. This suggests that overall community assemblages, combined with the lack of commercially important species, have been affected by "top-down" reef community impacts that originate from anthropogenic and local environmental stressors. Whilst "top-down" impacts have severe effects on reef community structure, it does have the capacity to recover by achieving MPA status.

4.1 Fishes

Overall fish abundance within the San Bernardo proposed area was moderate in relation to other sites assessed by CCC in Sogod Bay. Furthermore, high results of fish diversity including mean species richness (S'), mean Shannon's diversity (H') in addition to a moderate mean Pielou's evenness (J') (number of members within each species) was recorded within the proposed site. A high S' and lower J' , as indicated by San Bernardo fish results, is suggestive of a somewhat resilient and biologically diverse ecosystem. Biological diversity and species richness within an ecosystem is important in order to withstand environmental disturbances such as storms and disease. There has been

mounting research studying the exacerbating effects of structural reef loss on fish communities (Feary *et al.* 2007; Garpe *et al.* 2006; Jones *et al.* 2004). Considering these, it can be assumed that the percentage of live coral cover within the San Bernardo survey site has aided in both the settlement potential and the provision of refuge for target reef fishes, while regulating their diversity and abundance (Feary *et al.* 2007; Garpe *et al.* 2006; Jones *et al.* 2004). Biological diversity and species richness within an ecosystem is important in order to withstand environmental disturbances such as storms and disease. Given the mounting research studying the exacerbating effects of structural reef loss on fish communities (Feary *et al.* 2007; Garpe *et al.* 2006; Jones *et al.* 2004), it can be assumed that the percentage of live coral cover within the Bunga survey site has aided in both the settlement potential and the provision of refuge for specific target reef fishes, regulating diversity and abundance of these reef fishes. Therefore, reef fish within Bunga proposed MPA could be benefited from the establishment of an MPA due to the associated preservation of live coral cover.

Whilst species richness of target reef fish was comparable across the shallow reef flat and the reef slope, a greater abundance of fish was recorded along the shallow reef. This suggests variability depth-use patterns among target species. Factors controlling species distributions and community structure along a single gradient may be complex, and can be a response to a number of physical and biological parameters. The existing results thus highlight the importance of taking into account the reef slope and its associated depth gradient to greater understand the daily movements of target reef fishes. The reef fish within the proposed site could benefit from the establishment of an MPA due to the associated preservation of live coral cover. However, due to shallow coral

reefs (<30m deep) being subjected to unprecedented levels of disturbance (population growth and associated increase in fishing pressures, climate change), inclusion of the reef slope and deeper reef habitats will be a necessary consideration. This is to ensure effective MPA designation that encompasses depth as a factor for both fish habitat and as a refuge for fishery-targeted species.

4.2 Commercially Important Fishes

When assessing the commercially important fishes, herbivorous fish biomass (Parrotfish) was greater than other commercially important fish biomass (Snapper, Grouper). Parrotfish and other herbivorous fishes play a profound role in exposing reef substrate for coral settlement and limiting macroalgal growth (Bellwood 1994). Due to only a handful of species having the capacity to perform this herbivorous role in favouring coral growth and larval settlement, it is important that herbivores are given protection from unsustainable fishing practices and ensuring that these roles remain a functional part of ecosystem interaction (Mouillot *et al.* 2014).

Low biomass values for Grouper and Snapper species, as well as low average length of all commercially important species, suggest the possibility that maturation is not being favoured within this site. However, due to the data being obtained at a family level resolution, it cannot be concluded that all recorded species were sexually immature at the time of the survey due to differences in maturation rates between species within the same family. Due to records of the movements of Grouper and Snapper, and that individuals displayed a preference towards the reef slope (11m transect), further analysis would need to be undertaken to determine what these reproductive parameters are (especially age and size at maturity), and their associated reliance on varying reef flats and sloping habitats. These commercially important species are particularly vulnerable to overfishing because they are

large, and therefore highly desirable and sought after. Studying the life history of these species show that they are slow growing, long-lived, with many changing sex as they grow (Shapiro 1989; Sadovy *et al.* 1994). Epinepheline serranids (Groupers) are among the most vulnerable coral reef fishes to overexploitation due to the formation of temporally and spatially predictable fish spawning aggregations (Coleman *et al.* 2000; Sadovy and Domeier, 2005). Targeting both fish spawning aggregations and reproductively active individuals may cause population-level changes that affect reproductive output, including skewed aggregation sex ratios due to sexual selection, size reductions, changes in genetic diversity, and loss or decline of fish spawning aggregation (Chapman *et al.* 1999; Sadovy and Domeier, 2005). Whilst the implementation of a MPA will support the home range and feeding grounds of Grouper species outside of their reproductive periods (March – April), few reports show the effectiveness of MPAs in limiting or preventing fish spawning aggregation loss, or in improving population level abundance (Nemeth 2005). This is due to reproductive individuals needing to leave their feeding grounds to access their spawning location, possibly existing outside of MPA boundaries and hence exposing themselves to exploitation. Further studies to identify where Groupers may concentrate during reproductive periods will be necessary to establish full protection of this commercially important species. Establishing migratory pathways, and no-take areas in fish spawning locations during peak reproductive season (March – April) are suggestive strategies that could ensure adequate and effective protection of these reproductively complex species within Sogod Bay.

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

been overfished in the area and would benefit from site protection.

4.3 Butterflyfish Diversity and Abundance

Butterflyfish abundance and diversity was also recorded in the survey, due to their energetic demands being so intimately linked to the existence and overall condition or “health” of the coral substrate (Crosby and Reese, 1996). By analysing butterflyfish diversity and abundance independently of total fish results, butterflyfish presence can act as an indicator of change to hard coral cover on a reef (Crosby and Reese, 1996). Many species of butterflyfish are Obligate corallivores, depending on the live tissue of corals for their food. Other corallivorous butterflyfish include coral as a measurable part of their diet, but also utilise other food items. These are referred to ‘Facultative’ corallivores and tend to be more resilient than ‘Obligate’ corallivores to disturbances that hinder live coral cover. Furthermore, the targeted Obligate corallivorous species used in the survey show strong preferences for fast growing (FGC) *Acroporid* species, providing a further dimension of sensitivity to the system. Although hard coral cover represented nearly a third of the substrate recorded in the site, FGC accounted for only a fraction of this proportion. However, the relatively high percentage Obligate butterflyfish recorded suggests that the percentage of hard coral cover within the San Bernardo proposed MPA site is sufficient to support their dietary requirements.

4.4 Invertebrates

The high diversity of target invertebrate species recorded at San Bernardo is suggestive of a resilient and biologically diverse ecosystem. However, commercially important invertebrate species including *Nephropidae* (lobster), *Teuthida* (squid), *Thelonota ananas* (prickly redfish sea cucumber), *Stichopus chloronotus* (greenfish sea cucumber), and *Holothuria edulis* (pinkfish sea cucumber) were absent from the survey. These species, which in many cases are slow growing and slow

moving, are particularly vulnerable to overexploitation, with historic and current records indicating that extraction pressures are still high in the area.

Long Spine Sea Urchins, Other Gastropods and Feather Duster Worms were the most abundant invertebrates across all transects. The most numerous invertebrate, the Long Spine Sea Urchin, plays an important ecological role on coral reefs, due to its herbivorous diet, which prohibits the potential for algal dominance over coral. This ecosystem function is particularly significant on reefs where herbivorous fish, such as Parrotfish or Rabbitfish, have been depleted.

27 Giant Clams were recorded in total, with 7 individuals larger than 21cm. This abundance and presence of large, mature giant clams, suggests that pressures of extraction are low within this area. 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 are eventually incorporated into the reef framework (Neo *et al.* 2015). Future scientific and social surveys of giant clam populations will be needed to determine whether current populations are re-establishing from past or current fishing pressures.

The high abundance of *Acanthaster planci* (CoTs), with 12 individuals recorded across the survey site, could be associated with a number of anthropogenic impacts, such as the low number of their predators at the survey site, including Triggerfish, Pufferfish and Humphead Wrasse, which is correlated with overfishing. A combination of industrial and agricultural runoff, and extreme weather events each year, can contribute to a high nutrient influx in the water. In turn, this triggers a profusion of phytoplankton in the water, increasing the survival rate of CoTs larvae which have a feeding preference for phytoplankton. The relatively high percentage of hard coral across all transects is likely to be correlated with the large numbers of CoTs. Transects

O04, O05, and O07 presented the highest individuals of *Drupella* whilst also displaying the highest abundance of hard coral cover. As both CoTs and *Drupella* are voracious corallivorous predators on the reef it can be assumed that there is an association with the high cover of hard coral, and the abundance in both hard CoTs and *Drupella*.

It must be noted that CoTs presence is important for maintaining healthy, diverse coral communities. By feeding on diseased coral and preferentially predating fast-growing species such as *Acropora* sp. (Pratchett 2005), they can facilitate the control of disease and increase competition between coral species leading to higher diversity. The low recording of *Acropora* Tabulate (ACT) and *Acropora* Branching (ACB) corals across transects, suggest the CoTs population is compromising the health of the reef. In addition to this, the high recording of the corallivorous gastropod *Drupella cornus* must also be considered as an additional factor affecting the success of *Acroporid* sp. corals in San Bernardo.

4.5 Substrates

The most prevalent substrate was Hard Coral, followed by Rock and Sand, closely followed by Rubble. The prevalence of hard coral and rock within the San Bernardo survey area indicates that regardless of the seasonal exposure of the site to strong currents, settlement potential of coral larvae is supported by stable substrate within the area. Furthermore, Coralline Crustose Algae (CCA), sponges, and other encrusting organisms do have the capacity to ultimately stabilise rubble conditions over time (Edwards *et al.* 2010).

When analysing hard coral cover within the San Bernardo survey site, the presence of all three coral classifications (fast growing, competitor, and stress tolerant corals) suggests that the reef ecosystem is capable of supporting a diverse community assemblage when environmental conditions are favourable for settlement. The high abundances of competitor and stress tolerant coral across

the transects suggests that slight disturbance from processes such as storms and siltation have allowed disturbance adapted corals to dominate, due to their suitability to the site over faster growing corals. Nearshore reefs dominated by long-lived competitor and stress tolerant corals may be considered of high conservation value due to their longer replacement time. Regardless, the fragility of hard corals to both anthropogenic and environmental factors indicate that corals can only benefit in both size and reproductive success from the establishment of an MPA with associated conservation strategies (Edinger and Risk 2000). Future surveys of the San Bernardo proposed MPA will be necessary to determine if the percentage of hard coral cover recorded in these surveys is on the decline, and if so, what are the associated pressures leading to its demise. It is important to note that the effects of bottom-up processes, namely ocean acidification, cannot be easily detected in-situ without advances in technology or experimental conditions.

Whilst the prevalence of hard coral cover and morphology across the survey site suggests that environmental variables (pH, temperature, nutrient balance) are in favour of CaCO_3 production and coral growth, the low abundance of particular reef-reliant fish species suggests that whilst the hard-coral cover type achieves rugosity with regards to 3D formation, it is structural complexity that drives biodiversity (Hiatt and Strasburg 1960). Metrics of structural complexity correlate strongly with indicators of reef health such as fish abundance, coral and macroalgal cover (Friedlander and Parrish 1998). Living things create structure, and structure must pre-exist for those living things to find shelter from predators, scavenge, avoid turbulence, or perform other actions necessary for them to thrive (Hixon and Beets 1993). Due to most reef fishes being closely associated with the reef substratum, they are subsequently highly susceptible to disturbances that alter the biological and/or physical structure of coral reef habitats (Chong-Seng *et al.* 2012). There

are different roles for reef complexity at different scales. Understanding these potential drivers of species richness for these reef fishes is therefore fundamental for the management of the coral reef habitat within the San Bernardo proposed site.

The substrate community assemblage for the San Bernardo proposed MPA has shown to have the potential for a high grading of structural complexity, that is capable of supporting a large diversity of reef fish and invertebrate species. By improving the current level of structural complexity, the associated herbivorous and grazing reef fish and invertebrates can both be protected, whilst promoting a coral dominant reef ecosystem. Removing top-down stressors such as overfishing, CoTS outbreaks, and limiting recreational impacts by establishing an MPA status with associated conservation strategies, will provide the San Bernardo reef with a greater chance of survival and longevity to these major bottom-up disturbances.

4.6 Impacts

The presence of fishing trash suggests that the San Bernardo proposed MPA site is an active fishing ground, with either the absence of or the small sizing of key commercially important species within transects. Should they continue, these fishing pressures would be unsustainable for commercially important fish and invertebrate populations. A combination of the absence or small sizing of some key commercially important species suggests fishing pressures and practices within this site are species selective and therefore unsustainable for commercially important fish invertebrate populations. and Socio-economic drivers such as poverty, lack of appropriate institutions, and population growth have influenced the overfishing of reef fisheries (Teh *et al.* 2013). As a result, the decision to implement an MPA in this area will be having to be made to incorporate a balance between protecting coral reefs within the San Bernardo proposed area and allowing people to use them for social and economic purposes (Teh *et al.* 2013).

Other trash was also recorded across the survey site. If the San Bernardo site was to develop into an established MPA, coastal management regimes will need to be created to effectively control threats originating outside of the MPA boundary (CTI-CFF 2013). Due to corals being non-selective feeders, ingestion of microplastics have been recorded when the plastics are present in seawater (Hall *et al.* 2015).

Although the San Bernardo proposed MPA site was exposed to a low percentage of bleaching and coral disease, the presence of these are correlated with exposure to high levels of nutrients in the water, which exacerbates the effects of declining coral health. Corals have such specific environmental parameters, that slight fluctuations in the natural equilibrium of their environment can trigger catastrophic outbreaks of bleaching and disease. Agricultural and industrial runoff, sewage and sedimentation all contribute to a decrease in water quality, in turn off-setting the optimal conditions for coral growth and survival.

Overall, the establishment of an MPA within the San Bernardo proposed reef site has the potential to promote positive improvement in the coral reef community assemblage and structure if top-down stressors such as overfishing are removed. Whilst this will be more beneficial in ensuring food security and social stability in the San Bernardo proposed area by increasing fish and invertebrate populations, it will also alleviate pressures on the reef substratum from high disturbance pressure such as *Acanthaster planci* and *Drupella cornus* outbreaks. Adequate protection and enforcement within the MPA boundary, as well as controlling coastal threats originating outside of the boundary, will be critical in alleviating top-down pressures to this reef system. This would in turn assist in resilience and adaptation tactics to future bottom-up disturbances associated with storms and climate change.

6. Recommendation

Results from the Barangay San Bernardo, Limasawa Municipality proposed Marine Protected Area site indicates that the surveyed reef is in a capable position of supporting a higher assemblage of reef fish and invertebrate species, if assigned MPA status and associated top-down reef stressors from overfishing and CoTS outbreaks are removed. Whilst the exposure of the site has resulted in the growth of select coral morphologies, the ability for the site to offer the structural complexity, settlement potential and dietary requirements necessary for target reef fish suggests a disturbance adapted site that has a greater chance of survival and longevity against major bottom-up disturbances. In addition to this, its location will also assist in creating a connective network between other established MPAs within Sogod Bay and around the island of Limasawa, allowing the protection of species with large dispersal and geographic ranges.

The ideal MPA would cover 31.96 ha (Table 7) and include all twelve surveyed transects within its boundaries (Fig. 19a). Although the reef showed considerable signs of overfishing and pollution, an MPA including the entire survey area would allow for the most promising chances of successful reef improvement and recovery.

Figure 19b provides an alternative option that covers 17.74 ha (Table 7) of reef and does not include transects O09-O12. It does include transects O02 and O04 which showed high abundances of Hard Coral cover, fish (including butterfly and commercial fish species) in addition to high invertebrate abundances. This option also includes transect O08, which had a high recording of Groupers and Hard Coral cover as well.

A third option, as depicted in figure 19c, covers an area of 23.77 ha (Table 7) of reef

while excluding the northernmost transects, O01-O04, while including transects that showed a considerable amount of Hard Coral cover (i.e. transects O08, O11 and O12).

The final designated site for San Bernardo, Limasawa, must be decided in consultation with the local Barangay, local fishers and the municipal government of Limasawa. To ensure effectiveness of the San Bernardo proposed MPA is reached, a series of management recommendations have been detailed.

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

Due to the presence and size of commercially important fish and invertebrate species found within San Bernardo reef, the boundary placement will allow both their habitat niche and home range to be protected. For maximum protection and greater recovery time of these stocks, the level of exploitation within this MPA should follow the guidelines associated with 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 NTA's allowing restricted fishing practices (hook and line only) (Table 3). Such buffers have typically been placed outside of the marked boundary, and act as an invisible barrier. As a result, it is the MR that experiences the most amount of exploitation, with the lack of demarcation leading to associated defiance of the MR guidelines. NTA's can be prone to exploitation by members of the wider community that fish within the MPA boundary. Adding two additional buoys of a different colour on either side of the marked MPA area will decrease fisherman misunderstanding, whilst increasing the level of protection within the NTA itself. Due to a number of established MPA's within

Sogod Bay following only an MR guideline, additional buoys will be effective in highlighting MPA's that have been established following the guidelines of an NTA, and therefore require a different protocol.

Table 7. Boundary coordinates for the proposed Marine Protected Area (MPA) in Barangay San Bernardo 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).

Option	Demarcation Buoy	Easting (UTM)	Northing (UTM)
a	A-1	726564.02	1099801.02
	A-2	726333.68	1099759.90
	A-3	726390.10	1098911.07
	A-4	726724.50	1098960.31
	A-MR1	726280.82	1099800.30
	A-MR2	726344.91	1098853.03
b	B-1	726564.02	1099801.02
	B-2	726338.94	1099766.52
	B-3	726394.88	1099270.72
	B-4	726662.66	1099306.25
	B-MR1	726282.80	1099809.80
	B-MR2	726351.90	1099215.20
c	C-1	726618.42	1099525.51
	C-2	726365.17	1099509.57
	C-3	726388.08	1098903.18
	C-4	726727.43	1098970.10
	C-MR1	726311.94	1099556.50
	C-MR2	726340.70	1098842.48
Total Areas (ha)			
	Option a	Option b	Option c
NTA	24.41	12.28	17.08
MR	7.55	5.46	6.69
SUM	31.96	17.74	23.77

2. High MPA Enforcement

Mounting research on the topic indicates that permanent closure of fishing within the San Bernardo proposed site could aid in preventing marine resources from becoming depleted, as well as maintaining or even enhancing yields from areas adjacent to them. High enforcement to prevent illegal fishing or poaching within the site will be necessary to ensure ecological benefits are obtained. A recent study by Di Franco *et al.* (2016) found a strong relationship between high enforcement and fisherman incomes. This relationship suggests that the ecological benefits determined by high enforcement (i.e. increase in fish density / biomass within the MPA) most likely translate into economic benefits via spill-over processes, enhancing fisheries catches in the MR buffer zone (Di Franco *et al.* 2016). CCC advises the implementation of a management board to oversee the effective running of the MPA. 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 San Bernardo.

3. Fisherman Engagement

MPAs that actively engage fishermen 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). This suggests that user

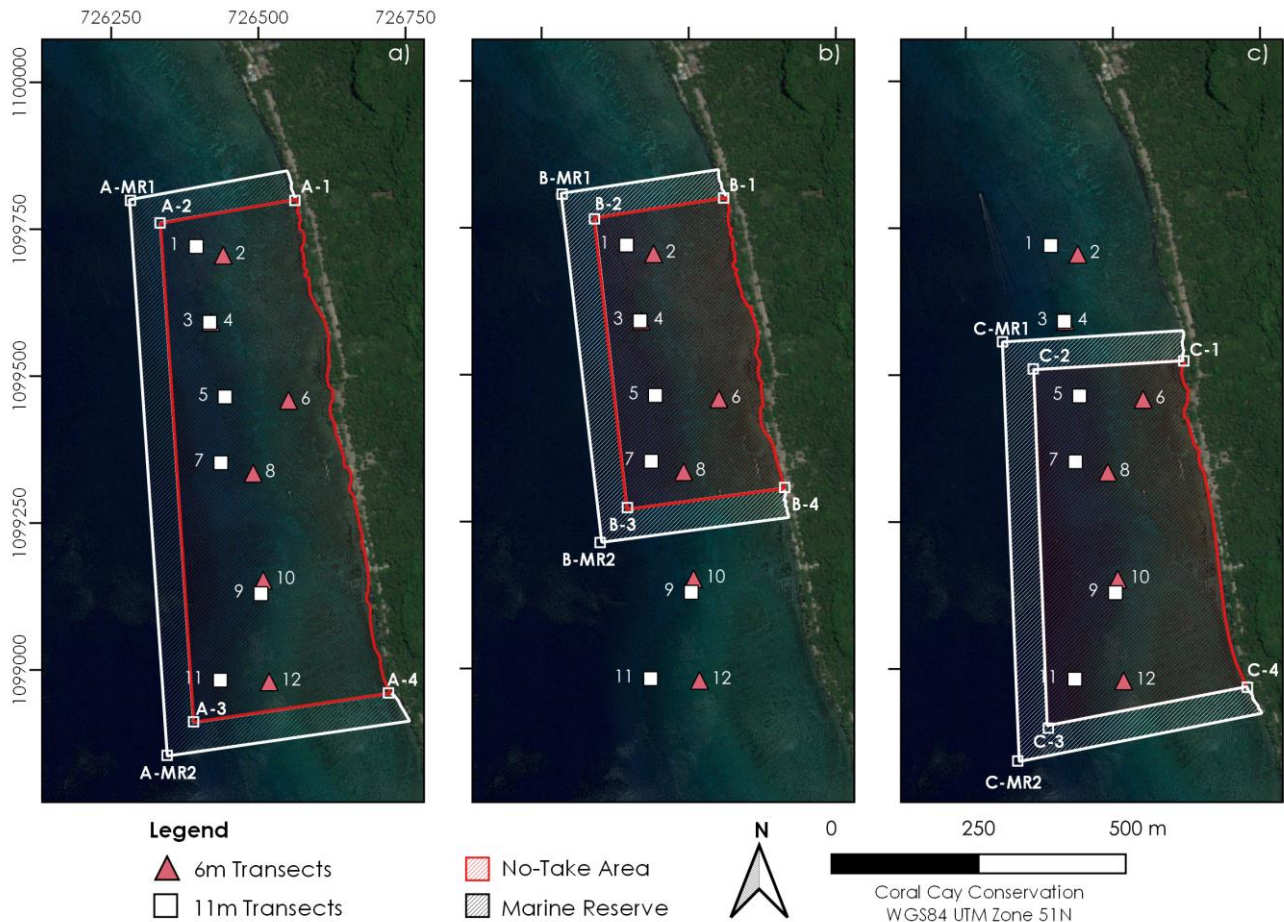


Figure 19. Proposed boundary locations for a No-Take Area (NTA) and Marine Reserve (MR) for the Barangay San Bernardo, Limasawa, in order of priority (a, b and c), the Philippines. The proposed constitutes to a Marine Protected Area (MPA). Demarcation buoy locations are highlighted and sequentially labeled.

participation in management can lead to a greater perceived legitimacy of MPA management, which is a critical step towards user compliance. Compliance towards MPA guidelines, whilst initially may be dictated by the level of enforcement, is a necessary step towards long-term sustainability. If stakeholders are not engaged in the management process, more surveillance and enforcement associated with controlling this lack of compliance, could lead to a negative attitude of stakeholders toward the MPA (Di Franco *et al.* 2016; Pollnac *et al.* 2001). This in turn would distance MPA managers from stakeholders, potentially resulting in law infringements by local fisherman. Ensuring fishermen participate in either formal or informal rulemaking on the MPA management board (suggested in point 2)

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 San Bernardo proposed MPA receives a large influx of single-use plastic items from the adjacent community. If full protection and recovery is to be obtained within the MPA, coastal management regimes to control these anthropogenic-induced threats originating outside of the MPA need to 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*, 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 survey's and training, as well as education days focussing on thinking beyond plastic.

5. Develop Alternative Livelihoods and Skills

A Management Effectiveness Assessment Tool (MEAT) has been conducted by CCC on established MPAs within Sogod Bay. These results have indicated that the communities that are failing in MPA enforcement and user compliance are as a result of the false expectation that MPA establishment alone will lead to increased livelihood opportunities. MPAs do not directly equate to increased tourism, nor does it necessarily equate to increased local income to those stakeholders directly affected by the MPA. With an improved assessment of tourism potential, the capacity for the community to provide services for tourism-related activities, and actual community needs, talents and interests, a tourism plan with associated investment needs could be established. If livelihood expectations are not met, it will have impacts on the management of the MPA. Considering non-tourism business opportunities related to MPA establishment (e.g. MPA members given business opportunities, including law enforcement personnel) could overcome this issue. It will also be integral to the management committee to discuss plans and commitment 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 supplementary factors to consider in the decision-making process. As such, the scenarios outlined here should be used as the initial step in opening a dialogue between all relevant stakeholders in order to come to the best possible conclusion for

all parties. Combining an ecosystem approach to fisheries (EAF) and community-based management (CBM), empowering the local user group level and conferring high levels of transparency in a triangulated consortium, CCC aims to facilitate the local Barangay San Bernardo in achieving measurable levels of effectiveness from their designated MPA. By establishing clear, community driven objectives and goals during the formation of the San Bernardo MPA, CCC hopes to address the key challenge to successful MPAs by ensuring that the MPA by-laws, policies and restrictions fit into the greater ecological, social and economic context; contextualising not only the needs for the fauna and flora present within its boundaries but the needs of the local stakeholders and that of the municipality under the Republic Act No. 8550.

If, after detailed consultation and evaluation, an MPA is designated in Barangay San Bernardo, 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 San Bernardo should be reviewed with consultation between all stakeholders involved. Whilst the site would benefit greatly from protection, establishment should only occur with the support of the local community, and with management and monitoring from both Barangay and Municipal levels.

7. References

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8. Appendices

Appendix A

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

Common Name	Latin Name	Visayan Name
*Angelfish	<i>Pomacanthidae</i>	Adlo
Barracuda	<i>Sphyrnidae</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)	<i>(Pomacentridae)</i>	
*Anemonefish	<i>Amphiprion sp.</i>	
*Sergeant Damsel	<i>Pomacentridae</i>	
Emperor	<i>Lethrinidae</i>	Katambak
*Fusilier	<i>Caesionidae</i>	Dalagangbukid
*Goatfish	<i>Mullidae</i>	Timbongan
*Grouper	<i>Serranidae</i>	Lapu-lapu
*Jack/Trevally	<i>Carangidae</i>	Talakitok
Lionfish	<i>Scorpaenidae</i>	
*Lizardfish	<i>Synodontidae</i>	
*Moorish Idol	<i>Zanclus cornutus</i>	Sanggowanding
*Moray Eel	<i>Muraenidae</i>	
*Parrotfish	<i>Scaridae</i>	Mulmul
*Pufferfish	<i>Tetraodontidae</i>	
*Rabbitfish	<i>Siganidae</i>	Kitong
Ray	<i>Rajiformes</i>	
*Sandperch	<i>Pinguipedidae</i>	
Scorpionfish/Stonefish	<i>Scorpaenidae</i>	
*Snapper	<i>Lutjanidae</i>	Maya-maya
*Spinecheeks	<i>Nemipteridae</i>	Silay
*Squirrelfish/Soldierfish	<i>Holocentridae</i>	
*Surgeonfish	<i>Acanthuridae</i>	Indangan
*Unicornfish	<i>Naso sp.</i>	
*Sweetlips	<i>Haemulidae</i>	Lipti
*Toby	<i>Tetraodontidae</i>	
*Triggerfish	<i>Balistidae</i>	Pakol
(Wrasse)	<i>(Labridae)</i>	
*Crescent Wrasse	<i>Thalassoma lunare</i>	
Humphead Wrasse	<i>Cheilinus undulatus</i>	
*Red Breasted Wrasse	<i>Cheilinus fasciatus</i>	

* Indicates species seen and recorded during surveys in Barangay San Bernardo, Limasawa. The lack of a * indicates this species was not seen during surveys.

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

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

* Indicates species seen and recorded during surveys in Barangay San Bernardo, Limasawa. The lack of a * indicates this species was not seen during surveys.

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

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

* 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	O07	O08	O09	O10	O11	O12
O01		-		-								
O02	+											
O03												
O04	+										+	+
O05												
O06												
O07												
O08												
O09												
O10												
O11		-		-								
O12				-								

Figure B1. Matrix showing significant differences in mean fish abundance per 500m³ across the survey site in San Bernardo, Limasawa, Southern Leyte. 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	O07	O08	O09	O10	O11	O12
O01				+								
O02												
O03												
O04	-											
O05												
O06												
O07												
O08												
O09												
O10												
O11												
O12												

Figure B2. Matrix showing significant differences in Shannon-Weiner Diversity Index (H') in fishes per 500m³ across the survey site in San Bernardo, Limasawa, Southern Leyte. 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	O07	O08	O09	O10	O11	O12
O01		-		-								
O02	+										+	
O03												
O04	+										+	+
O05												
O06												
O07												
O08												
O09												
O10												
O11		-		-								
O12				-								

Figure B3. Matrix showing significant differences in mean target butterflyfish abundance per 500m³ across all survey sites, in San Bernardo, Limasawa, Southern Leyte. 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	O07	O08	O09	O10	O11	O12
O01												
O02												
O03												
O04												-
O05												
O06												
O07												
O08												
O09												
O10												
O11												
O12				+								

Figure B4. Matrix showing significant differences in mean Obligate butterflyfish abundance per 500m³ across all survey sites, in San Bernardo, Limasawa, Southern Leyte. 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	O07	O08	O09	O10	O11	O12
O01												
O02										-		
O03												
O04								-				
O05								-		-		
O06												
O07								-		-		
O08				+	+		+			+	+	+
O09												+
O10		+			+		+	-			+	+
O11								-		-		
O12								-	-	-		

Figure B5. Matrix showing significant differences in mean Facultative butterflyfish abundance per 500m³ across all survey sites, in San Bernardo, Limasawa, Southern Leyte. 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	O07	O08	O09	O10	O11	O12
O01								-	-			
O02								-				
O03								-	-	-		
O04								-				
O05								-				
O06								-				
O07								-				
O08	+	+	+	+	+	+	+				+	+
O09	+		+									+
O10			+									
O11								-				
O12								-	-	-		

(b)

	O01	O02	O03	O04	O05	O06	O07	O08	O09	O10	O11	O12
O01								-				
O02								-				
O03								-	-	-		
O04								-				
O05								-				
O06								-				
O07								-				
O08	+	+	+	+	+	+	+				+	+
O09			+								+	+
O10			+									
O11								-	-			
O12								-	-			

(c)

	O01	O02	O03	O04	O05	O06	O07	O08	O09	O10	O11	O12
O01								-				
O02								-				
O03								-	-	-		
O04												
O05								-				
O06								-				
O07								-				
O08	+	+	+		+	+	+		+		+	+
O09			+					-			+	+
O10			+									
O11								-	-			
O12								-	-			

Figure B6. Matrices showing significant differences in butterflyfish (a) species richness, (b) Shannon-Weiner Diversity Index (H') and (c) Pielou's evenness (J) per 500m³ across survey sites in San Bernardo, Limasawa, Southern Leyte. 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	O07	O08	O09	O10	O11	O12
O01												
O02				+					+			
O03												
O04			-						+			+
O05												
O06									+			
O07												
O08									+			
O09		-		-		-		-		+	+	+
O10									-			
O11									-			
O12				-					-			

(b)

	O01	O02	O03	O04	O05	O06	O07	O08	O09	O10	O11	O12
O01									+			
O02										+	+	
O03												
O04										+	+	
O05										+	+	
O06												
O07												
O08										+	+	
O09	-									+	+	
O10		-		-	-			-	-			
O11		-		-	-			-	-			
O12												

(c)

	O01	O02	O03	O04	O05	O06	O07	O08	O09	O10	O11	O12
O01		+	+			+		+	+		+	+
O02	-			+						+		
O03	-			+						+		
O04		-	-			+		+	+		+	+
O05												
O06	-			-						+		
O07												
O08	-			-						+		
O09	-			-						+		
O10		-	-			-		-	-			
O11	-			-								
O12	-			-								

Figure B7. Matrices showing significant differences in Parrotfish(a), Grouper (b), and Snapper (c) abundance per 500m³ across survey sites in San Bernardo, Limasawa, Southern Leyte. 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	O07	O08	O09	O10	O11	O12
O01		+										
O02	-		-						-			
O03		+		+	+		+	+		+	+	
O04			-						-			-
O05			-						-			
O06												
O07			-						-			
O08			-						-			
O09		+		+	+		+	+		+	+	
O10			-						-			
O11			-						-			
O12				+								

(b)

	O01	O02	O03	O04	O05	O06	O07	O08	O09	O10	O11	O12
O01												
O02										+	+	
O03												
O04										+	+	
O05										+	+	
O06												
O07												
O08												
O09												
O10		-		-	-							
O11		-		-	-							
O12												

(c)

	O01	O02	O03	O04	O05	O06	O07	O08	O09	O10	O11	O12
O01		+				+		+	+		+	+
O02	-			-						-		
O03												
O04		+				+		+	+		+	+
O05												
O06	-			-						-		
O07												
O08	-			-						-		
O09	-			-						-		
O10		+				+		+	+		+	+
O11	-			-						-		
O12	-			-						-		

Figure B8. Matrix showing significant differences in Parrotfish(a), Grouper (b), and Snapper (c) Biomass (Kg) per 500m³ across survey sites in San Bernardo, Limasawa, Southern Leyte. 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	O07	O08	O09	O10	O11	O12
O01		+			-	-	-	-	-	-		-
O02	-		-	-							-	
O03		+			-	-	-	-	-	-		-
O04		+				-		-				-
O05	+		+									
O06	+		+	+							-	
O07	+		+									
O08	+		+	+								
O09	+		+									
O10	+		+									
O11		+				+						-
O12	+		+	+							+	

Figure B9. Matrix showing significant differences in mean invertebrate abundance per 100m² across the survey site in San Bernardo, Limasawa, Southern Leyte. 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	O07	O08	O09	O10	O11	O12
O01												
O02												
O03				-								
O04			+									+
O05												
O06												
O07												
O08												
O09												
O10												
O11												
O12				-								

(b)

	O01	O02	O03	O04	O05	O06	O07	O08	O09	O10	O11	O12
O01		+				+						
O02	-					+						
O03						+						
O04						+		+	+	+		+
O05						+		+		+		+
O06	-	-	-	-	-		-		-		-	
O07						+		+		+		+
O08				-	-		-				-	
O09				-		+					-	
O10				-	-		-				-	
O11								+	+	+		+
O12				-	-		-				-	

(c)

	O01	O02	O03	O04	O05	O06	O07	O08	O09	O10	O11	O12
O01		+				+		+	+	+		
O02	-					+						
O03												
O04						+		+		+		
O05						+				+		
O06	-	-		-	-		-		-		-	
O07						+		+		+		
O08	-			-			-				-	
O09	-					+					-	
O10	-			-	-		-				-	
O11						+		+	+	+		
O12												

Figure B10. Matrices showing significant differences in invertebrate species richness (a), Shannon's Diversity Index (b) and Pielou's evenness (c) per 100m² across all transects in San Bernardo, Limasawa, Southern Leyte. 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.

	HC	SC	SP	RKC	RC	SI	RB	SD	NIA	OT
HC		+	+	+		+	+	+	+	+
SC	-		-		-		-	-	-	-
SP	-	+		+	-	+	-	-	+	+
RKC	-		-		-	+	-	-	-	-
RC		+	+	+		+	+	+	+	+
SI	-		-	-	-		-	-	-	-
RB	-	+	+	+	-	+			+	+
SD	-	+	+	+	-	+			+	+
NIA	-	+	-	+	-	+	-	-		
OT	-	+	-	+	-	+	-	-		

Figure B11. Matrix showing significant differences in Substrate type cover per 20m across all transects in San Bernardo, Limasawa, Southern Leyte. HC; Hard Coral, SC; Soft Coral, SP; Sponge, RKC; Recently Killed Coral, RC; Rock, SI; Silt, RB; Rubble, SD; Sand, NIA; Nutrient Indicator Algae and OT; Other. 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	O07	O08	O09	O10	O11	O12
O01		-		-				-			-	
O02	+											+
O03								-				
O04	+											+
O05												+
O06												
O07												+
O08	+		+						+			+
O09								-				
O10												
O11	+											+
O12		-		-	-		-	-			-	

Figure B12. Matrix showing significant differences in Hard Coral cover per 20m across all transects in San Bernardo, Limasawa, Southern Leyte. 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	O07	O08	O09	O10	O11	O12
O01									-		-	
O02											-	
O03					+		+					
O04												
O05			-					-	-		-	
O06												
O07			-					-	-		-	
O08					+		+					
O09	+				+		+					
O10												
O11	+	+			+		+					
O12												

Figure B13. Matrix showing significant differences in Rock cover per 20m across all transects in San Bernardo, Limasawa, Southern Leyte. 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	O07	O08	O09	O10	O11	O12
O01			+	+				+			+	+
O02												
O03	-			+					-			
O04	-		-		-	-	-		-	-	-	-
O05				+								
O06				+								
O07				+								
O08	-								-			
O09			+	+				+			+	+
O10				+								
O11	-			+					-			
O12	-			+					-			

Figure B14. Matrix showing significant differences in Sand cover per 20m across all transects in San Bernardo, Limasawa, Southern Leyte. 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.

	ACB	ACE	ACS	ACD	ACT	CB	CE	CF	CM	CS	CMR	CHL	CME	CTU
ACB		+	+		-	-	-	-	-	-		+		
ACE	-				-	-	-	-	-	-	-			
ACS	-				-	-	-	-	-	-	-			
ACD					-	-	-	-	-	-	-			
ACT	+	+	+	+		-	-		-	-		+	+	+
CB	+	+	+	+	+			+			+	+	+	+
CE	+	+	+	+	+			+	-		+	+	+	+
CF	+	+	+	+		-	-		-	-		+	+	+
CM	+	+	+	+	+		+	+			+	+	+	+
CS	+	+	+	+	+			+			+	+	+	+
CMR		+	+	+		-	-		-	-		+	+	+
CHL	-				-	-	-	-	-	-	-			
CME					-	-	-	-	-	-	-			
CTU					-	-	-	-	-	-	-			

Figure B15. Matrix showing significant differences Hard Coral lifeform cover per 20m as percentage of total Hard Coral Cover across all transects in San Bernardo, Limasawa, Southern Leyte. 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. ACB= Acropora Branching, ACE= Acropora Encrusting, ACS= Acropora Submassive, ACD= Acropora Digitate, ACT= Acropora Tabulate, CB= Non-acropora Branching, CE= Non-acropora Encrusting, CF= Non-acropora Foliose, CM= Non-acropora Massive, CS= Non-acropora Submassive, CMR= Non-acropora Mushroom, CHL= Heliopora spp., CME= Millepora spp. And CTU= Tubipora spp..

	O01	O02	O03	O04	O05	O06	O07	O08	O09	O10	O11	O12
O01									-		-	+
O02									-		-	+
O03									-		-	
O04												+
O05												
O06												+
O07												
O08												+
O09		+	+	+							+	+
O10											+	+
O11		+	+	+					-	-		
O12	-	-		-		-		-	-	-		

Figure B16. Matrix showing significant differences in Non-Acropora Massive (CM) cover per 20m as percentage of total Hard Coral Cover across all transects in San Bernardo, Limasawa, Southern Leyte. 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	O07	O08	O09	O10	O11	O12
O01								+				
O02												
O03												
O04												
O05												
O06												
O07												
O08	-											
O09												
O10												
O11												
O12												

Figure B17. Matrix showing significant differences in Non-Acropora Submassive (CS) cover per 20m as percentage of total Hard Coral Cover across all transects in San Bernardo, Limasawa, Southern Leyte. 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	O07	O08	O09	O10	O11	O12
O01		-	-	-	-		-			-		
O02	+											
O03	+								-			
O04	+											
O05	+											
O06												
O07	+											
O08												
O09			+									
O10	+											
O11												
O12												

Figure B18. Matrix showing significant differences in Non-Acropora Branching (CB) cover per 20m as percentage of total Hard Coral Cover across all transects in San Bernardo, Limasawa, Southern Leyte. 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.

	FGC	STC	CC
FGC		-	-
STC	+		
CC	+		

Figure B19. Matrix showing significant differences in Hard Coral growth type cover per 20m as percentage of total Hard Coral Cover across all transects in San Bernardo, Limasawa, Southern Leyte. FGC; Fast Growing Corals, STC; Stress Tolerant Corals, CC; Competitor Corals. 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	O07	O08	O09	O10	O11	O12
O01		-	-	-	-		-	-	-	-	-	-
O02	+											
O03	+					+						
O04	+											
O05	+											
O06			-							-		
O07	+											
O08	+											
O09	+											
O10	+					+						
O11	+											
O12	+											

Figure B21. Matrix showing significant differences in Competitor Corals (CC) growth type cover per 20m as percentage of total Hard Coral Cover across all transects in San Bernardo, Limasawa, Southern Leyte. 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	O07	O08	O09	O10	O11	O12
O01			+	+	+	+	+		+	+		
O02												
O03	-											
O04	-											
O05	-											
O06	-									+		+
O07	-											
O08												
O09	-											
O10	-					-						
O11												+
O12						-					-	

Figure B21. Matrix showing significant differences in Stress Tolerant Corals (STC) growth type cover per 20m as percentage of total Hard Coral Cover across all transects in San Bernardo, Limasawa, Southern Leyte. A green '+' indicates abundance was significantly higher at the surveyed transect on the left compared to transect at the top ($p < 0.05$). A blue '-' indicates that abundance was significantly lower at the transect on the left compared to transect at the top ($p < 0.05$). Blank cells indicate no significant difference.

Appendix C



Figure C1. Mean abundance of target fish species and families per 500m³ with standard error ($\pm$ SE) in San Bernardo, Limasawa, Southern Leyte.

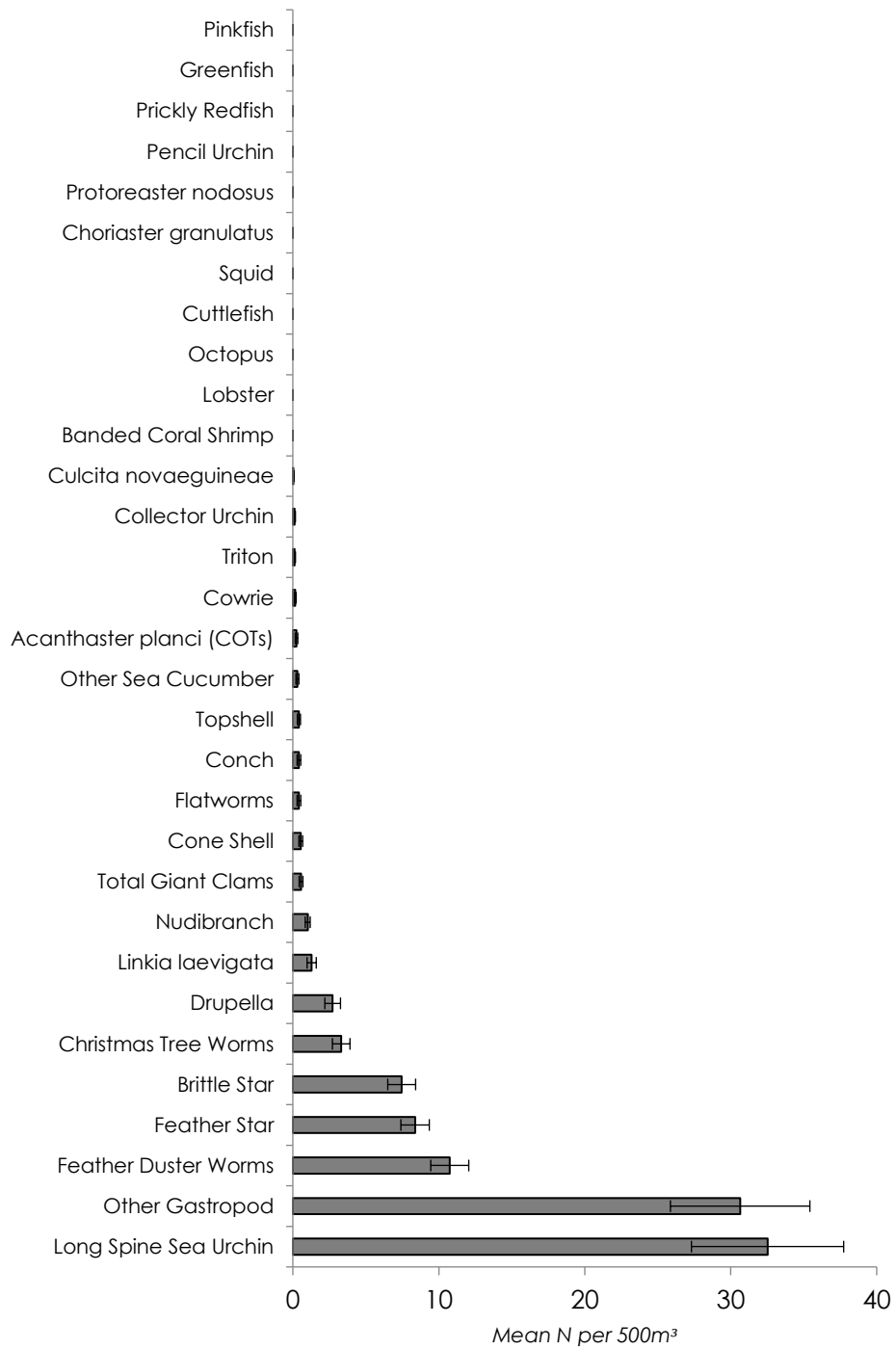


Figure C2. Mean abundance of target invertebrate species and families per 500m³ with standard error ($\pm$ SE) in San Bernardo, Limasawa, Southern Leyte.

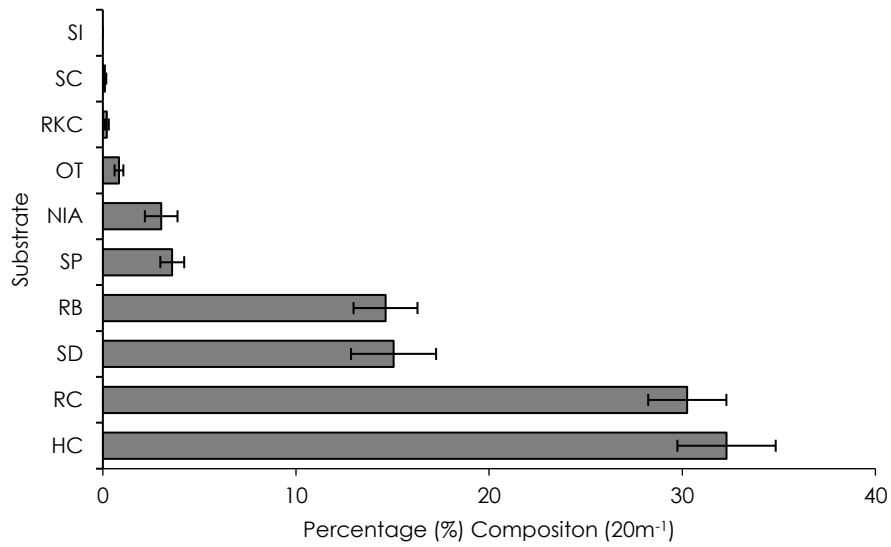


Figure C3. Mean composition (%) substrates per 20m with standard error ($\pm$ SE) in San Bernardo, Limasawa, Southern Leyte. SI; Silt, SC; Soft Coral, RKC; Recently Killed Coral, OT; Other, NIA; Nutrient Indicator Algae, SP; Sponge, RB; Rubble, SD; Sand, RC; Rock, HC; Hard Coral.

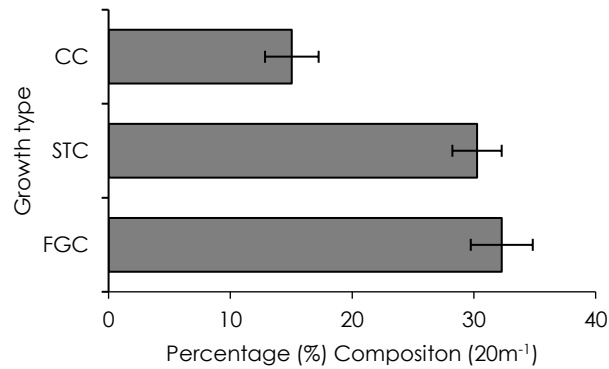


Figure C4. Mean composition (%) of coral growth types with standard error ($\pm$ SE) across transects San Bernardo, Limasawa, Southern Leyte. CC; Competitor Corals, STC; Stress Tolerant Corals; FGC; Fast Growing Corals.

Appendix D

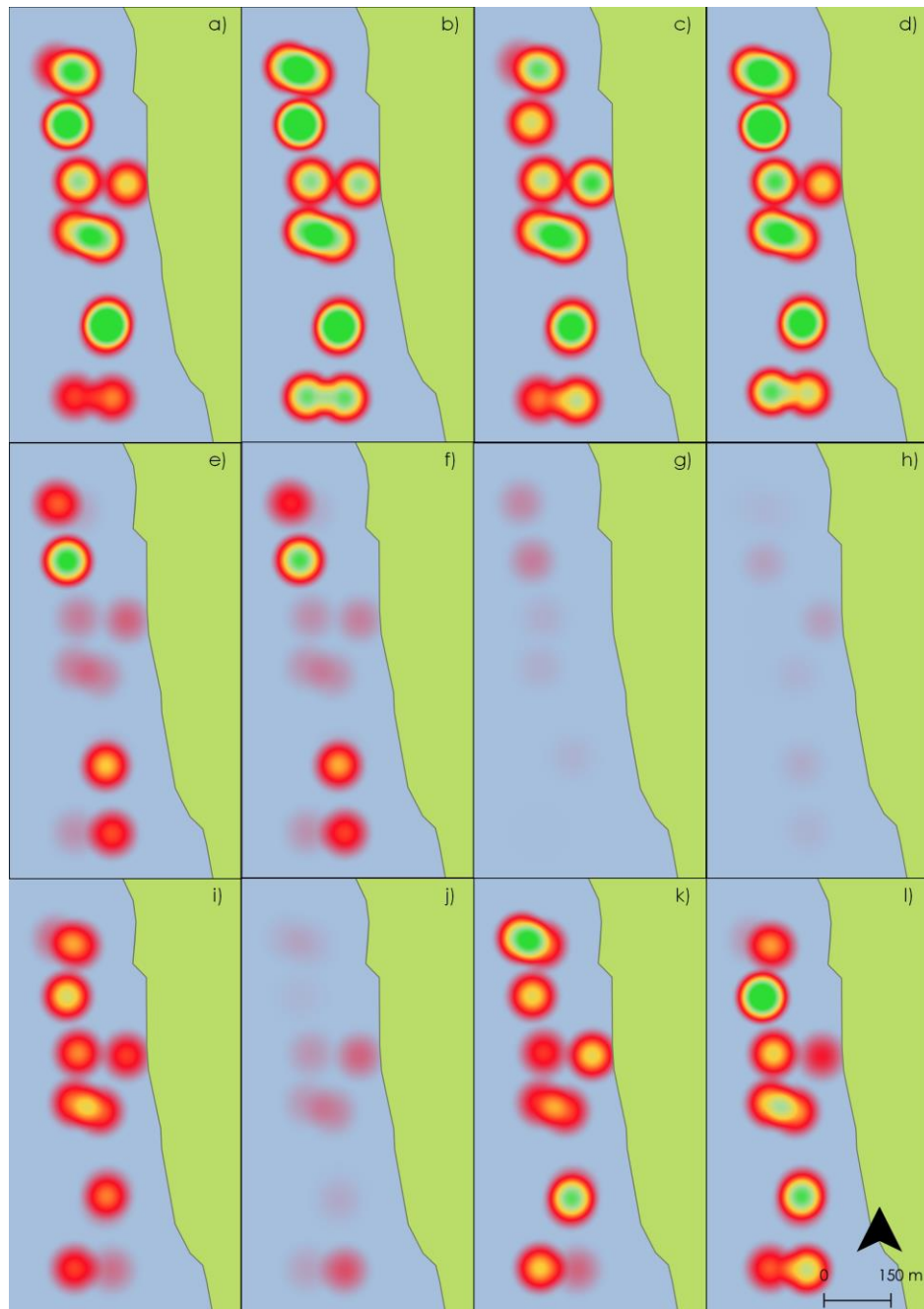


Figure D1. Heat map representing a) Target Fish Abundance, b) Target Fish Diversity, c) Invertebrate Abundance, d) Invertebrate Diversity, e) Total Commercial Fish Biomass, f) Parrotfish Biomass, g) Snapper Biomass, h) Grouper Biomass, i) Proportion (%) Hard Coral Cover of overall substrates, j) Proportion (%) Fast-growing Coral cover as percentage of overall Hard Coral cover, k) Proportion (%) Stress-tolerant Coral as percentage of overall Hard Coral cover and l) Proportion (%) Competitor Coral as percentage of overall Hard Coral cover, for all transects in Pandan, Liloan, the Philippines. Green is used to indicate areas representing larger quantities of variables, while red is used to indicate areas representing lower values in comparison to overall results.

*Note that although values obtained from the surveys in San Bernardo, Limasawa were used in the creation of the above maps, the spatial variation of results between each transect is displayed, and do not depict actual values. Further, these depictions are to represent results obtained in the survey area only, and should not be compared in respect to other sites throughout Sogod Bay. Green show areas with "high" values in relation to other transects within the San Bernardo, Limasawa proposed area, though may be lower than other sites within Sogod Bay in comparison.