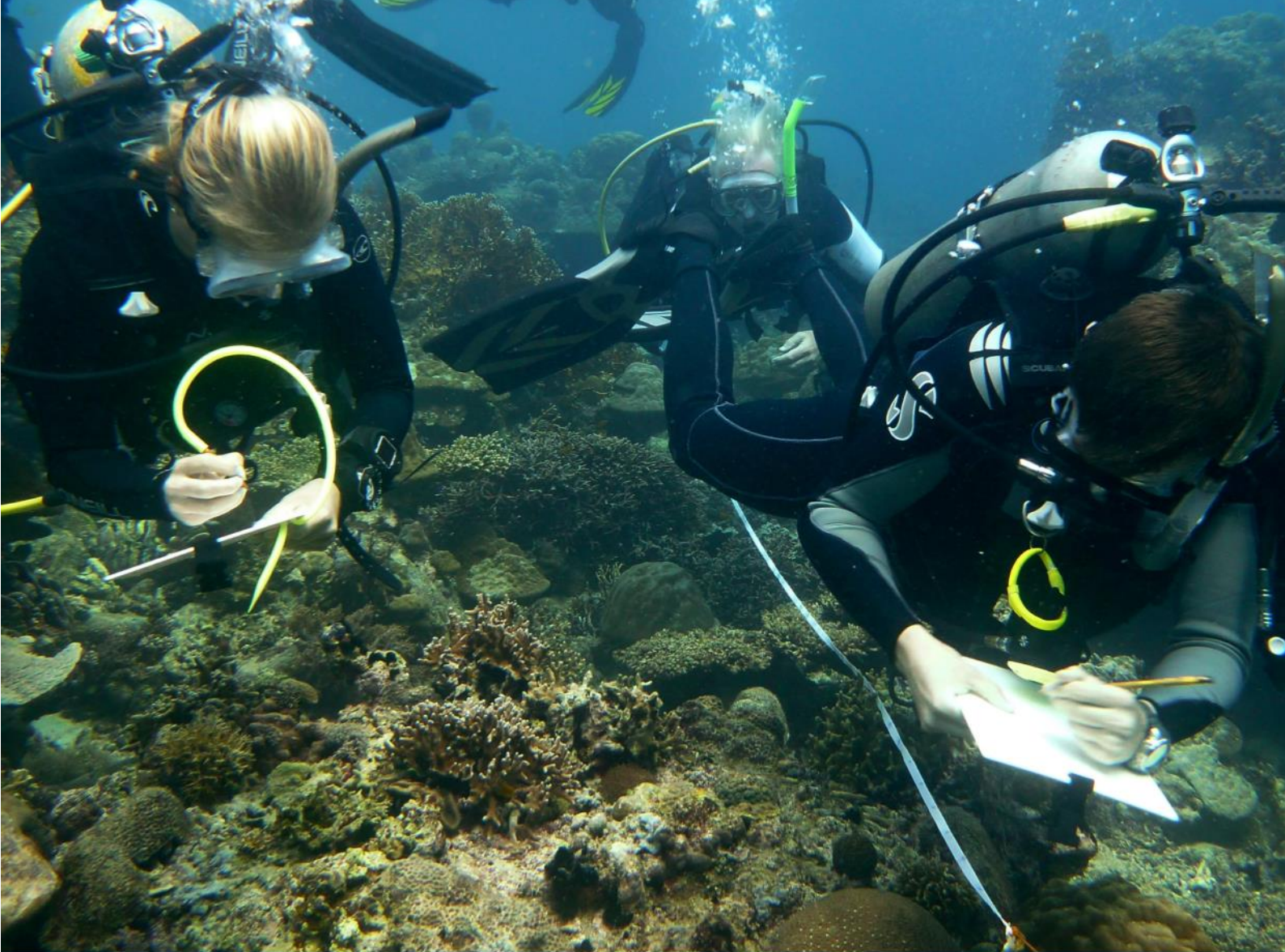




LRCP

Southern Leyte Coral Reef Conservation Project

Assessing the Efficacy of Small-Scale Marine Protected Areas in the Philippines: A Triennial Case Study Barangay Napantao 2013 - 2015



Report Date: February 2017

Tom Dallison & Alex Ferguson

In partnership with the Southern Leyte
Provincial Government, Philippines





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Executive Summary

- Coral Cay Conservation (CCC) conducted a triennial (2013 – 2015) assessment of the coral reef associated fauna and flora communities and anthropogenic impacts, in relation to the established marine protected area (MPA) in the waters of Barangay Napantao, Sogod Bay, Southern Leyte, Philippines.
- An augmented Reef Check protocol was conducted resulting in an annual total of six 100m transects at a depth of 12m. Three transects were located inside of the MPA with the remaining three outside. Data regarding the abundance and diversity of fishes and invertebrates were collected in combination with anthropogenic impacts and benthic substratum composition. This equated to a total of 36 individual 100m transects, throughout the temporal scale. Each 100m transect was separated into four 20m replicates with 5m inter-replicate gaps.
- Populations of fish throughout the sample period exhibited significant declines ($p = <0.05$) on the coral reef as a whole. The species richness of fishes showed no significant trends however preliminary analysis suggests that species decline is occurring at a greater rate outside of the MPA than inside. Furthermore, the diversity of communities outside the MPA displayed a significant decrease ($p = <0.05$) with communities inside of greater diversity and evenness. Each year of the sample period, the diversity of fishes inside of the MPA was greater than that recorded outside ($p = <0.05$).
- The abundance and diversity of invertebrates was stable showing no significant temporal trends or spatial differences.
- Scaridae (Parrotfish) were the dominant commercially important fish family, contributing the greatest standing biomass both inside and out of the MPA throughout the sample period. However, the populations were composed of small cohorts, with a lack of large (>40cm) adults. Lutjanidae (Snapper) and Scaridae abundance decreased outside of the MPA ($p = <0.05$).
- Hard Coral cover decreased by 19% inside the MPA over the sample period ($p = >0.05$). Hard coral was dominated by *Acropora* sp. inside the MPA each sample year conferring a higher complexity. Stress-tolerant corals became the dominant life trait of species inside the MPA in 2015, however the coral composition was deemed to be well balanced and diverse. The composition of sponge outside of the MPA declined from 2013 to 2015 with silt declining across the coral reef ($p = <0.05$).
- The results portrayed are indicative of an MPA that is buffering against species decline but is failing to increase the productivity of the fishery. Although results suggest that the MPA is maintaining the *status-quo*, it is failing to achieve desired objectives. The protected portion of the coral reef is more complex in benthic structure than areas that are unprotected indicating received benefits from the MPA. However, further temporal monitoring may indicate significant negative trends in benthic substratum composition.
- The MPA and respective coral reef are displaying signs of detrimental stressors on near and far-field levels and as a result, CCC recommends that ordinance and directives are adjusted to further enforce MPA by-laws as signs of poaching and overfishing are

prevalent. Furthermore, the promotion of transparency at the local user-group level is recommended to empower local fishers further on a co-management basis.

- Regarding long-term recommendations, CCC recommends that discussions and regional consortiums be developed to engage communities on an inter-municipality level with regards to the potential establishment of Sogod Bay as a region wide MR practicing an ecosystem-based approach to fisheries (EAF). Standardised education material and ordinance will need to be established to achieve this. The Sogod Bay MR will practice a multi-use zonation spatial plan aiming to preserve livelihoods, whilst providing opportunities for alternative livelihoods and increasing the proportion of populations above the poverty line whilst decreasing fishery pressure.



Acknowledgments

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

- The ex-Provincial Governor for Southern Leyte, Hon. Ricardo Mercado (now the current Congressman) for his valued support and guidance throughout the Napantao sample period
- Provincial Governor for Southern Leyte, Hon. Damian G. Mercado, Vice-Governor Coco Hon. Christopherson M. Yap and the Provincial Board members
- Sir, Nedgar Garves and all the staff at the Provincial Tourism Office
- Ma'am Eva Abad and all the staff at the Provincial Environmental and Natural Resource Management Office (PENRMO)
- Dr Arturo Isip, Department of Education, Southern Leyte Division
- All members of the Sogod Bay Sustainable Marine Management Alliance (SBSMMA)
- Hon. Samson Gumutan Jr., Municipal Mayor of San Francisco
- Servando Tio Jr., SB Secretary of San Francisco
- The Barangay Captain and Barangay Council of Napantao
- The members of the Napantao Fish Sanctuary Steering Committee
- Dr Gloria Reyes, Homer de Dios and all staff of Southern Leyte State University
- Our Filipino staff: Tata, Bok Bok, Jesse, 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.



Abbreviations

LRCP:	Southern Leyte Coral Reef Conservation Project
CCC:	Coral Cay Conservation
SDP:	Skills Development Programme
UVC:	Underwater Visual Census
NTA:	No-Take Area
NTMP:	No-Take Marine Park
CaCO ₃ :	Calcium Carbonate
ha:	Hectare (1 ha = 0.01km ²)
NPV:	Net- Profit Value
L _m :	Length of Maturity (cm)
CPUE:	Catch Per Unit Effort (kg/effort ⁻¹)
FAD:	Fish Aggregation Device
MPA:	Marine Protected Area
MR:	Marine Reserve
IUCN:	International Union for Conservation of Nature
EBM:	Ecosystem Based Management
EAF:	Ecosystem Approach to Fisheries
CT:	Coral Triangle
MSY:	Maximum Sustainable Yield
LRFFT:	Live Reef Food Fish Trade
PGSL:	Provincial Government of Southern Leyte
TL:	Total Length (cm)
L:	Length (cm)
W:	Individual Mass (g/500m ³ ⁻¹)
LWR:	Length-Weight Relationship
SL:	Standard Length (cm)
PIT:	Point Intercept Transect
N:	Abundance
S:	Species Richness
MWU:	Wilcoxon-Mann-Whitney U
SRCC:	Spearman's Rank Correlation Coefficient Statistical Analysis
SST:	Sea Surface Temperature (°C)
r _s :	Spearman's Correlation Coefficient
HC:	Hard Coral
SC:	Soft Coral
RKC:	Recently Killed Coral
RC:	Rock
SI:	Silt
RB:	Rubble
SD:	Sand
NIA:	Nutrient Indicator Algae
BC:	Blue Coral (Helioporidae)
FC:	Fire Coral (Milleporidae)
OC:	Organ Pipe Coral (Tubiporidae)
H':	Shannon-Wiener Diversity Index
J':	Pielou's Measure of Evenness
ln:	Natural Logarithm
SE:	Standard Error (±)
EAM:	Epilithic Algal Matrix
f:	Frequency

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Coral Cay Conservation

Founded in 1986, Coral Cay Conservation (CCC) is dedicated to:

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

CCC works in collaboration with government bodies and non-governmental organisations within a specific host country, and does not receive monetary payment for the services provided (Fig. 1). CCC is primarily self-financed through an innovative volunteer participatory scheme in which international volunteers are given the opportunity to gain valuable experience by joining a phase of each project, in return for financial contribution towards project costs. Upon arrival, volunteers are entered into a Skills Development Programme (SDP) that trains them in the skills of marine fauna and flora identification, underwater visual census (UVC) methodologies and further underwater data collection methods. The

SDP is under the guidance of highly experienced and qualified marine scientists, prior to assisting in the acquisition of data. Finances generated from the volunteer programme allow CCC to provide a range of services, including data collection, assimilation and synthesis as well as conservation and environmental education. Technical skills training and other capacity building programmes are provided for international volunteers and local community stakeholders.

CCC has been successfully operating volunteer based conservation programmes in developing countries for 31 years with several internationally notable accomplishments, including the establishment of MPAs around the world. This includes, but is not limited to the creation of the UNESCO World Heritage Site in Belize, the Danjungan Marine Reserve and Wildlife Sanctuary for Negros in the Philippines and the development of several no-take areas (NTAs) around Sogod Bay, Southern Leyte, the Philippines.



Figure 1. Schematic diagram demonstrating Coral Cay Conservation's (CCC) implementation strategy within a specified host country of which CCC are based. The sustenance of livelihoods and poverty alleviation are completed through the restoration and protection of valuable socio-economic ecosystems (coral reefs and forests), accompanied by the promotion of sustainable resource extraction and building local capacity.

1. Introduction

1.1 Coral Reefs

Coral reefs are highly productive systems with the majority residing in shallow, nutrient-poor tropical and sub-tropical coastal waters (Polovina, 1984; Cardini *et al.*, 2014). Corals are of the taxonomic phylum Cnidaria and form a mutualistic symbiotic relationship with a photosynthetic single-celled dinoflagellate alga (*Symbiodonium* sp.), colloquially called *Zooxanthellae* (Rädecker *et al.*, 2015). This relationship enables the coral or coral polyp to fix carbon, and as a result produce a hard, calcium carbonate (CaCO_3) structure or skeleton, termed a corallite (Fig. 2). Coral polyps form large colonies of individuals, with each polyp building their respective corallite. Over a long period of time, with mortality and reproduction (Fig. 2a & 2b), large hard coral structures are built. These structures support the highly complex three-dimensional architecture of coral reefs; hosting highly bio-diverse fauna and flora communities.

The coral reef matrix provides both ecological and socio-economic benefits and services. Evidence indicates that an increased architectural complexity

supports higher ecological, economic and social significance in comparison to coral reefs that demonstrate a reduced complexity (Fig. 3) (Alvarez-Filip, 2010). The high levels of complexity on coral reefs provide niche opportunities for fish and other fauna, consequently, resulting in the increased abundance of fishes and invertebrates, species richness and biomass (e.g. Wilson *et al.*, 2007; Gratwicke *et al.*, 2006; Risk, 1972). Coral reef architectural complexity also provides important services to the benefit of human society (Alvarez-Filip, 2010). For example, the dispersion of wave energy along coastlines reduces the rate of erosion, acting as a natural coastal defence (Sheppard *et al.*, 2005). Additionally, highly complex coral reefs have the ability to support essential fisheries, utilised by local communities for subsistence and to generate income.

The social and economic importance of coral reefs can be further highlighted when placed into economic terms. Studies have previously attempted to quantify the global value of coral reefs (Martinez *et al.*, 2007; Brander *et al.*, 2006; Cesar *et al.*, 2003) with estimates of a total net benefit up to USD\$29.8 billion per year. Conversely,

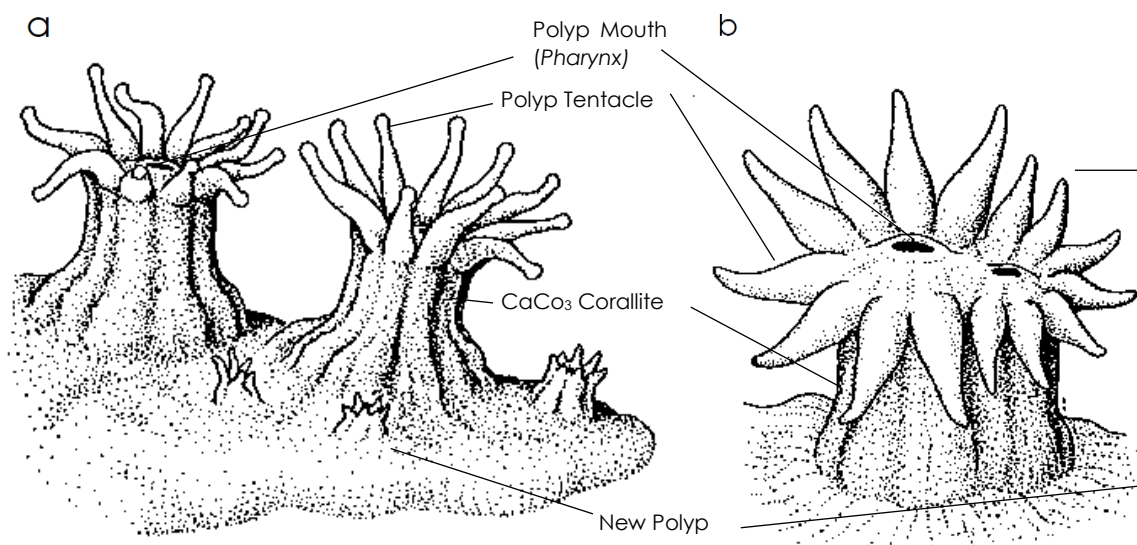


Figure 2. Structural diagrams of a coral polyp's key morphological features. Represented are two different methods of coral polyp asexual reproduction under the term of budding; extratentacular budding (a), and intratentacular budding (b). Retrieved and modified from Barnes (1986).

Brander *et al.* (2006) estimated that the average value of one hectare (ha) of coral reef held the annual value of USD\$2,800. The true value of coral reef ecosystems differs amongst countries, however, all demonstrate their socio-economic and service values. Within the Philippines it was estimated by Samonte-Tan and Amredilla (2004) that the Net Present Value (NPV) of the Philippines' coral reefs was upwards of USD\$449 million roughly translating into approximately USD\$266,122 per km² (USD\$2661 ha⁻¹). It was further recorded that through SCUBA diver's willingness to pay to dive within marine parks throughout the country's archipelago, annual potential returns ranged from USD\$5,300 to USD\$1 million (Arin and Kramer, 2002), with the global value of bio-diversity and fisheries from coral reef ecosystems being USD\$5.5 billion (18%) and USD\$5.7 billion (19%) of the total USD\$29.8 billion value, respectively.

The pressures currently placed on coral reefs on a global scale are extensive, and are only set to rise as the human population places greater resource and economic dependence on coral reef ecosystems.

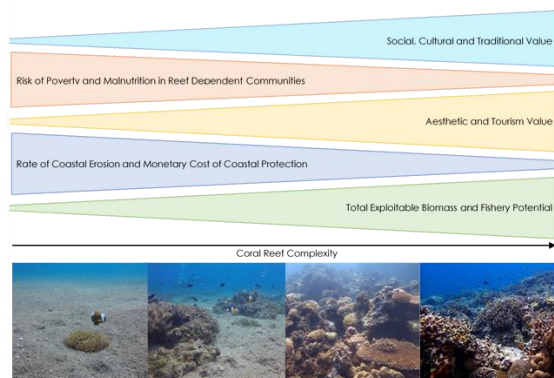


Figure 3. A schematic diagram describing the value and cost of particular ecosystem services and goods, with regards to their respective relationship with a coral reef that is characterised by high levels of complexity. Within the diagram, the x axis represents an increasing coral complexity, aided by photographs of coral reef topography. The respective triangular shapes depict value or amount of the goods received with an increasing width representing an increase in value or amount. Photographs are of coral reef survey sites within Sogod Bay, southern Leyte, the Philippines on behalf of and by Coral Cay Conservation.

1.2 Threats to Coral Reefs

The threats that face coral reefs throughout the world's oceans are diverse; each with its own significant impact on the reef's respective ecosystem. The stressors and impacts experienced by coral reefs can be categorised into three tiers; "far-field", "regional-field", "near-field".

Regional and far-field stressors are those that act over larger, even global, scales (McClanahan *et al.*, 2014). The root cause for the majority of these stressors is the result of anthropogenic modification of the Earth's surface, its climate and ocean chemistry (McClanahan *et al.*, 2014).

Near field stressors are impacts or stressing factors that are a result of local activity or local phenomena under the direct influence of the local human population. Near field stressors such as point-source pollution, local overfishing and destructive fishing practices are often ubiquitous amongst coral reef systems. In contrast to regional and far field stressors, near field stressors do not pose the same barriers to mitigation, and thus, management practices can be tailored to each individual reef, or stressor. The impact of fisheries on coral reefs is widely published (e.g. Bozec *et al.*, 2016; Mumby, 2006; Hughes, 2003) and is known to be a problematic combination, in tandem with increasing human population trends.

Coral reef fisheries are considered small-scale, non-target and multi-gear in nature. Artisanal, technologically poor fishing gears are utilised by their respective fishers (Fig. 4) (Teh *et al.*, 2013) and have been shown to carry a strong impact on coral reefs (McClanahan *et al.*, 2014). In 2000, it was estimated that 15-35% of the 6.2 million fishers throughout the global coral reef regions operate on a small-scale (Sadovy 2005). Further highlighted in 2008, was the fact that small-scale fishers account for 90% of fishers worldwide (Teh *et al.*, 2013; Gonzalez *et al.*, 2008). In 2013, it was approximated by the UN Oceans Atlas (2013) that 3.5 billion people lived within 200km of the coast, suggestive of immense pressures on already highly impacted coral

reef ecosystems. To contextualise this further, southeast Asia exhibited the highest fisher population size of 3.35 million, with the greatest contributors being Indonesia and the Philippines (1.7 million and 912,000, respectively) (Teh *et al.*, 2013).

With coral reef fisheries being over-exploited on a global scale (Teh *et al.*, 2007), 55% of the world's coral reefs are considered to be threatened with 33% highly threatened through overfishing and destructive fishing practices, mitigating these near field stressors is a necessity for local and national governments (Kronen *et al.*, 2010; McClanahan *et al.*, 2008; Teh *et al.*, 2007; Cinner and McClanahan, 2006).

Fish are an important component of any coral ecosystem, playing a key role in the maintenance of the coral reef whilst providing a large proportion of the standing biomass, promoting local biodiversity through niche occupation (Dallison, 2015; Aquilar-Medrano and Calderon-Aquilera, 2015). Coral reef fishes occupy a range of functional groups (e.g. herbivore, coralivore, invertivore) (Bellwood *et al.*, 2004). A functional group can be categorised as a collection or group of different species that all perform a similar role on the reef, despite their

taxonomic differences, i.e. herbivorous parrotfish (Scaridae) are essential in preventing coral being smothered by algae on reefs. These functional groups are essential to preserving the ecosystem services and goods and there have been many studies that have explored their importance (e.g. Cheal *et al.*, 2013). Over-exploitation of these fishes and their respective functional groups through overfishing can often lead to devastating consequences on coral reefs, such as trophic cascades and reduced resilience, proving detrimental for their long-term sustainable exploitation (Cinner *et al.*, 2009). With a healthy community comprising of fishes, invertebrates and other coral reef associated organisms, coral reefs maintain the ability to resist phase shifts, regenerate and retain critical function (Bellwood *et al.*, 2004).

In combination with the removal of functional groups, disrupting the coral reef ecosystem's respective communities, the removal of juvenile cohorts with varying rates can also hold significant consequences for the ecosystem services provided (Weatherdon *et al.*, 2015). The respective selectivity of particular fishing gear results in individuals and species being removed at varying rates, with often, the



Figure 4. Artisanal fishermen reel in their gill-net on board their wooden constructed boat within a tropical coral reef fishery. Gill-nets can be highly detrimental to coral reef associated fish stocks as smaller mesh sized gill-nets are deployed as catches decrease, ultimately removing a greater percentage of the juvenile cohort. The majority of the fish caught within tropical fisheries are for subsistence, however, some are commercially sold to local markets. As human populations increase in coastal and fishery dependent communities, the demand for resources increases often resulting in a 'race to fish' mentality by fishers that increases the number of fishers and the amount of fish removed from the fishery – often tipping the fishery from sustainable to overfished. Photo credited to Tristan Brown (2016).

larger individuals being removed first (Jackson *et al.*, 2001). One of the indicators to overfishing is the total composition of catch that are sexually immature juveniles (Froese, 2004). For many species of fish, their length is related to their ability to spawn and thus, their life-stage. Therefore, by examining a species-specific length (cm) of first maturity (L_M), fisheries managers can determine the total composition of juveniles within a catch. This is an essential component of fisheries management, as the removal of such juvenile cohorts, before the individual fish reach their respective L_M , can result in the natural and fishing mortality surpassing the rate of recruitment, ultimately reducing population size and fish stocks. Furthermore, as the size of fish decreases, resulting in a decrease in the amount of biomass (kg) caught for a unit of effort, fishers will place more effort into the fisheries in order to maintain catch rates (Fig. 5). This principle can be encapsulated under a measure of fishery well-being; termed as the Catch per Unit Effort (CPUE)($\text{kg}/\text{effort}^{-1}$).

Decreases in CPUE and the resulting decrease in fishery productivity can form the basis of the first signs of an array of negative and positive feedback loops that stem from the socio-economical behaviour of fishers (Steneck, 2009). With the strong

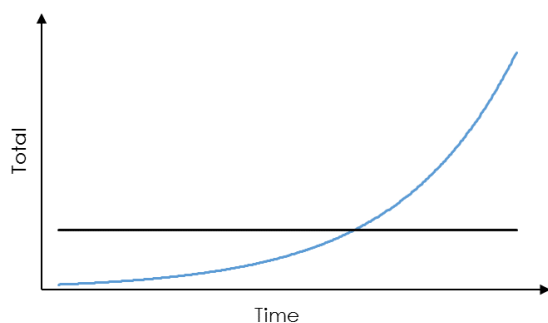


Figure 5. A schematic displaying the relationship between effort (blue) on behalf of a fisher and the total catch (black) when fishers within the fishery are practicing overfishing by removing juvenile sexually immature fish. As more fish are removed from the fishery and populations start to decrease, the fisher must increase their effort to maintain their catch. Eventually, the fisher will reach the highest economically feasible effort, and catches will start to decline. This relationship is also witnessed as more fishers enter the fishery, often associated with increasing human population sizes.



Figure 6. Common results of the use of destructive fishing practices within coral reef ecosystems such as blast fishing and cyanide fishing. Blast fishing is the practice of using explosives to shock and stun fish resulting in them floating on the surface, a consequence of this practice is a reduction in the complexity of coral reefs as the complex three dimensional architecture is destroyed. Cyanide fishing is often deployed by the Live Reef Fish Food Trade (LRFFT) with the cyanide or other poison temporarily stunning the fish enabling the fisher to collect it. As fish swim away from the cyanide before they succumb to its toxic effects, fishes can hide amongst the coral instigating the fisher to aggressively damage coral in order to reach the fish. Furthermore, cyanide and other poisons can have highly detrimental impacts on the coral organisms ultimately leading to mortality.

influence of these social and economic drivers, fishers enter into a 'race to fish' mentality, and employ Malthusian fishing practices which often prove disastrous to coral reef communities, as wholesale destructive fishing gears are utilised (Steneck, 2009; Saila *et al.*, 1993). The use of dynamite or other explosives along with the use of poisons such as cyanide are often common within Malthusian fisheries (Saila *et al.*, 1993). The use of such destructive fishing practices can lead to a loss of the highly complex architectural reef structure, reducing complexity and becoming detrimental to the coral reef associated fishes (Fig. 6) (Saila *et al.*, 1993). The development of Malthusian practices within artisanal fisheries is an indicator that the fishers and their respective communities have entered into what is termed a "Poverty Trap" which is coupled with the inability of coral reefs and their respective biota to exhibit both ecological and economic recovery as well as a lack of alternative livelihoods (Smith, Clifton and Unsworth, 2010; Steneck, 2009).

As a result of the detrimental outcomes of overfishing on coral reefs and the induced

negative and positive feedbacks by local fishers for sustenance, coupled with the far, regional and near-field stressors, mitigation, remediation and prevention efforts by local, regional and national governments as well as resource managers are needed.

1.3 Mitigating the threats to coral reefs

The overall aim of coral reef management should be to sustain the ability of coral reefs to provide the ecosystem services, goods and resources that human communities and their subsequent welfare depends upon (Bellwood *et al.*, 2004). As previously discussed, coral reefs support the livelihoods of millions of communities, especially those that are integrated in subsistence fisheries (Cinner, 2014). With coral reefs exhibiting a high sensitivity to climate change and near-field induced stressors, there is a great need for mitigation and remediation.

There are numerous fishery and coral reef management tools that aim to protect biodiversity, instigate ecological and economic recovery, whilst preserving the livelihoods of stakeholders and the sustainable exploitation of marine resources. Communication, education and outreach efforts, in combination with appropriate training, are all critical elements of coral reef protection and conservation. Through the promotion of sustainable exploitation, managers are able to improve people's understanding of risks and ensure the correct implementation of management measures (Burke, 2011). Local-scale actions during a short-term time scale (<1 year) can include diversification within the fishery, by incorporating lower-impact fishing gears such as artisanal hook-and-line as opposed to high-pressure gears (Cinner *et al.*, 2012). Mid-term time scale actions include the installation of fish aggregation devices (FADs), enabling fishers to exploit pelagic species, thereby relieving pressure on coral reef associated fishes. Long-term time scale induced measures can incorporate and aim for the diversification and provision of alternative livelihood and economic streams. Many of the most common management measures that span over short, mid and long-term time frames are

the implementation of MPAs, NTAs and marine reserves (MRs) (Burke, 2011). MPAs are loosely defined as a marine area that is actively managed for conservation. They can range in their respective conservation efforts from completely restricting activity (NTAs) within extensive, complex frameworks with others limiting fishing activities or certain gears for the ecological benefit of the protected area (Burke, 2011). 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.”

Generally, the most desired benefit of an MPA is increased fish production, this occurs as a result of overspill and larval export from a NTA into surrounding waters, termed the ‘spill-over’ effect (Fig. 7). Over time, the displacement of fishing effort from the MPA increases the adult fish biomass and fecundity. This results in adult fish and larvae being exported to the buffer zone and its surrounding waters. Local fishery yields subsequently increase because they have a continual and sustainable supply of stock (Maliao *et al.* 2004). In areas where there is the potential for increased tourism and anthropogenic pressure on the marine environment for food, recreation and other resources, the benefits and necessities of having a network of functioning MPAs are increased.

MRs are areas of the marine environment where activities are partially restricted. MRs are preferable to areas of no protection but are not as effective as NTAs due to fishing pressure remaining present and being unselective in nature. The sizes, life-stages and species of fish and invertebrates within an MR can be extracted at the discretion of the established framework.

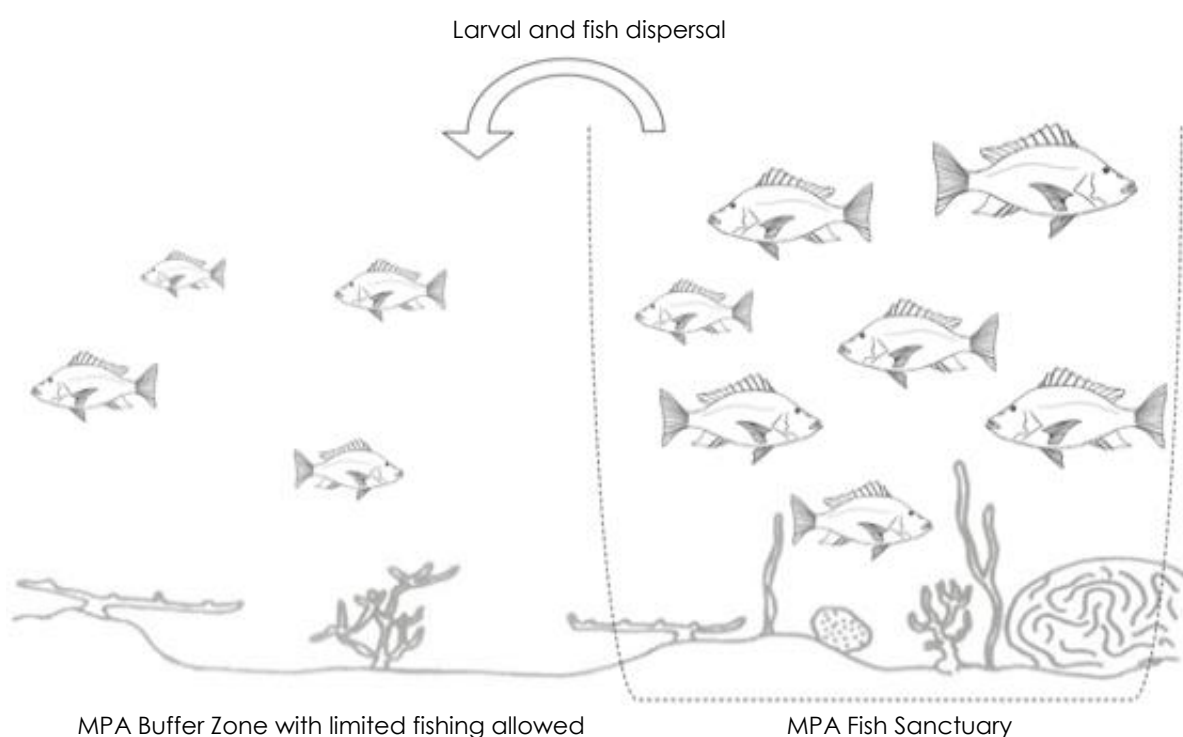


Figure 7. A schematic displaying the 'spill-over' effect that is witnessed through the establishment of marine protected areas (MPAs). As an area is protected from fishing activity, a resilient, ecological community develops. As populations increase and spawning as well as other life-stage events occur, juveniles or larvae spill outside of the MPAs boundaries, establishing within previously degraded areas.

The success of a protected area is entirely dependent upon the compliance of local stakeholders. Research has shown that the involvement of local stakeholders in the planning, implementation and management of their own MPA increases the sense of ownership and pride (Exton, 2010). 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).

A key aspect of the establishment of MPAs, NTAs and MRs is the identification of areas of ecological significance: aggregation, nursery and spawning grounds. These areas are utilised by coral reef and pelagic fishes during respective life-stages and are therefore essential to the recruitment and ecological recovery of communities. This approach is termed ecosystem based management (EBM) or an ecosystem approach to fisheries (EAF), whilst also including anthropogenic activities. With the main goal for local managers should be the successful implementation of EAF into local communities, through the integration of

social and economic dimensions. In this way, managers may achieve sustainability through co-management, and by demonstrating triangulation through local user group decision making, monitoring of both fisheries and the overall ecological status of the coral reef.

1.4 Coral Reefs of the Philippines

The Coral Triangle (CT) confers the world's highest marine diversity, in which over 500 species of coral and 37% of all coral reef associated fishes are found (Veron *et al.*, 2010). Located within the CT is the Philippines, renowned for its highly biodiverse marine ecosystems (Fig. 8). Overall, the Philippines encompasses 22,500km² of coral reefs, 9% of the total global coral reef area, placing the country third, behind Australia and Indonesia (Burke, 2011). With over 460 species of hard corals, representing around half of the total global reef building coral species (Tun *et al.*, 2004), more than 3,000 marine fish species of which 1,700 species are reef-associated (Froese and Pauly, 2016) and 42 mangrove species (Spalding, Kainuma and

Collins, 2010), the Philippines represents a key global hotspot for marine biodiversity.

The population of the Philippines commonly follows the same trends of increasing human population and marine resource exploitation as other countries within the CT, resulting in detrimental impacts upon marine systems (Wilkinson, 2008). It was estimated in 2011 that 40 million individuals reside within 30km of a coral reef, equating to approximately 45% of the total population (Burke, 2011). In addition to overfishing and the unsustainable exploitation of resources, increased sedimentation rates and pollution from land run-off are other examples of chronic impacts, and are highly detrimental to coral reef ecosystems within the Philippines. With a reduction in resilience on coral reefs, their ability to cope with perturbations are reduced (Brander et al., 2007). Overfishing and destructive fishing threaten 98% of reefs in the Philippines, while coastal development and watershed pollution threatens nearly 60% (Burke, 2011). It is estimated that the Philippines fisheries' yield 30% higher catches than the calculated Maximum Sustainable Yield (MSY) (Fig. 9) (Green et al., 2004), and are in need of management. Given the fact that the Philippines human population has demonstrated a 19% increase from 2003 to 2014 (World Bank, 2016), it can be assumed that the demand for marine resources has increased. Fish and fisheries constituted 38.7% capita-1 day-1 of animal protein intake for Filipino's, with a 16.1% capita-1 day-1 contribution to overall protein, in 2011 (FishStatJ, 2011). Reef fish are the main source of protein for the majority (FishStatJ, 2011), with other fisheries including the exploitation of giant clams (*Tridacna* sp.) and sea cucumbers (*Holothuridae* sp.). The importance of coral reef fisheries is emphasised by reports in 2003, that indicated over 2 million Filipinos directly relied upon fisheries for employment, with 1 million dependents through small-scale subsistence fisheries (5

to 35 tons per km² of fish) annually (Green et al., 2004, Barut et al., 2003). These systems are also commercially and economically important for the Live Reef Fish Food Trade (LRFFT). Coastal tourism and diving tourism, in particular, can provide alternative means of income for coastal communities as long as the industry is managed sustainably; reducing or limiting detrimental impacts.



Figure 8. A map of the Coral Triangle (CT) that demonstrates the location of all the respective countries located within the boundaries of the CT. The CT is considered a biodiversity hot-spot that contains over 500 species of hard coral. Located within the CT is the Philippines, an archipelago that consists of over 7,000 islands that encompasses 22,500km² of coral reefs, 9% of the global total. Coral Cay Conservation are based within Southern Leyte, which is highlighted with a circular green marker. Map produced using ArcGIS.

1.5 Coral reefs in Southern Leyte

Southern Leyte, one of the six provinces of the Eastern Visayas (Fig. 10) is bound in the north by the Leyte province, in the south by the Mindanao Sea, in the east by the Pacific Ocean and in the west by the Canigao Channel. Sogod Bay (10° 12' N, 125° 12' E) is surrounded by 132 km of coastline and is shared by 11 municipalities: Padre Burgos, Malitbog, Tomas Oppus, Bontoc, Sogod, Libagon, Liloan, San Francisco, Limasawa, Pintuyan, and San Ricardo.

Sogod Bay is an important fishing ground and the area is rich in tuna, flying fish, herrings, anchovies, shell-fish and Spanish

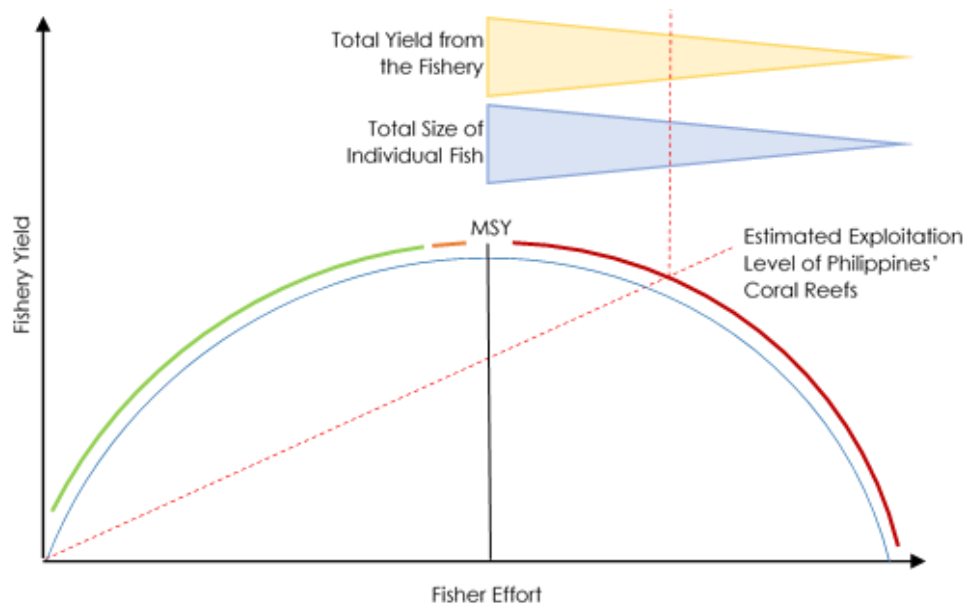


Figure 9. A simplified and adapted maximum sustainable yield (MSY) curve applied to the estimate that, in 2003, the Philippines' coral reef fisheries were fished 30% beyond the MSY (Green et al., 2003). The concept of MSY is when a fish stock is fished at the MSY, fish that would normally enter into the population and increase numbers are removed, enabling the population to remain productive for an indefinite amount of time. If the fish stock is fished below the MSY (green), the fish stock will continue to increase, with population increase rates decreasing as more effort is placed into obtaining fishery yield. Fishing just before or on the MSY (orange) can be risky, as without continuous monitoring, fishing effort could surpass the MSY and result in the population decreasing. Fishing beyond the MSY (red) can be termed as overfishing. This scenario results in a decrease in fishery yield (yellow triangle) and individual fish size (blue triangle) with an increased effort as fishers try to maintain catch. The two triangles resemble quantity and size, with an increased width representing a greater quantity or size. Estimates of the Philippines coral reef fisheries being fished 30% beyond the MSY (red dashed line) can be cross-referenced with the yield and size triangles to give an anecdotal guide to the current status of the Philippines fisheries.

mackerel. It is also a feeding ground for charismatic mega-fauna such as pilot whales, melon-headed whales, dolphins, manta rays and whale sharks.

The bay is characterised by naturally limited mangrove areas, narrow fringing coral reefs, limited seagrass beds and narrow intertidal areas and beaches (Calumpong et al., 1994). While the reefs of Sogod Bay are, in many places, in good condition, they face a number of anthropogenic threats. Signs of overfishing are widespread, with commercially important species such as parrotfish (Scaridae sp., mulmul), groupers (Serranidae sp., lapu lapu), snappers (Lutjanidae sp., maya maya) and sweetlips (Plectorhinchus sp., lipti) present in low numbers throughout the bay.

Currently there are ±23 established MPAs within Sogod Bay covering an estimated 170 ha. These figures will increase in the coming years as more MPAs are designated. The size of the MPAs ranges

from 2 ha (Maujon/Juangon Fish Sanctuary) to 45 ha (Limasawa Fish Sanctuary), with a mean average size of 8.7 ha. The sizes for several MPAs are not known, as accurate GPS coordinates are not available.

1.6 The Southern Leyte Coral Reef Conservation project (LRCP)

In 2002, CCC, in partnership with the Provincial Government of Southern Leyte (PGSL), established the LRCP. Three main objectives were developed:

- I. To conduct scientific assessments of the coral reefs and associated marine habitats in Sogod Bay in order to produce habitat maps and support the sustainable management of marine resources.
- II. To build capacity within government bodies, local organisations and the communities of Southern Leyte to enact sustainable

management of marine resources through training schemes.

- III. To raise awareness of marine conservation issues within the population of Southern Leyte through community engagement and educational programmes.

Between 2002 and 2012 scientific surveys focused on mapping and evaluating the overall status of the reefs in Sogod Bay, with the ultimate goal of identifying key areas of biodiversity. This was in order to establish the appropriate management network needed to conserve and protect biologically rich areas. During this time, MPAs were established throughout Sogod Bay, many with the assistance of CCC. As this occurred, demand increased for ecological monitoring activities within MPAs, to enable successful ecological and socio-economic adaptive management. In 2013 a summary of baseline survey data was produced (Longhurst *et al.*, 2013) and the decision was taken, in collaboration with PGSL, to refocus survey work predominately on MPA monitoring. Alongside this monitoring work, it was agreed that CCC would, when requested, assess specific sites proposed as MPAs.

This report summarises the true effects of the Napantao MPA on the area's fauna, concentrating on the abundance and diversity of coral reef associated fishes, invertebrates and the biotic and abiotic benthic composition. This report encompasses data from 2013 to 2015 and highlights CCC's efforts in the continuous monitoring of this MPA.



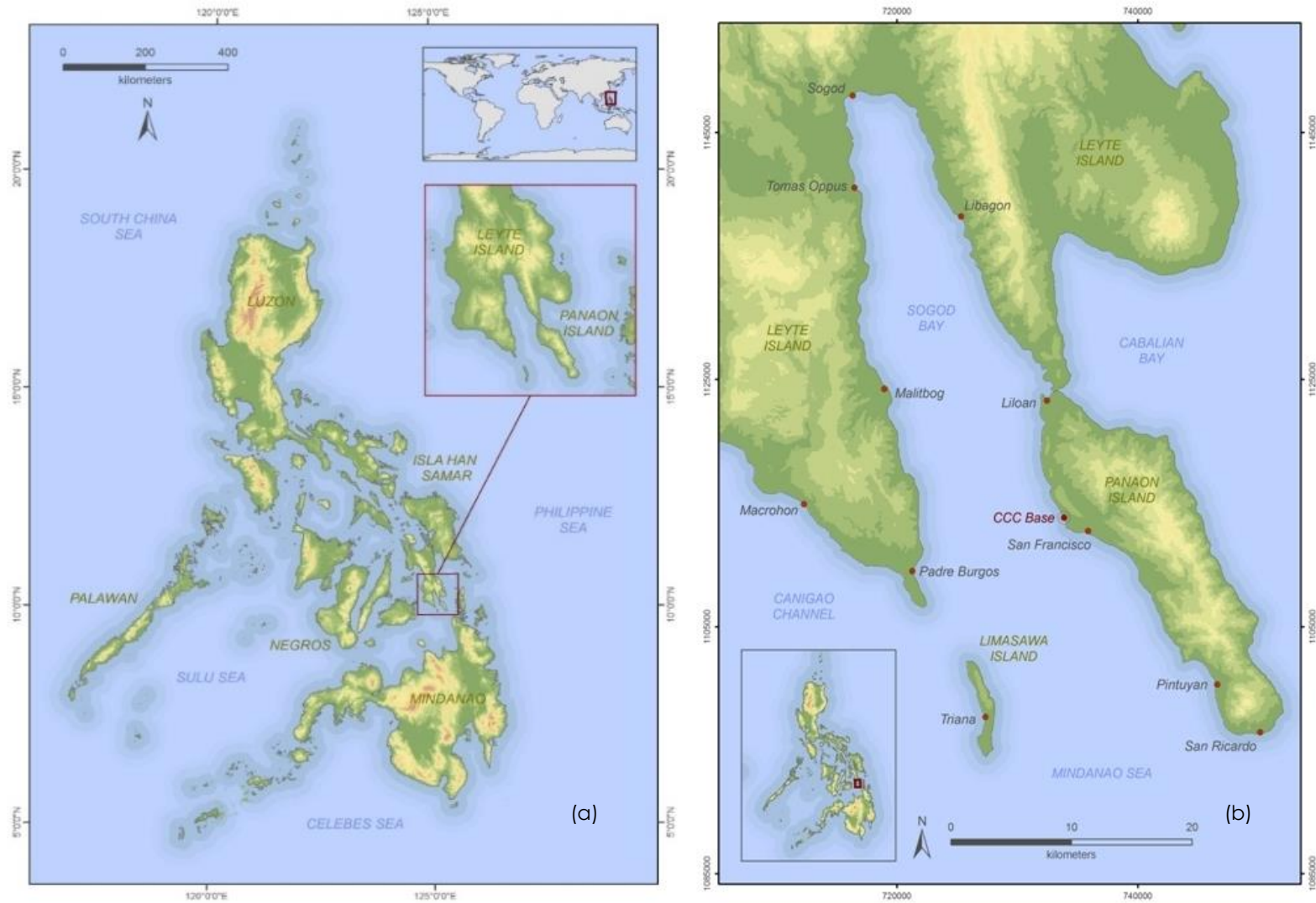


Figure 10. A map of the Philippines (a) and the Southern Leyte Province (b) with Sogod Bay at the centre. The Coral Cay Conservation (CCC) project site is located in the Municipality of Sand Francisco on the south-eastern side of the bay.

2.0 Methodology

2.1 Characterization of the Napantao MPA

The Barangay of Napantao is located on the western coastline of Panoan Island within the municipality of San Francisco, southern Leyte, the Philippines. This region is characterised by calm waters and little precipitation from roughly September to June, a period known as *Amihan*, governed by the northeast trade winds. From June to September, the trade winds switch to south-westerly which leads to increased levels of precipitation and storm surges with hot, humid weather, termed the monsoon season or *Habagat*.

The Napantao MPA, was established in 1996 and covers 5 hectares. The barangay Napantao is home to around 300 people, of which ± 25 are fishers (estimated from most recent records). The boats used by the local fisher folk are mostly non-motorised. The MPA is to the east of the village (Fig. 11). There is a Bantay Dagat hut that is supervised part-time. Currently, the MPA has a relatively good infrastructure in comparison to other MPAs within Sogod Bay (Fig. 11, Table 1).

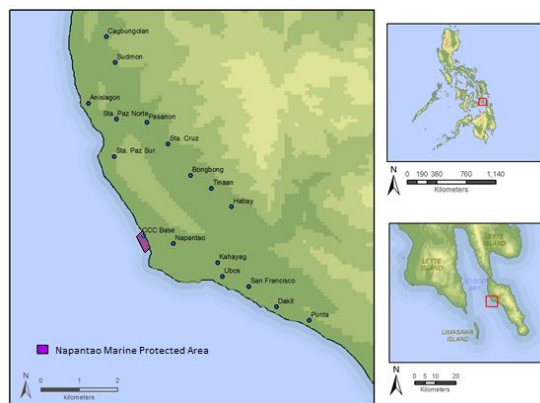


Figure 11. A map indicating the current location of the Barangay Napantao marine protected area (MPA) that is located within Sogod Bay, southern Leyte, the Philippines. The MPA covers a total area of 5 hectares and was established in 1996. The location of the Coral Cay Conservation's (CCC) scientific base alongside other barangay's is exhibited.

Table 1. Summary of the marine protected area (MPA) established infrastructure of the Barangay Napantao, southern Leyte, Philippines.

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

2.2 Data Collection

2.2.1 Biophysical Survey

The assessment of the MPA was conducted using an enhanced Reef Check methodology. The Reef Check methodology is widely recognised and was developed in the 1990s. CCC has augmented the methodology by adding additional target species of fish, coral and other invertebrates to better reflect the high biodiversity of the area (Appendix A). Survey transects were conducted at depths of 12 metres, both inside and outside the MPA on a biannual basis (Fig. 12). Each transect was 100 metres in length and divided into 4 replicates of 20m. Between each replicate there was a 5m inter-replicate gap where no data was recorded allowing robust statistical analysis.

2.2.2 Underwater Visual Census (UVC) for the Assessment of Fishes

The diversity and abundance of fishes was recorded using UVC. Selected fish families and species recognised as being indicators of fishing pressure, LRFFT and reef health were recorded (Table A1). The abundance and species richness of Chaetodontidae (Butterflyfishes) was also determined and

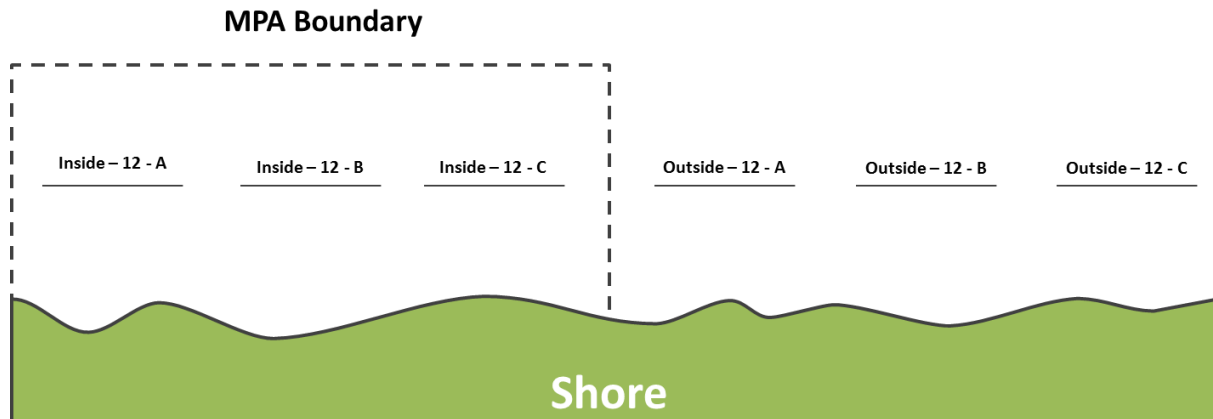


Figure 12. The established survey plan of the marine protected area (MPA) assessments that were conducted over the space of three years within the Napantao MPA, Sogod Bay, southern Leyte, the Philippines. Each transect equated to 100m in length and was sub divided into 4x20m replicates, separated by a 5m inter-replicate gap.

separated into two groups (Obligate and Facultative) based on their feeding guilds. The total length (TL)(cm) of three commercially important fish families (local name, taxonomic nomenclature) was also recorded to enable biomass (kg) calculations to be determined - Groupers (Lapu Lapu, Serranidae), Parrotfish (Mulmul, Scaridae) and Snappers (Maya Maya, Lutjanidae).

Fish data were collected along a 'belt' transect, where fish abundance was recorded within an 5x5x5m box along four 20m replicates (Fig. 13). This equated to a total area surveyed per transect of 2,000m³. Surveying was carried out by two SCUBA divers swimming side by side along the transect and recording target fishes. The divers stopped every 5m and waited 1 minute for target fishes to resume natural behaviour before proceeding.

2.2.3 Biomass Calculations

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

important fish family in accordance with Froese *et al.* (2013) and Froese and Pauly (2000).

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

(1)

$$W = aL^b$$

Equation 1. Length-weight relationships were used to determine the biomass (kg) of each individual recorded on the Barangay Napantao 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).

In order 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) studies and where FishBase listed the study as “doubtful” were excluded.

The respective genera within each family were individually analysed and the subsequent geometric mean determined for the allometric LWR coefficients. To establish the overall allometric coefficient values for the family, the geometric mean was also calculated. For genera that did not supply studies of values that complied with this report's selection criteria, a Bayesian approach was taken in accordance with Froese *et al.* (2013). If no Bayesian approach was readily available, the following geometric means were used for data deficient families of the three families: $a = 0.0112$ and $b = 3.04$. When a target species was categorised as a differing body-form to the status-quo of the family, such as Barramundi Cod (*Cromileptes altivelis*) considered as short and deep by FishBase, special consideration was taken with the species' respective allometric coefficients.

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

Following the discussed process, the appropriate a and b values for each commercially important fish family were determined (Table 3).

2.2.4 Underwater Visual Census (UVC) for the Assessment of Invertebrates

The abundance and diversity of invertebrates was recorded along the same 100m belt transect locations as were used for the assessment of fish within and outside the MPA (Table A2). SCUBA divers followed an 'S' shape to ensure even area coverage. Target invertebrates were established based on their respective value as commercially important species, as a food source for local fishers and their

relative functional group including their value in the collection of curios. Data were collected along a 20m replicate, assessing the area 2.5m either side of the transect line equating to a total area of 100m² replicate⁻¹ (400m² transect⁻¹) (Fig. 14). No data were recorded within the 5m inter-replicate gap.

2.2.5 Point Intercept Transect (PIT) for the Benthic Substrate Composition

Benthic composition was measured by recording biotic and abiotic benthic categories along a point intercept transect (PIT). Along the transect line, benthic organisms and substrate types were recorded at 0.5m intervals (Fig. 15). To minimize bias, a plumb line was dropped at each designated 0.5m point and the substrate type underneath was recorded. Every replicate contained 40 benthic points.

Benthic categories were: sand, rock, rubble, silt/mud, nutrient indicator algae, sponge, recently killed coral, soft coral, hard coral and any other biotic lifeforms. Hard corals were further classified by lifeform and certain targets were also noted to genus or species level (Table A3).

2.2.6 Impact Assessment

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

Table 2. The calculated Length-Weight allometric coefficients to determine the biomass (kg) of sized Grouper, Snapper and Scaridae over a tri-nominal period of 2013 to 2015 within the Napantao marine protected area (MPA), southern Leyte, the Philippines.

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

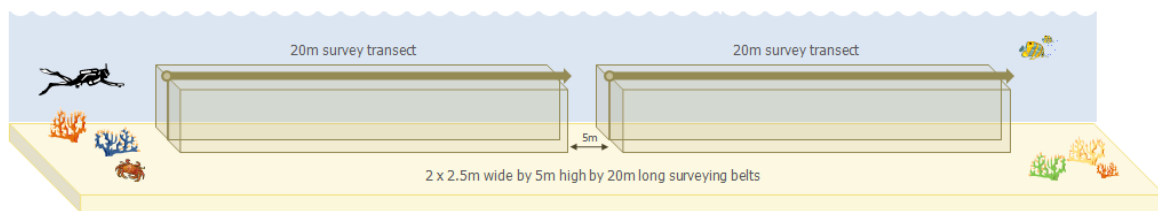


Figure 13. Schematic diagram representing the augmented ReefCheck methodology conducted by Coral Cay Conservation (CCC) surveyors in the assessment of the diversity and abundance of fishes within the Barangay Napantao marine protected area (MPA), Sogod Bay, southern Leyte, the Philippines. Each conducted transect is separated into 4 x 20m replicates segmented by 5m inter-replicate gaps with the abundance of fishes recorded 5m either side of the transect. The presented schematic only represents two of the four 20m replicates.

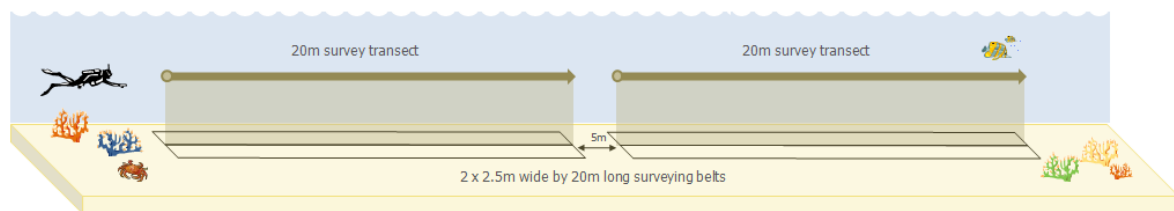


Figure 14. Schematic diagram representing the augmented ReefCheck methodology conducted by Coral Cay Conservation (CCC) surveyors in the assessment of the diversity and abundance of invertebrates within the Barangay Napantao marine protected area (MPA), Sogod Bay, southern Leyte, the Philippines. Each conducted transect is separated into 4 x 20m replicates segmented by 5m inter-replicate gaps with the abundance of invertebrates recorded 2.5m either side of the transect. The presented schematic only represents two of the four 20m replicates.

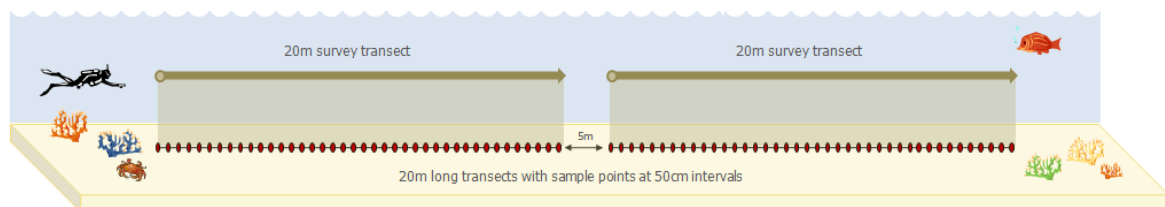


Figure 15. Schematic diagram representing the undertaken point intercept methodology conducted by Coral Cay Conservation (CCC) surveyors in the assessment of benthic composition within the Barangay Napantao marine protected area (MPA), Sogod Bay, southern Leyte, the Philippines. Each conducted transect 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.

2.3 Data Analysis

All analysis was conducted using R v3.2.4 (R Core Team, 2016) through the use of various statistical and graphical packages within the user face.

Each 20m replicate ($n = 72$) was treated as an independent sample. Each independent sample was analysed over a period from 2013 to 2015 with each annual data collection resulting in $n = 24$ samples recorded over two separate monthly periods. Community assemblages present on the coral reef and throughout the sample period were described using abundance (N), species richness (S) and the Shannon-Weiner diversity index (H') (Shannon, 1948) with the complementary Pielou's measure of species evenness (J') (Pielou, 1967). S represents the number of different species found in an ecological community. 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 utilising H' and S (Equation. 2).

$$J = \frac{H'}{H' \max} \quad (2a)$$

$$H' \max = \log e (S) \quad (2b)$$

Equation 2. (a) Pielou's measure of species evenness (J) as described by Pielou (1967) where: H' is the Shannon-Weiner diversity index value; $H \max$ is the product of equation (b); S is the total amount of species recorded in the sample equating to species richness; $\log e$ is the natural logarithm ($\ln$).

To remove the effect of seasonality changes conferred by coral communities, the arithmetic mean was produced from the amalgamation of each monthly period for each year to produce $n = 6$ data sets for each year inside ($n = 3$) and outside ($n = 3$)

of the MPA boundaries. Standard error ($\pm$ SE) were also presented. Furthermore, data were amalgamated to produce one arithmetic mean value for inside the MPA boundary and one for outside for each year sampled.

Following preliminary analysis, the data were tested for normality using Shapiro-Wilks tests, typically used on small data sets to check for normality, that demonstrated the data to be non-parametric ($p = > 0.05$) (Shapiro & Wilk, 1965; Thode, 2002). Square-root transformations of the non-parametric data did not sufficiently alter the data to warrant using parametric based analysis (O'Hara & Kotze, 2010; Morris, 2014). Thus, non-parametric Wilcoxon-Mann-Whitney U (MWU) tests were used to test for statistically significant ($p = < 0.05$) differences in the abundance of fishes, commercially important fishes, target Chaetodontidae, invertebrates, and substrates between all transects, both inside and outside the MPA. MWU tests were also utilised to test for significant differences in biomass (kg) between commercially important fishes as well as invertebrate diversity. Spearman's Rank Correlation Coefficient (SRCC) statistical analysis was carried out on temporal data to test for correlations between results of UVC obtained data, benthic substrate composition data and biomass (kg) data against the triennial period of 2013, 2014 and 2015.

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

3.0 Results

3.1. Biophysical Assessment

Over the tri-annual period during which data were recorded, surveys were conducted on average at 10:13 $\pm$ 00:10am with the mean sea surface temperature (SST) being 28.19 $\pm$ 1.1 $^{\circ}$ C. The water temperature at 10m below the surface dropped to 27.51 $\pm$ 0.11 $^{\circ}$ C, SST and the temperature at 3m displayed no significant correlation (SRCC, p = >0.05) whereas the temperature at 10m decreased over the sample period (r_s = -0.27, p = <0.05) (Table B1). The visibility ranged from 8m to 35m with a mean of 18.03 $\pm$ 0.55m, relating to turbidity. The physical distance from survey locations to the closest population centre and considerable freshwater input were 1.87 $\pm$ 0.03km and 1.10 $\pm$ 0.03km, respectively. Major storm events, considered significant to physically damage coral structures, throughout the sample period were recorded as minimal, with 2014 receiving the greatest number of incidents followed by 2015. The overall anthropogenic impact on the site was considered to be low (1). Delineating the overall anthropogenic impact further, harvesting of invertebrates and artisanal fishing practices were found to be low, whilst commercial fishing practices for vertebrates had no impact on the surveyed site (0). The pollution levels, including industrial pollution were also considered to be low.

3.2. Coral Reef Community Analysis

3.2.1 Coral Reef Associated Fishes

Over the sample period, from 2013 to 2015, a total of 15,872 fishes were recorded from 27 families and one, independent superorder (Table 4). The greatest sampled fishes were Fusiliers, of the family Caesionidae (5,830) with the least represented family being Ephippidae (Spadefish) (3) and Batoidea (rays), a superorder, holding the lowest accumulative abundance of 2 from 2013 to 2015 (Table 4).

Throughout the sample period in both inter-boundary locations, Fusiliers (Caesionidae) dominated the coral reef associated fish communities in all years, excluding 2013 outside of the MPA where cardinalfish (Apogonidae) were the dominant taxa (19.04 $\pm$ 3.75 500m³⁻¹). Charismatic megafauna were recorded in low abundance with *Eretmochelys imbricate* (Hawksbill Turtle) recorded 11 times, with 5 in 2014. Elasmobranchii (Sharks and Manta Rays) were absent from the survey site.

The abundance of fishes recorded outside the MPA boundary represented the highest density of N = 151 $\pm$ 28.50 500m³⁻¹ in 2014, and the lowest density in 2015 (N = 70.08 $\pm$ 7.40 500m³⁻¹), a 53.73% decrease (Fig. 16). Overall, N of fishes outside of the MPA boundary demonstrated a 17.06% decrease, however this decrease was not deemed significant (MWU, p = >0.05). Comparatively, N of fishes inside the MPA boundary also decreased by 21.19%, with 2014 representing the highest and 2015 the lowest (N = 144.38 $\pm$ 28.44 500m³⁻¹ and N = 92.96 $\pm$ 20.85 500m³⁻¹, respectively) (Fig. 16). This decrease in N inside the MPA boundary was significant (U = 159.5, p = <0.05) (Fig. 17). There was an observed negative correlation between N of fishes inside the MPA over the tri-annual period (r_s = -0.29, p = <0.05) (Table B1). The abundance of fishes over the coral reef as a whole declined from 2013 to 2015 (r_s = -0.20, p = <0.05) (Table B1).

Both inter-boundary locations demonstrated a preliminary negative correlation in S over the sample period, however this was not deemed to be significant (p = >0.05). H' was calculated to be H' = 2.27 $\pm$ 0.09 500m³⁻¹ with a high level of evenness (J' = 0.82 $\pm$ 0.03 500m³⁻¹) in 2015, a 1.73% increase from 2013. In comparison, H' from 2013 to 2015 outside of the MPA boundaries decreased by 13.76% (Fig. 16). The decrease in H' observed from 2013 to

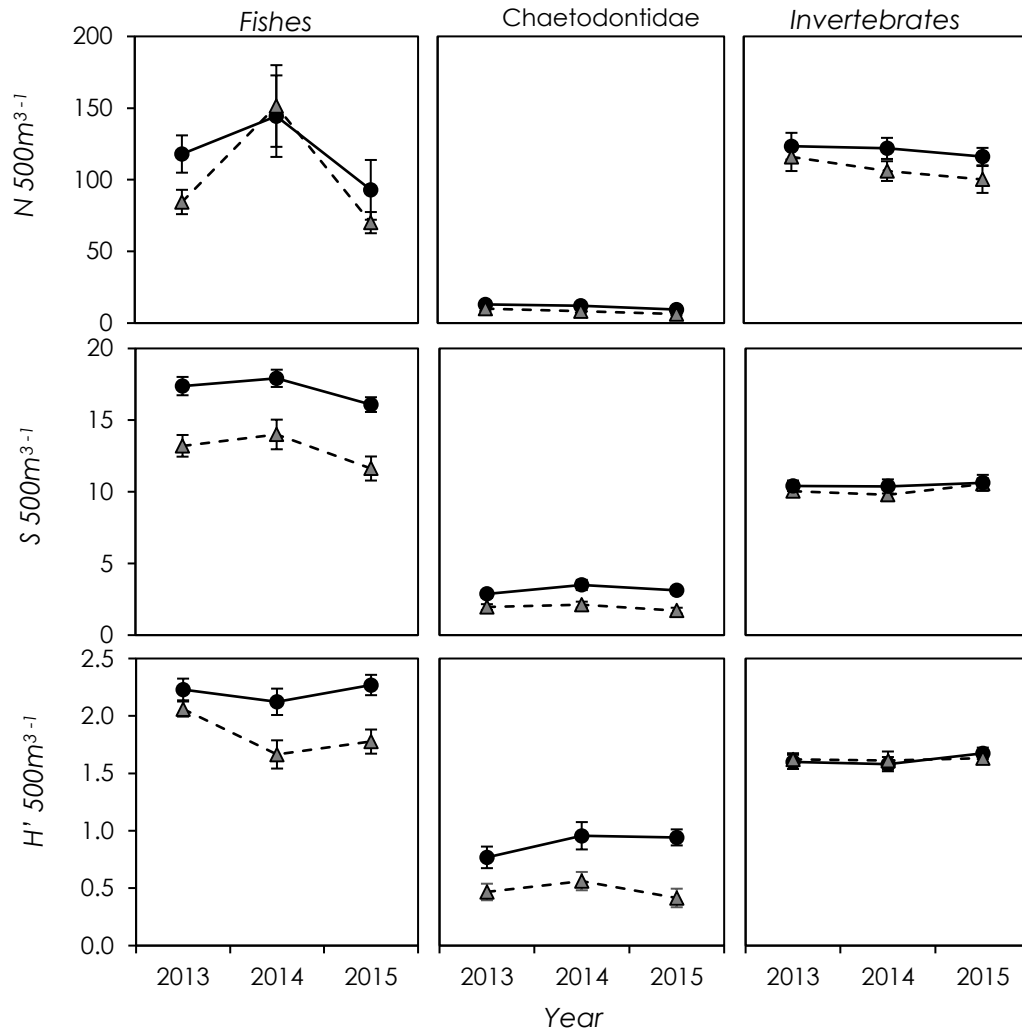


Figure 16. Mean abundance (N), species richness (S) and Shannon-Wiener diversity index (H') per 500m³ for coral reef associate fishes, Chaetodontidae and invertebrates (100m²⁻¹) over a tri-annual period from 2013 to 2015 for Napantao marine protected area (MPA), southern Leyte, the Philippines. The data is represented in two sets with the standard error (SE) given; inside the MPA boundaries (Black filled circle); and outside the MPA boundaries (Grey filled triangle).

2015 outside of the MPA was characterised by a significant negative correlation ($r_s = -0.27$, $p = <0.05$) (Table B1) and significantly different 2013 and 2015 H' values ($U = 402$, $p = <0.05$) (Fig. 17).

On a spatial scale, comparing the N , S and H' of fishes inter-boundary, all inside values, excluding N in 2014, showed a percentage increase in comparison to their respective outside value. N inside the MPA boundary in 2013 was 39.60% higher than N outside (Fig. 20), however this was not significant (MWU, $p = >0.05$). Each year of the tri-annual sample period (2013, 2014 and 2015) the recorded S and H' inside of the MPA boundaries were significantly higher than those recorded outside of the MPA boundaries ($p = <0.05$) (Fig. 17).

Throughout the sample period and survey site, the dominant Chaetodontidae species recorded was *Chaetodon baronessa* (Eastern Triangle Butterflyfish). *C. baronessa* density was the greatest in 2013 inside the MPA boundaries (7.83 ± 0.78 500m³⁻¹) with the lowest density at 4.46 ± 0.42 500m³⁻¹ inside the MPA in 2015 (-43.09%). Inside of the MPA boundaries, Chaetodontidae abundance decreased by 27.48% from $N = 13.04 \pm 1.13$ 500m³⁻¹ in 2013 to $N = 9.46 \pm 0.77$ 500m³⁻¹ in 2015 (Fig. 16), a significant decrease ($U = 403.5$, $p = <0.05$) (Fig. 17). This decline in abundance can be further confirmed by a significant negative correlation ($r_s = -0.28$, $p = <0.05$) (Table B1). Chaetodontidae N outside of the MPA followed the same negative trend ($r_s = -0.24$, $p = <0.05$) resulting in an overall

			Fishes						Chaetodontidae						Invertebrates					
			'13		'14		'15		'13		'14		'15		'13		'14		'15	
			I	O	I	O	I	O	I	O	I	O	I	O	I	O	I	O	I	O
N	'13	I						+	+			+	+	+						
		O																		
	'14	I						+	+			+		+						
		O																		
	'15	I	-		-									+						
		O	-		-	-					-		-							
S	'13	I		+		+		+		+		+		+						
		O	-		-			-		-		-								
	'14	I		+		+		+		+		+		+						
		O	-		-			-		-		-								
	'15	I		+					+		+			-						
		O	-		-			-		-		+								
H'	'13	I		+		+		+		+		+		+						
		O	-			+		-		-		-								
	'14	I				+		+		+		+		+						
		O	-	-	-			-		-		-								
	'15	I		+		+			+		+			+						
		O	-	-	-			-		-		-								

Figure 17. A left-to-right Wilcoxon-Mann-Whitney U test for significance matrix of abundance (N), species richness (S) and Shannon-Wiener diversity index (H') index values of coral reef associated fishes within the Napantao marine protected area (MPA), southern Leyte, the Philippines. Filled sections represent a statistically significant difference ($p < 0.05$). Significant increases ('+', Green) and significant decreases ('-', Red) are given of the respective N value inside and outside of the MPA boundaries.

decrease in Chaetodontidae N on Napantao reef ($r_s = -0.25$, $p = <0.05$). The abundance of Chaetodontids inside of the MPA was significantly higher than that recorded outside in 2014 and 2015 (MWU, $p = <0.05$).

On Napantao reef, both inside and outside of the MPA boundaries, 2014 saw the highest mean diversity, in respect to their comparative annual sample periods with inside values of $S = 3.50 \pm 0.36$ 500m³⁻¹ and $H' = 0.96 \pm 0.12$ 500m³⁻¹ (Fig. 16). The evenness of Chaetodontidae taxa was also the greatest in 2014 both inside and outside ($J' = 0.88 \pm 0.02$ and $J' = 0.81 \pm 0.05$, respectively). No significant correlations or differences were recorded within the same inter-boundary location on the same temporal scale (Table B1, Fig. 17). During each year over the tri-annual sampling period, the N and S of Chaetodontidae inside of the MPA boundaries increased in

comparison to the values outside the MPA boundaries in a multiplicative trend with the greatest increases being recorded in 2015 ($N = 49.34\%$ and $S = 82.93\%$). In addition, each year of sampling, the S and H' were greater inside of the MPA boundaries in comparison to those values outside (MWU, $p = <0.05$) (Fig. 17). The abundance of Obligate *Chaetodon* sp. resembled a negative correlation inside the MPA from 2013 to 2015 ($r_s = -0.43$, $p = <0.05$) (Fig. 18). The decrease in abundance of Obligates outside of the MPA did not significantly decrease although analysis was suggestive ($r_s = -0.23$, $p = 0.05087$). The abundance of facultative *Chaetodon* sp. also declined outside of the MPA boundaries ($r_s = -0.27$, $p = <0.05$). Other trends were not found to be significant (Fig. 18).

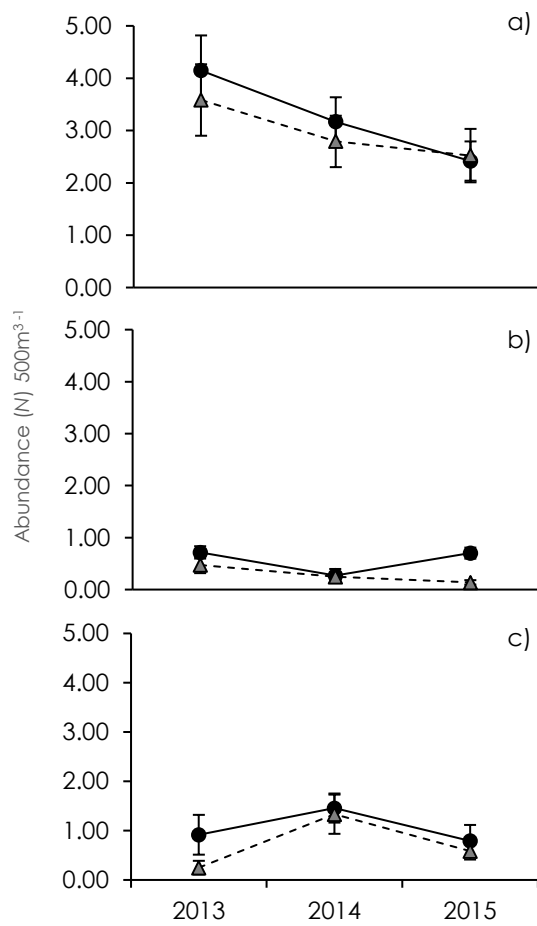


Figure 18. The arithmetic mean abundance (500m⁻³) of obligate coralivores (a); facultative coralivore (b); and other chaetodontids (c) whose feeding modes were not analysed inside (Black filled circled) and outside (Grey filled triangle) of the Napantao MPA, southern Leyte, the Philippines from 2013 to 2015.

3.2.2 Coral Reef Associated Invertebrates

A total of 16,408 marine invertebrates were recorded from 2013 to 2015. Composing of 1 phylum, 6 classes, 1 order, 11 families, 1 genus and 7 species (Table B2). The highest represented invertebrate was brittle stars of the class Ophiuroidea (6,642) whilst Octopodidae and Sepiidae were recorded in the least abundance (1 and 1, respectively) (Table B2). Of the target invertebrates, five were not present on the reef: Triton (Ranelidae); Squid (Lolingidae); Chocolate Drop Starfish (*Protoreaster nodosus*); Prickly Redfish Sea Cucumber (*Thelenota ananas*); and Greenfish Sea Cucumber (*Stichopus hermanni*). The invertebrate community was dominated by Ophiuroidea throughout the sample period both inside and outside of the MPA, with the highest density recorded in 2013 outside of the

MPA (49.71 ± 5.69 100m⁻²) with the lowest density of 36.04 ± 5.27 100m⁻² outside of the MPA in 2015.

The abundance of invertebrates inside and outside of the MPA boundaries suggests a negative correlation between 2013 and 2015 (Fig. 16), however these were not calculated to hold a significant correlation (SRCC, $p = >0.05$) (Table B1). Furthermore, no significant correlation was found for the diversity of invertebrates over the sample period, despite the data indicating a positive trend post 2014 (Fig. 16, Table B1). No significant differences were found between years or locations on both spatial and temporal scales regarding N , S and H' (Fig. 17). Crown of Thorns Seastar (CoTs, *Acanthaster planci*) abundance (100m⁻²) decreased from 2013 to 2015 both inside and outside of the MPA (75% and 100%, respectively). In addition, the majority of Giant Clam (*Tridacna gigas*) sampled throughout the entire period at both locations were measured between 20 – 30cm (28.13%) with the second greatest cohort residing within the size category of <10cm (25%). Lobster (Nephropidae), Triton's trumpet (Charonia), Sea Cucumbers (Holothuroidea) and Squid, Octopus and Cuttlefish, of the class Cephalopoda, all commercially important invertebrate families, were absent or recorded in insignificant abundance throughout the sample period. In contrast, *Diadema* sp. were recorded in relatively high abundance both inside and outside of the MPA, over the sample period (8.88 ± 1.01 100m⁻² and 7.26 ± 1.06 100m⁻², respectively).

3.2.3 Commercially Important Fishes

Of the commercially important fishes recorded and sized, the size structures of the populations ranged, dependent on family (Fig. 19). 2013, inside of the MPA was dominated by Scaridae in the size class 11-20cm ($f = 112$), of which transferred outside of the MPA ($f = 87$) (Fig. 19). This is in comparison to relatively low Serranidae and Lutjanidae frequencies inside the MPA ($f = 93$ and $f = 96$, respectively) of which both families held the greatest frequencies

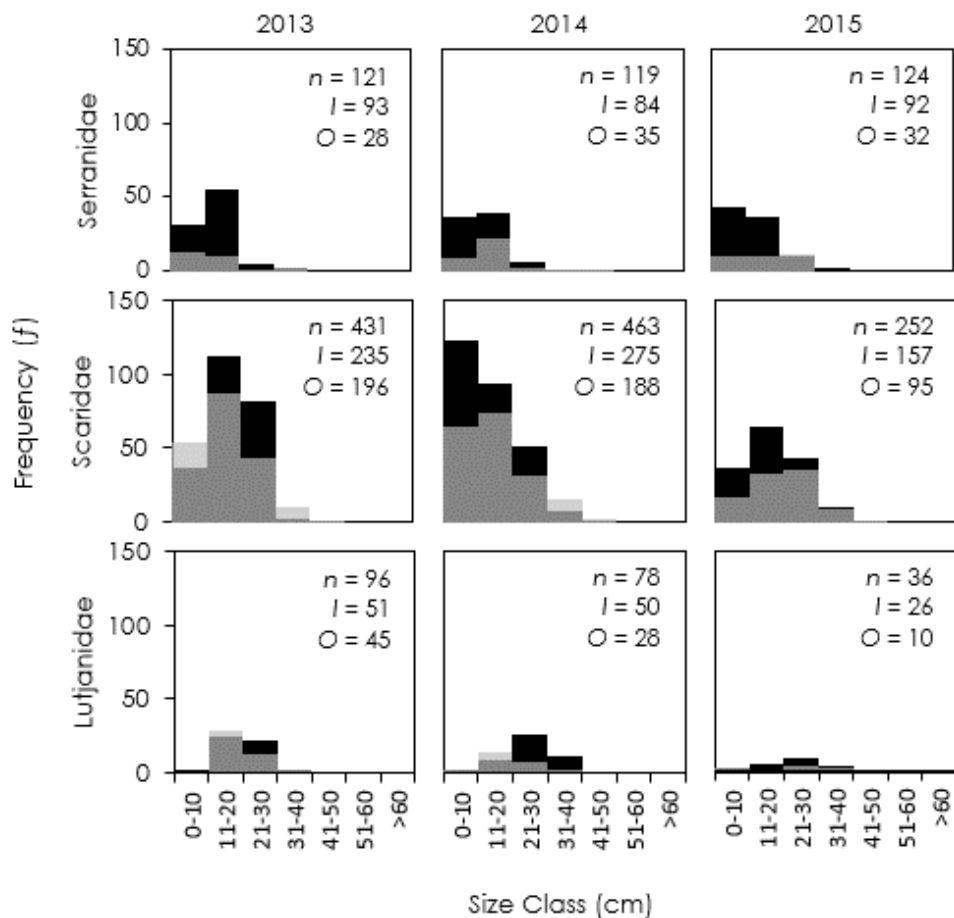


Figure 19. Length-frequency histograms for commercially important species: Serranidae (Grouper); Scaridae (Parrotfish); and Lutjanidae (Snapper). The accumulative frequency is representative for the frequency inside (Black) and outside (Grey) of the Napantao marine protected area (MPA), southern Leyte, the Philippines from 2013, 2014 and 2015. Dark grey represents overlapping frequencies. The total accumulative f (n); the accumulative f inside the MPA (I); and the accumulative f outside the MPA (O) are given.

in the size class 10-20cm ($f = 55$ and $f = 25$) (Fig. 19). In 2014, the majority of Scaridae individuals recorded were <10cm in length inside of the MPA ($f = 123$), whereas, individuals recorded outside of the MPA were between 11-20cm ($f = 74$) (Fig. 19). In comparison to the dominant size class in 2014, Scaridae recorded in 2015 were 11-20cm ($f = 65$) in length inside the MPA, with the second greatest frequency recorded for individuals between 21cm and 30cm ($f = 44$).

The accumulated frequency of Serranidae was stable in all three years (2013 $n = 121$; 2014 $n = 119$; and 2015 $n = 124$), however the size structure of the populations inside the MPA adjusted from those dominated by fishes between 11-20cm to an even spread of lengths between 0.1cm and 20cm (Fig. 19). In each year, the f of Serranidae

recorded were greater inside of the MPA than outside of the MPA (Fig. 19). Outside of the MPA boundaries, the greatest proportion of sized fish were between 21cm and 30cm in length, however this represented a comparatively reduced f to the same size class inside the MPA (Fig. 19). Serranidae populations continued to be dominated by smaller individuals in 2015 (Fig. 19). The size structure of Lutjanidae differed from 2013 to 2015 (Fig. 19). 2014 and 2015 consisted of individuals that ranged from 11-20cm ($f = 26$ and $f = 10$, respectively) inside of the MPA, however the accumulative frequency decreased (Fig. 19). Scaridae were recorded in the highest densities inside the MPA boundary in 2013, 2014 and 2015 (9.79 ± 0.66 500m³⁻¹, 11.46 ± 0.47 500m³⁻¹ and 6.54 ± 0.20 500m³⁻¹,

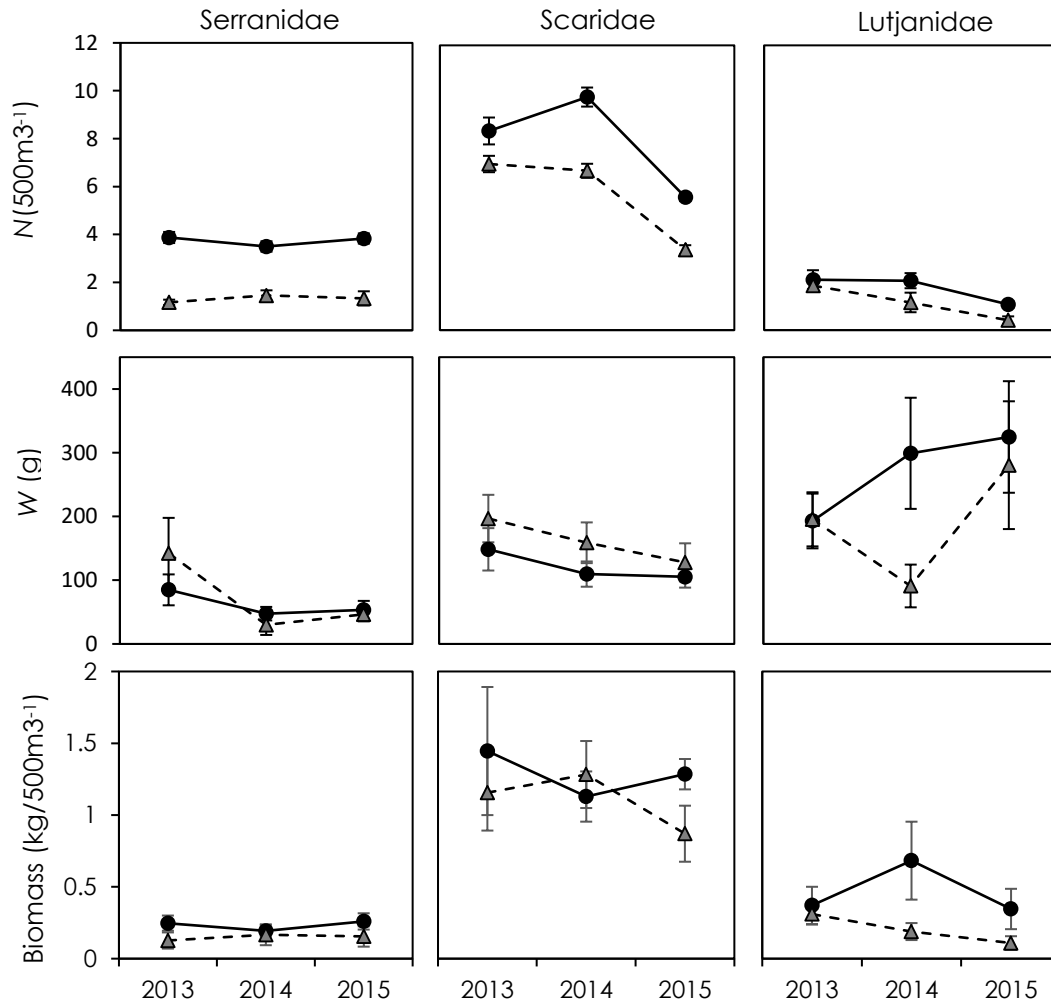


Figure 20. Mean abundance 500m⁻³ (N), Individual weight g/500m⁻³ (W) and mean biomass kg/500m⁻³ for commercial important fishes (Grouper (Serranidae), Parrotfish (Scaridae) and Snapper (Lutjanidae)) over a tri-annual period from 2013 to 2015 for Napantao marine protected area (MPA), southern Leyte, the Philippines. The data is represented in two sets with the standard error (SE) given; inside the MPA boundaries (Black filled circle); and outside the MPA boundaries (Grey filled triangle).

followed by Serranidae (Fig. 20). Lutjanidae represented the lowest density inside and outside the MPA in 2015 (1.08 ± 0.15 500m⁻³ and 0.42 ± 0.16 500m⁻³) (Fig. 20). Scaridae density decreased by 33% inside the MPA from 2013 to 2015 with Lutjanidae exhibiting the greatest decrease of 49% (Fig. 20). However, such decreases in density were not determined as significant (MWU, $p = >0.05$) (Fig. 21) and no significant correlation was observed (SRCC, $p = >0.05$) (Table B1). The same trends of decreasing abundance were observed over the sample period for Scaridae and Lutjanidae (-33% and -78%) outside of the MPA boundaries with both exhibiting negative correlations ($r_s = -0.30$, $p = <0.05$ and $r_s = -0.39$, $p = <0.05$, respectively).

Changes in N by Serranidae were not significant (MWU, $p = >0.05$) nor were any significant correlations determined. In comparison between the abundance of Serranidae, Scaridae and Lutjanidae inside and outside of the MPA boundaries, from the observable data, all three exhibited a higher abundance inside throughout the sample period (Fig. 20), however only Serranidae and Scaridae exhibited significant spatial differences ($p = <0.05$) (Fig. 21). Lutjanidae, inside of the MPA, held the greatest W (g) with a mean of $W = 324.77 \pm 87.19$ g in 2015 with lowest recorded in 2013 at $W = 192.93 \pm 42.95$ g (Fig. 20), however, this difference was not deemed significant (MWU, $p = >0.05$) (Fig. 21).

			Grouper (Serranidae)						Parrotfish (Scaridae)						Snapper (Lutjanidae)					
			'13		'14		'15		'13		'14		'15		'13		'14		'15	
			I	O	I	O	I	O	I	O	I	O	I	O	I	O	I	O	I	O
N	'13	I		+		+		+						+						+
		O	-		-		-			-				+						+
	'14	I		+		+		+	+		+	+	+							+
		O	-		-		-			-				+						
	'15	I		+		+		+		-				+						
		O	-		-		-		-	-	-	-	-		-	-	-			
W	'13	I		-				+												
		O	+		+		+													
	'14	I		-				+									+			
		O														-				
	'15	I		-				+												
		O	-		-		-													
Biomass	'13	I					-	-												+
		O																		+
	'14	I																		+
		O					-	+												
	'15	I	+			+														
		O	+			-									-	-	-			

Figure 21. A left-to-right Wilcoxon-Mann-Whitney U test for significance matrix of abundance (N), species richness (S) and Shannon-Wiener diversity index (H') index values of coral reef associated fishes within the Napantao marine protected area (MPA), southern Leyte, the Philippines. The statistical analysis was conducted with a confidence level of 95% and therefore filled sections of the matrix represent a statistically significant difference ($p < 0.05$). Significant increases ('+', Green) and significant decreases ('-', Red) are given of the respective N value inside and outside of the MPA boundaries.

This is in comparison to the W of Scaridae and Serranidae inside of the MPA boundaries with Serranidae representing the lowest mean W of fishes recorded; the lowest being recorded in 2014 (47.51 ± 10.62 g) (Fig. 20). No correlations (SRCC, $p > 0.05$) were calculated for each commercially important family inside the MPA boundaries over the sample period (Table B1). Conversely, no correlations between the W and 2013, 2014 and 2015 were observed outside of the MPA (Table B1) with the lowest recorded W being 29.97 ± 15.86 g in 2014 represented by Serranidae (Fig. 20). In combination with the 2015 W recorded inside the MPA for Lutjanidae, the outside W (280.52 ± 100.24 g) was also the greatest in comparison to Serranidae and Scaridae outside W values (Fig. 20). On a spatial scale, differences in W inter-

boundary were deemed to be significant ($p < 0.05$) for Serranidae in 2013 and 2015 as well as Lutjanidae in 2014 (Fig. 21).

Scaridae held the greatest mean biomass ($\text{kg } 500\text{m}^3^{-1}$) inside the MPA throughout the sample period with greatest mean biomass of $1.45 \pm 0.45 \text{ kg}/500\text{m}^3^{-1}$ in 2013 (Fig. 20). Scaridae biomass in 2013 subsequently decreased by 11% to $1.28 \pm 0.11 \text{ kg } 500\text{m}^3^{-1}$, in 2015 (Fig. 20) however, this decrease was not significant (SRCC, $p > 0.05$) (Fig. 21). Serranidae biomass was the lowest in 2014, inside the MPA, at $0.19 \pm 0.04 \text{ kg } 500\text{m}^3^{-1}$ and was subsequently the poorest represented commercially important family between 2013 and 2015 (Fig. 20). No correlations in mean biomass were calculated for Serranidae, Scaridae and Lutjanidae inside the MPA during the sample period (SRCC,

$p = >0.05$). Scaridae also represented the greatest biomass outside of the MPA in 2013, 2014 and 2015 ($1.16 \pm 0.26 \text{ kg } 500\text{m}^3^{-1}$, $1.28 \pm 0.23 \text{ kg } 500\text{m}^3^{-1}$ and $0.87 \pm 0.20 \text{ kg } 500\text{m}^3^{-1}$, respectively) (Fig. 20). The lowest biomass outside of the MPA was in 2015, with Lutjanidae ($0.11 \pm 0.05 \text{ kg } 500\text{m}^3^{-1}$) exhibiting a 65% decrease from 2013 ($0.31 \pm 0.07 \text{ kg } 500\text{m}^3^{-1}$) (Fig. 20), a negative correlation ($r_s = -0.30$, $p = <0.05$), which is supported by a significant difference in 2013 and 2015 biomass values ($U = 398.5$, $p = <0.05$). This resulted in a negative correlation ($r_s = -0.18$, $p = <0.05$) for Lutjanidae on Napantao coral reef as whole. The temporal changes in Serranidae, both inside and outside of the MPA, between 2013 and 2015, were minimal (Fig. 20).

On a spatial scale, comparing biomass values in the same year either side of the boundary, no significant differences (MWU, $p = >0.05$) were observed for Serranidae, Scaridae and Lutjanidae (Fig. 21). The greatest difference inter-boundary was observed in the mean biomass of Lutjanidae in 2014 with an inside biomass of $0.68 \pm 0.27 \text{ kg } 500\text{m}^3^{-1}$ and an outside biomass of 0.19 ± 0.06 , a 72% difference (Fig. 20).

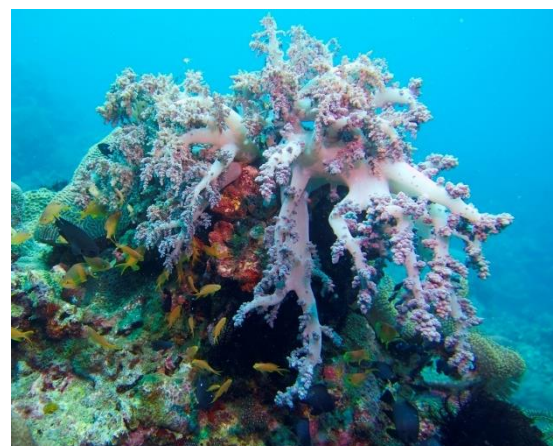
No *Bolbometopon muricatum* (Green Bumphead Parrotfish) or *Cromileptes altivelis* (Barramundi Cod) were recorded over the entire sample period in either inter-boundary location.

3.2.4 Benthic Substrate Composition

Mean hard coral (HC) cover (%) decreased by 19% from $47.81 \pm 3.32 \% 20\text{m}^{-1}$ in 2013 to $38.65 \pm 3.54 \% 20\text{m}^{-1}$ in 2015 inside the MPA boundaries (Fig. 22a, Table 4) however this decrease was not calculated to be significant (MWU, $p = >0.05$, SRCC, $p = >0.05$). On a spatial scale, the HC composition was also higher inside the MPA than outside the MPA ($27.60 \pm 4.11 \% 20\text{m}^{-1}$) in 2013 (Fig. 22a) ($U = 392.5$, $p = <0.05$) (Fig. 23). *Acropora* branching corals were the dominating lifeform inside of the MPA each sample year (Table 5). Comparatively, outside of the MPA, non-*Acropora* sub-massive corals dominated 2013 (19.46 ± 4.35

%) with non-*Acropora* encrusting and non-*Acropora* massive corals dominated 2014 and 2015, respectively (Table 5). Soft coral (SC) composition from 2013 to 2015 showed no significant change in physical composition in both inter-boundary locations, despite a 45% increase outside of the MPA (Fig. 22b, Table 4). In comparison, the composition of sponge outside of the MPA can be characterised by a negative correlation ($r_s = -0.26$, $p = <0.05$) (Table B1) over the sample period falling from $6.46 \pm 1.00 \% 20\text{m}^{-1}$ in 2013 to $3.54 \pm 1.29 \% 20\text{m}^{-1}$ in 2015 (-45%) (MWU, $p = >0.05$) (Table 4, Fig. 22). Recently Killed Coral (RKC) composition decreased over the tri-annual period both inside and outside of the MPA (-44% and -63%, respectively) (Table 4), however, no significant differences (MWU, $p = >0.05$) or correlations (SRCC, $p = >0.05$) were calculated for RKC on both spatial and temporal scales (Fig. 22). The amount of Rock (RC) inside of the MPA increased by 26% (Table 4) from 2013 to 2015 resulting in a significantly higher composition ($U = 296.5$, $p = <0.05$) (Fig. 23) inside of the MPA in $p = <0.05$ (Fig. 23) in comparison to outside of the MPA (Fig. 22).

The composition of Silt (SI) decreased over the site overall ($r_s = -0.34$, $p = <0.05$) with SI composition representing the greatest decrease of 100% from 2013 to 2015 inside the MPA (Table 4) ($r_s = -0.38$, $p = <0.05$) (Fig. 22, Table 4, Table B1). The composition of Rubble (RB), Sand (SD) and Nutrient Indicator Algae (NIA) showed no decrease or increase over the sample period.



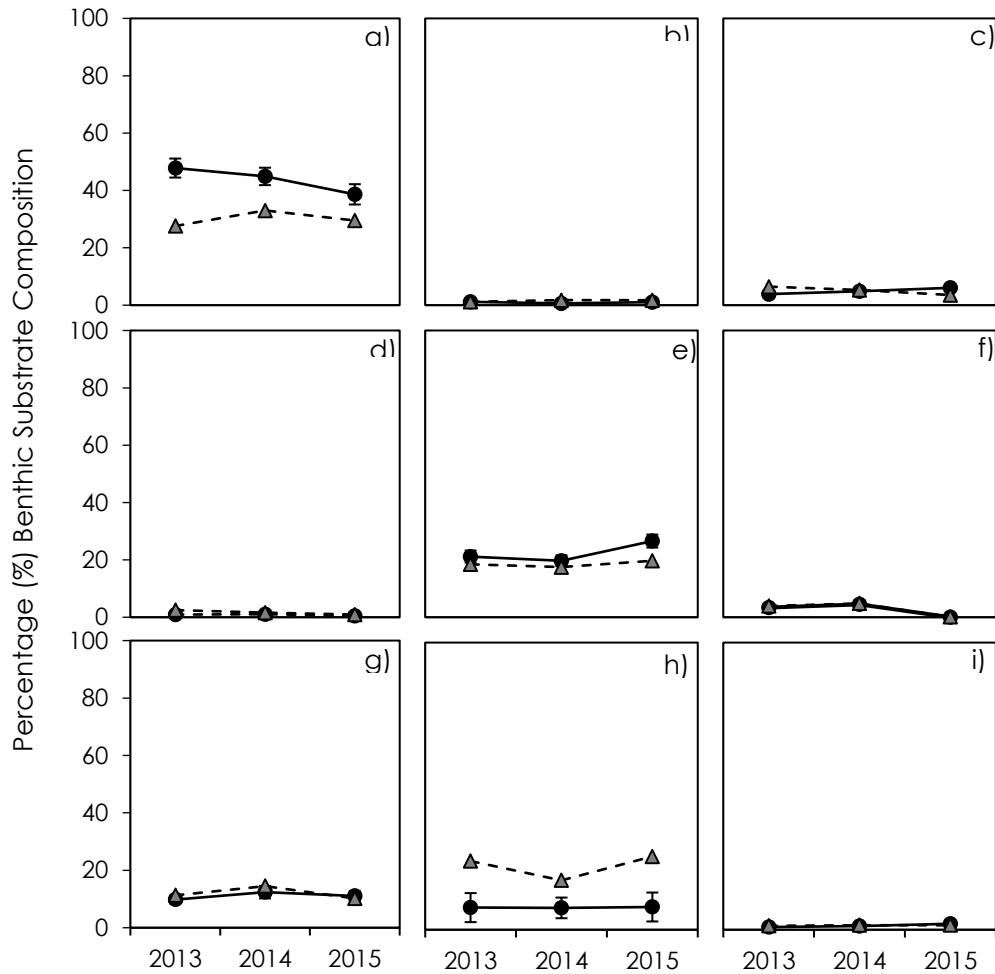


Figure 22. The percentage (%) composition of benthic substrate; a) Hard Coral (HC); b) Soft Coral (SC); c) Sponge (SP); d) Recently Killed Coral (RKC); e) Rock (RC); f) Silt (SI); g) Rubble (RB); h) Sand (SD); and i) Nutrient Indicator Algae (NIA) over a tri-annual period from 2013 to 2015 for Napantao marine protected area (MPA), southern Leyte, the Philippines. The data is represented in two sets with the standard error (SE) given; inside the MPA boundaries (Black filled circle); and outside the MPA boundaries (Grey filled triangle).

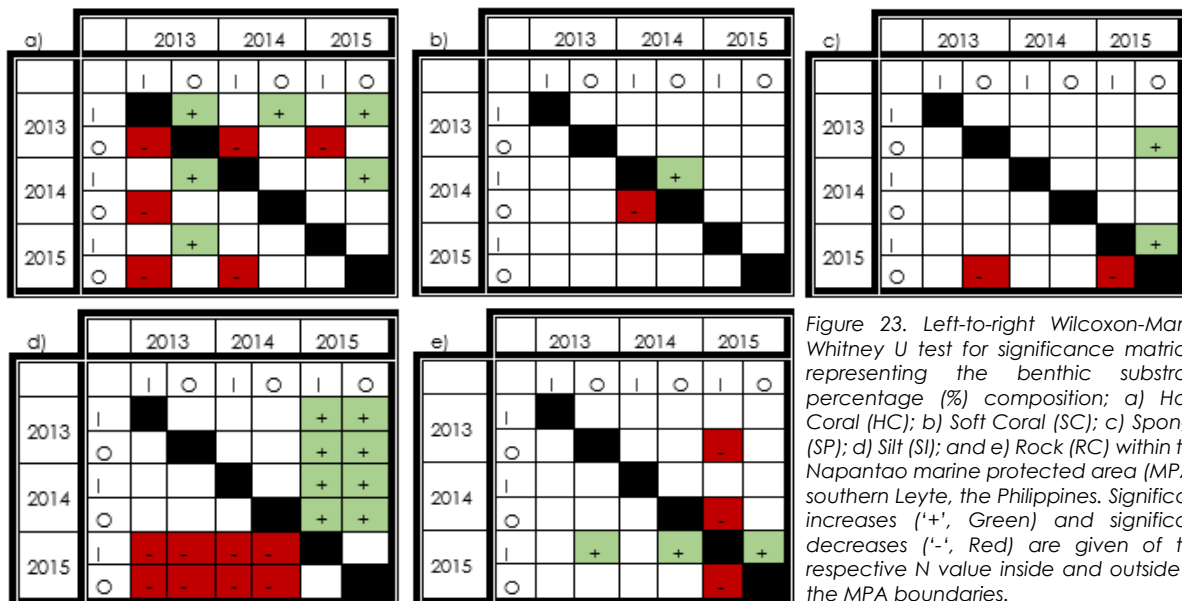


Figure 23. Left-to-right Wilcoxon-Mann-Whitney U test for significance matrices representing the benthic substrate percentage (%) composition; a) Hard Coral (HC); b) Soft Coral (SC); c) Sponge (SP); d) Silt (SI); and e) Rock (RC) within the Napantao marine protected area (MPA), southern Leyte, the Philippines. Significant increases ('+', Green) and significant decreases ('-', Red) are given of the respective N value inside and outside of the MPA boundaries.

3.2.5 Scleractinian Hard Coral Life Traits

The benthic substrate composition of fast-growing corals was greater inside the MPA in comparison to outside during each year of sampling (MWU, $p = <0.05$) (Fig. 26). The greatest recorded composition was in 2013, inside the MPA ($41.11 \pm 8.95 \% 20m^{-1}$) with the lowest in 2014 ($34.58 \pm 9.38 \% 20m^{-1}$) (MWU, $p = >0.05$) (Fig. 24). Competitor corals inside the MPA, in 2013, were the lowest HC life trait category ($27.46 \pm 6.91 \% 20m^{-1}$), however they composed the greatest percentage composition in 2014 ($38.74 \pm 8.80 \% 500m^3^{-1}$) (MWU, $p = >0.05$). Competitor corals outside the MPA, in 2014, were significantly higher in comparison to their respective composition inside the MPA boundaries ($U = 185.5$, $p = <0.05$) (Fig. 26). Stress tolerant corals increased by 12% from 2014 to 2015, becoming the dominant HC category inside the MPA in 2015 ($38.35 \pm 7.54 \% 20m^{-1}$) (Fig. 24) whilst exhibiting an 8% increase outside of the MPA from 2014 to 2015 (Fig. 25), however neither increase in composition was determined as significant (MWU, $p = >0.05$) (Fig. 26). In combination, no correlations were observed in the HC life traits composition over the temporal scale (Table B1).

Table 4. Percentage (%) change in the benthic substrate % composition for Hard Coral (HC); Soft Coral (SC); Sponge (SP); Recently Killed Coral (RKC); Rock (RC); Silt (SI); Rubble (RB); Sand (SD); Nutrient Indicator Algae (NIA) from 2013 to 2015 both inside and outside of the Napantao marine protected area (MPA), southern Leyte, the Philippines.

Percentage (%) Change in Benthic Substrate Composition		
Substrate	Inside	Outside
HC	-19%	7%
SC	-9%	45%
SP	57%	-45%
RKC	-44%	-63%
RC	26%	7%
SI	-100%	-97%
RB	13%	-9%
SD	3%	7%
NIA	122%	15%

Table 5. The mean percentage (%) composition ($20m^{-1}$) of recorded coral lifeform in each sample year and respective inter-boundary location of the Napantao marine protected area (MPA), southern Leyte, the Philippines. The lifeforms described are as follows; *Acropora* branching (AB); non-*Acropora* sub-massive (NASM); non-*Acropora* encrusting (NAE); non-*Acropora* massive (NAM). The standard error (SE) is represented for each composition

Year	Location	LF	%	SE
2013	Inside	AB	33.37	6.70
2013	Outside	NASM	19.46	4.02
2014	Inside	AB	24.32	5.43
2014	Outside	NAE	19.83	4.33
2015	Inside	AB	29.67	6.04
2015	Outside	NAM	20.82	5.68

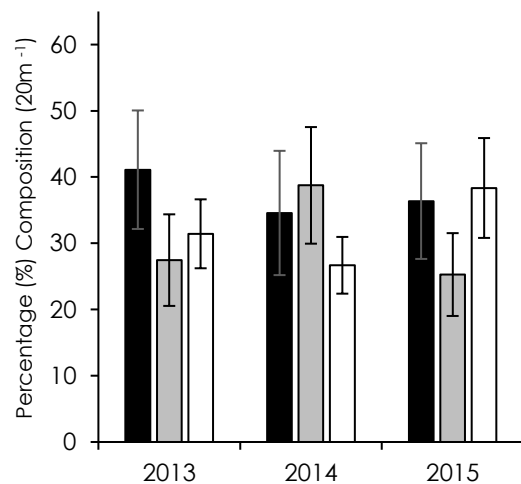


Figure 24. Percentage (%) composition ($20m^{-1}$) of coral lifeform Life trait; Fast Growing Coral (Black); Competitor Coral (Grey); and Stress Tolerant (White) over a tri-annual survey period (2013, 2014 and 2015) inside the Napantao MPA boundaries, southern Leyte, the Philippines.

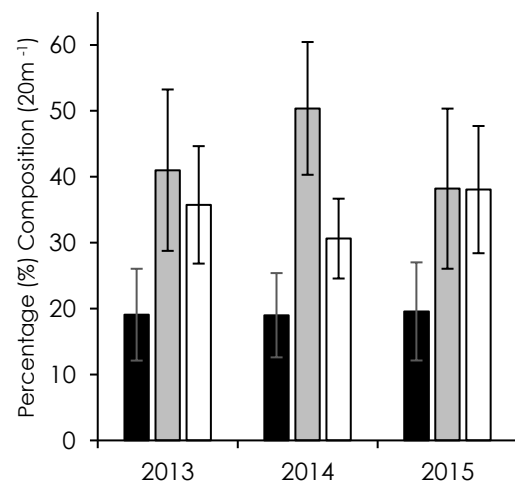


Figure 25. Percentage (%) composition ($20m^{-1}$) of coral lifeform life trait; Fast Growing Coral (Black); Competitor Coral (Grey); and Stress Tolerant (White) over a tri-annual survey period (2013, 2014 and 2015) outside the Napantao MPA boundaries, southern Leyte, the Philippines.

		Fast-Growing Corals						Competitor Corals						Stress-Tolerant Corals					
		2013		2014		2015		2013		2014		2015		2013		2014		2015	
		I	O	I	O	I	O	I	O	I	O	I	O	I	O	I	O	I	O
2013	I		-		+		+				-								
	O	-			+		-					+							
2014	I		-		+		+				-		+						
	O	-		-		-		-					+						
2015	I		+		+		+		-	-	-								
	O	-		-		-					-								

Figure 26. A left-to-right Wilcoxon-Mann-Whitney U test for significance matrix of abundance (N), species richness (S) and Shannon-Wiener diversity index (H') values, of coral reef associated fishes within the Napantao marine protected area (MPA), Southern Leyte, the Philippines. The statistical analysis was conducted with a confidence level of 95% and therefore filled sections of the matrix represent a statistically significant difference ($p < 0.05$). Significant increases ('+', Green) and significant decreases ('-', Red) are given of the respective N value inside and outside of the MPA boundaries.



4.0 Discussion

This study aimed to assess the effect of the Barangay Napantao MPA on the coral-reef associated communities and benthic substratum, this was expanded to assess the impacts regarding the fishery and its respective governance. Accepting natural fauna behaviour and variability, including the relatively short temporal scale, difficulties were found drawing conclusions on the true effect. This study suggests that the MPA is not reaching its established targets of improved fishery production and increasing the ecological status of the reef residing within the MPA boundaries. The MPA, in contrast, is indicative of one that is buffering against the species decline of fishes, however, a greater temporal scale is required with the majority of variables analysed suggestive of decreasing trends.

4.1 Coral Reef Associated Vertebrate and Invertebrate Communities

The minimal to no abundance of charismatic mega-fauna is of concern for the area, in both an ecological context as well as for eco-tourism purposes. Sea turtles hold a significant role in characterising coral reef communities through their major predatory roles, being arbitrators in the competition for space on coral reefs (Lutz *et al.*, 1996). *E. imbricate*, the Hawksbill Turtle, are invertivores and remove large quantities of sponges from coral reefs, exposing rock and other hard substrates that subsequently increase the recruitment levels of HC (Lutz *et al.*, 1996). Others remove turf algae, that can reduce HC cover through smothering. Their absence or presence can have significant impacts on the community structure of coral reefs with



their presence, as well as the presence of other charismatic mega-fauna, that often lead to the conclusion of a coral reef in a good ecological status. Sea turtles are at the threat of regional, far-field and near-field stressors (CTI-CFF, 2013; ADB, 2014). Their removal to supply the curios trade as well as the poaching of eggs have a significant impact to populations within the CT and the Philippines (CTI-CFF, 2013; ADB, 2014). It is likely that their lack of abundance on Napantao is a direct result of such prescribed impacts. Sharks and Manta Rays are also at the detriment of anthropogenic stressors with reports suggesting that the shark finning industry and the harvesting of both Manta Rays and Whale Sharks for their gills has increased in the seas surrounding the Philippines (Fowler *et al.*, 2002; O'Malley *et al.*, 2013). The ecological role and importance of sharks on coral reefs is discussed by Roff *et al.* (2016). Manta Rays are estimated to be worth approximately USD\$1 million throughout their life-time to the eco-tourist trade (O'Malley *et al.*, 2013), highlighting the need for protection.

The community structure of the Napantao coral reef, both inside and outside of the MPA boundaries, was dominated by Caesionidae with the exception being recorded in 2014 outside of the MPA as the community structure was dominated by Apogonidae. Caesionidae exhibit behaviour that is adapted for their planktivorous mode of life, often forming large schooling aggregations during the day (Carpenter, 1988). Their respective diurnal behaviour offers a supportive conclusion to their dominance throughout the Napantao reef site. In contrast, it is suggested that Caesionidae are often targeted through artisanal fishing practices and their absence from a reef can suggest intense fishing (Campbell and Pardede, 2005). Their dominance was expected due to the recorded low levels of artisanal practices occurring within the area,

primitively suggesting that fishing inside of the MPA is minimal. Apogonidae exhibit nocturnal feeding behaviour on coral reefs and show a high level of fidelity to their daytime resting sites, often forming large multi-specific aggregations that are thought to be highly dependent on the coral benthic substratum (Gardiner and Jones, 2005). Gardiner and Jones (2005) presented results that suggested Apogonidae within the CT show a high degree of preference to branching corals, specifically *Porites cylindrica* (a non-Acropora branching competitor coral) (Edinger and Risk, 2000). Therefore, Apogonidae's dominance outside of the MPA can be supported through the highest recorded HC composition (%) outside of the MPA in 2014 as well as non-Acropora branching coral and competitor corals characterising the inter-boundary location. This substrate characteristic in addition to the mean time of the day surveys were conducted would therefore increase the probability of surveyors observing Apogonidae. Due to Apogonidae preference in selectivity for substratum that confers a complex three-dimensional architectural structure, their dominance is indicative of a coral reef in a complex state, beneficial to other coral reef associated species (Saila *et al.*, 1993, Gardiner and Jones, 2005).

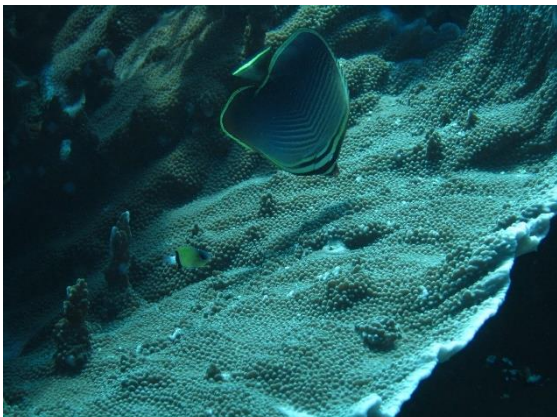
On a spatial scale, each year of the sample period, the abundance of fish inside and outside the MPA was not significantly different. This could be due to a spill-over effect from the MPA or it may suggest high levels of illegal fishing within the MPA boundary (Russ & Alcala 2004). However, the higher S and H' inside the MPA each year could indicate a positive effect within the MPA. A greater H' value is often associated with healthier reef systems as high diversity typically increases a reef's resilience to anthropogenic and non-anthropogenic stressors (e.g. overfishing, acidification) (Chapin *et al.*, 2002). Thus, although the unprotected areas surrounding the MPA may have similar fish abundances they may be less resilient to

ecosystem perturbations. In contrast, the abundance of fishes within the protected area decreased 2013 and 2015 inside the MPA with trends in abundance outside of the MPA not significant. This decreasing trend is suggestive of acute disturbances within the localised area, taking into account far-field and regional stressors. Decrease in local HC cover can result in significant reduction in the abundance of coral reef associated fishes (Pratchet *et al.*, 2011). The HC cover inside and outside of the MPA exhibited substantial decreases, however, with such decreases being deemed non-significant, it cannot be concluded that the variable HC cover throughout the sampled area was to the detriment of fish abundance. With H' presenting a negative correlation from 2013 to 2015 outside of the MPA, it is further suggestive of detrimental impacts within the area (Morris *et al.*, 2014). Decreases in HC cover have also been shown to decrease the diversity of coral reef fish communities, however, this decrease is characterised by >60% reduction in HC (Pratchet *et al.*, 2011), which is higher than that recorded for Napantao. This further supports the inconclusiveness of the impact of HC reduction on fish abundance and diversity within the area.

C. baronessa was the dominant Chaetodontidae species throughout the sample period both inside and outside of the MPA. *C. baronessa* is an obligate



coralivore (Pratchett and Berumen, 2008), a species that is dependent upon hard coral for food, with coral often constituting >80% of its diet (Stella *et al.*, 2011). Due to its highly selective prey preference, the abundance of *C. baronessa* enables it to be used as a proxy for coral reef health. When in abundance, *C. baronessa* feed almost exclusively on *Acropora hyacinthus* (Berumen *et al.*, 2005), a fast growing *Acropora* coral (Edinger and Risk, 2000), with studies also showing the species' preference to areas of high scleractinian cover (Pratchett and Berumen, 2008). *A. hyacinthus* composition can be characterised further as both inter-boundary sites exhibited decreases in *C. baronessa* abundance over the sample period, however, no correlations were determined for the composition of fast growing corals. Therefore, a decrease in the dominant prey of *C. baronessa* cannot be concluded to result in decreased abundances of *C. baronessa*. This is supported by Berumen *et al.* (2005) that noted a decrease in *C. baronessa*'s selectivity when the availability of *A. hyacinthus* decreased causing *C. baronessa* to feed on other coral in such instances, however, the overall physical condition of *C. baronessa* decreased, suggesting increased mortality rates. Decreases in the abundance and selectivity behaviour can, therefore, indicate a change in the quality and/or quantity of species-specific fast growing corals. This decreasing trend of *C.*



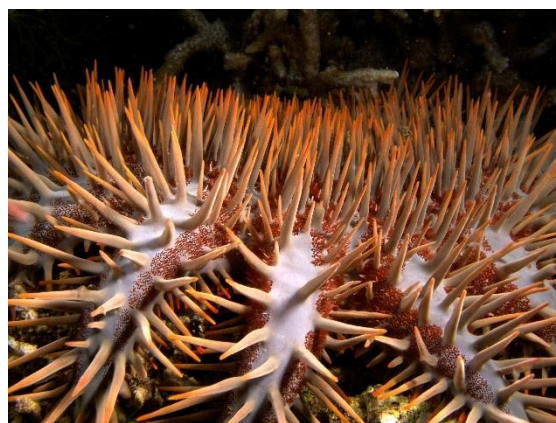
baronessa stands true for the abundance of Chaetodontidids throughout the sample period, exhibiting negative correlations both inside and outside of the MPA boundaries. These decreases indicate a reduced HC cover on Napantao reef, however, this is not supported by the analysis, further suggesting that Chaetodontidae populations are experiencing detrimental acute impacts. The variable differences in diversity of Chaetodontidae on a spatial scale can be assumed through the spatial variation and distribution of coral species, as the distribution of Chaetodontidae species can indicate localised bleaching conditions (Cole *et al.*, 2009) and variation of suitable habitat (Pratchett *et al.*, 2008).

Although this study provides a contextualised review of the abundance and diversity of coral reef fish communities, there are limitations of the utilised methodology that must be accounted for. UVC transects invoke a relatively small soak time through the various limitations of SCUBA based protocols and therefore any semi-diurnal changes in species-specific behaviour could not be accounted for (Dallison, 2015). Coral reef fishes are often considered to be highly sedentary, however there is evidence to suggest that many exploited reef fishes undertake diurnal intra and inter-reef migrations (Chapman and Kramer, 2000). However, with UVC transects being conducted during the day, and with studies stating that fish activity is minimal between 09:00 and 16:00 (McMellor and Smith, 2010), the full community structure was difficult to assess. Although the methodology utilised in handling the data for this report incorporated seasonality and migratory behaviour into the analysis, aiming to limit the impact of spawning migrations (Sale *et al.*, 2010), ontogenetic shifts, habitat selectivity (McAfee and Morgan, 1996) and home range relocations (Chapman and Kramer, 2000) as well as diel migrations

between feeding sites (Hobson, 1973), means their true impact on *N* and diversity cannot be holistically accounted for, and could therefore serve as a justified reason for the variability between sites and years in the community characteristics. Throughout this study and future studies, this limitation is accepted due to the diurnal fishing activities within the region and the biodiversity found on coral reefs (Bellwood *et al.*, 2012) as well as the protocols CCC have in place. Thus, addressing this limitation is unfeasible due to the citizen science structure of CCC. If further species or family-specific studies were to be conducted on Napantao coral reef then it is highly recommended that such studies incorporate the nocturnal, diurnal, home range and migratory behaviour of target species to assess their true abundance on coral reefs.

The abundance and diversity of invertebrates inside and outside of the MPA exhibited no correlations over the temporal scale, with differences in recorded values also presenting no significant differences in both locations. Therefore, initial analysis indicates that the invertebrate populations are stable. The decreasing *N* values call for the need for continued monitoring in combination with percentage changes on a temporal scale. Continued monitoring is also essential to assess the population of CoTs, as although both locations exhibited declines in their respective abundance, outbreaks can be rapid. The invertebrate populations inside of the MPA decreased at a slower rate than those outside, between 2013 and 2015, suggestive of an MPA that may be buffering against acute or chronic anthropogenic perturbations (Graham *et al.*, 2007). The lack of or minimal effectiveness of the Napantao MPA is supported through the well documented relationship between size and effect (Edgar and Barret 1992; Edgar *et al.*, 2014). Invertebrate populations and community diversity have been

demonstrated to significantly differ inside of an MPA, in comparison to outside, in MPAs that are characterised by a large coverage, specifically >5km² (Edgar and Barret 1999). Whilst Edgar *et al.* (2014) offer further solutions and key characteristics needed for a successful MPA, the small size of Napantao could be a key driver in the insignificant *N* and diversity results recorded for invertebrates. Although harvesting pressure was recorded as low within the MPA, due to the absence of a permanent Bantay Dagat present at Napantao, these low levels of fishing activity cannot be conclusive and therefore, the observed declines in invertebrate abundance could be a result of unrecorded fishing pressure induced on the Napantao coral reef communities. This is further supported by the sedentary behaviour of the majority of invertebrates sampled restricting them to local areas within the MPA (Edgar and Barret, 1999). This, therefore, suggests that the MPA boundary should act as a 'protective barrier', thus conserving populations and species within its boundaries in scenarios void of illegal fishing inside of an MPA. In contrast, the insignificant differences observed in both *N* and diversity could be a result of larval spill-over (Mumby and Steneck, 2008; Perez-Ruzafa *et al.*, 2008), with the area inside of the MPA producing larval recruits, effectively increasing levels of recruitment outside of the MPA.



The absence of commercially important

invertebrate species on Napantao reef, in both locations, is of concern for the ecological status of the coral reef as well as the socio-economic productivity. These species, which in many cases are slow growing and slow moving, are particularly vulnerable to over exploitation. *Tridacna* sp., another important commercial species, were observed on the surveys but in low numbers. Furthermore, all the individuals observed were relatively small in length. These results indicate that extraction pressure may be high in areas surrounding the MPA and that for certain species, the MPA is not enhancing stocks. This could be as a result of historical fishing pressure removing all individuals from the area prior to the establishment of the MPA. Despite being low, the abundance of small *Tridacna* sp. apparent on the survey may indicate that for this species, recruitment of new individuals is occurring but at a slow rate. *Tridacna* sp. exhibit sensitive traits (e.g. living on the surface of benthic substratum, usually rock, sessile, bearing a shell) that result in them becoming highly susceptible to shellfishing and over-exploitation (Jimenez *et al.*, 2015). In addition, abundance of Cephalopodids can

possibly be attributed to their diurnal migratory behaviours (Wearmouth *et al.*, 2013) and cryptic nature, in tandem with the previously discussed limited soak times resulting in a reduced chance of exposure.

The diversity of the invertebrate communities sampled inside and outside of the MPA boundaries can be deemed as positive. As no negative correlations were determined, it suggests that the diversity of the community is stable. Napantao, in 2015, held a higher relative diversity of invertebrate communities recorded in comparison to the local MPA in Punta (1.71 nm southeast of Napantao) in combination with *N*, both inside and outside of the MPA (Ferguson and Milne, 2015). Although the *N* recorded at Napantao for both inter-boundary locations were greater than those recorded at Punta, the difference between the *N* inside and outside was observed to be greater at Punta, possibly due to its larger area (10.5ha) (Edgar *et al.*, 2014). *S* on Napantao reef was also higher than that recorded for Punta, and therefore, coupled with measures of *N*, it can be assumed that the invertebrate communities on Napantao confer a higher



functional diversity than those that reside in Punta. While no consensual definition has been established for functional diversity (Laureto *et al.*, 2015), it can be thought of as an ecological characteristic that is the measurement of resilience to perturbations of studied communities, through traits that determine ecological functioning (Mouchet *et al.*, 2010). However, as the methodologies of this study did not categorise species and other taxonomic classifications based on their ecosystem function (e.g. Herbivore, Invertivore, Piscivore), this cannot be concluded and further studies should be discussed. Future studies should incorporate a functional characterisation into methodologies to assess the level of functional diversity as well as the functional redundancy (Johansson *et al.*, 2013), to evaluate the resilience of critical ecosystem functions and the communities of Napantao reef in a holistic sense.

The unsustainable harvesting of invertebrates can result in wholesale community-wide impacts on coral reefs, affecting the structure, functional diversity and resilience in small-scale invertebrate and fin-fish fisheries (Jimenez *et al.*, 2015), and can often result in phase-shifts and trophic cascades. The impact of over-exploiting invertebrates is further highlighted by Eddy *et al.* (2015), who further state that the true impact depends on which target species is being exploited. Therefore, there is a call for management plans to include the life history traits and species-specific policies, in order to manage and remediate invertebrate resources.

4.2 Commercially Important Fishes and the Resulting Status of the Napantao Small-Scale Fishery

In small-scale coral reef fisheries, the importance of commercial species such as Scaridae, Serranidae and Lutjanidae is formulated around, not only their subsistence value, but also the high

commodity value they hold for local fishers. Understanding the size structure of populations, the standing biomass and abundance both inside and outside of the MPA is of great conservation value. Of the three commercially important exploited groups, Scaridae were dominant regarding f throughout the sample period. However, this dominance also presented a declining observed f each sample year, both inside and outside of the MPA. Supported further by declining N . Despite Scaridae holding the greatest standing biomass inside and outside of the MPA, the size structure of this standing biomass was dominated by smaller individuals, supported by relatively low W values throughout. Therefore, the data suggest that the Scaridae populations found, specifically within the MPA boundaries, are dominated by smaller species and sexually immature individuals. The higher relative concentration of smaller sized Scaridae inside of the MPA is expected due to the high N of invertebrates found within the MPA boundaries. Juvenile parrotfish inhabit the epilithic algal matrix (EAM), predating on cryptobenthic invertebrates (Welsh, Goatly & Bellwood 2013). The results presented by Welsh, Goatly and Bellwood (2013) indicate that there is a rapid increasing somatic relationship with home-ranges until individuals reach 100-150mm in length at which point, this relationship breaks down. This rapid increase is thought to be driven by prey and resource availability, and although Napantao confers a higher N of invertebrates than other respective coral reefs within Sogod Bay (e.g. Seraphim *et al.*, 2016), many may not be available, thus requiring smaller parrotfish to increase their home ranges relatively; increasing their susceptibility to surveys through an increased cosmopolitan activity. Therefore, perceived populations of Scaridae inside of the MPA may be a result of survey error or multiple counts. The breakdown in the somatic relationship is thought to occur in some Scaridae species due to the ontogenic switch in behaviour that sees larger adults occupying harems (Welsh,

Goatly & Bellwood 2013). Furthermore, it can be argued that due to adult Scaridae presenting unprecedented reduced home ranges, in comparison to other taxa (Mumby & Wabnitz 2002; Marler *et al.*, 1995; Hinsch, Pen & Komdeur 2013), as well as preferences in species such as *Chlorurus sordidus* to practice place-familiarity (Welsh & Bellwood 2012), the results obtained were not in support of those where surveyors recorded the presence of schooling harems. The results obtained for the commercially important Scaridae are analytic of a population that holds high social and commercial value to local stakeholders and are thus a victim to overfishing. With this in mind, due to the temporal nature of the data, resolution can sometimes be lost and as a result, it is important to note the observable trends in N and biomass, accompanied by the change in size structure from 2014 to 2015. The observable decreases in N and an increase in biomass with a transition to a population of larger size structure is a positive one, indicative of an MPA that is protecting populations within its boundaries (Unsworth *et al.*, 2007; Edger *et al.*, 2014), however to conclude the effectiveness of the Napantao MPA, larger temporal data sets must be obtained.

In contrast to Scaridae, the size class and W of Lutjanidae individuals inside the MPA boundaries presented an increase from 2013 to 2015. However, the W obtained for individual Lutjanidae were highly variable indicating a range of weights were recorded, possibly due to the non-species specific nature of the practiced methodology. Unlike Scaridae, some Lutjanidae species (*Lutjanus deccusatus*) have demonstrated a positive ontogenic correlation between their home-range and total length (Nanami & Yamada 2008). The increasing home-range size of *L. deccusatus* is thought to be driven intra-specifically by resource availability and competition between those of the same size class (Nanami & Yamada 2008). As such, the results presented with regards to N , W and biomass of Lutjanidae inside of the MPA are partially expected. It can be

assumed that the decreasing N and respective biomass could be a result of increased agonistic behaviour in adult Lutjanidae and increased home-range size thus reducing their observability for surveyors and N . Furthermore, the f of smaller size classes inside of the MPA is likely due to displays of increased agonistic behaviour only reserved for individuals of the same size (Nanami & Yamada 2008). The activity of Lutjanidae is at its lowest during daylight, with stomach samples of species indicating photoperiod driven responses resulting in feeding behaviour peaking from dusk to sunrise (Kamukuru & Mgaya 2004). Therefore, although activity and surveyor observability may have had a role to play with the decreasing trends observed, it is thought that local stressors



such as overfishing in tandem with natural, ontogenic behavioural shifts are the driving factors behind the trends observed from Lutjanidae inside of the MPA. The same assumptions can be made for Lutjanidae recorded outside of the MPA. From 2013 to 2015 at both inter-boundary locations the size of Lutjanidae and their respective *W* increased, however, the 78% decrease observed abundance outside of the MPA is characteristic of a population that is highly subject to detrimental impacts. This further highlights the need for conservation addressing compliance and local stakeholder empowerment in order to protect Lutjanidae, and other commercially important species.

The abundance of Serranidae inside and outside of the MPA was perceived to plateau, indicating no significant declines or increases throughout the sample period. However, spatial significance was observed each sample year with Serranidae recorded in higher abundances inside the MPA than outside. Subsequently, the biomass recorded for Serranidae inside of the MPA in 2013 was significantly lower than that observed inside in 2015, however, this was not supported further by SRCC analysis, possibly due to the decrease in values in 2014. The Napantao MPA failed to increase the relative density of Serranidae inside its boundaries, however, contrastingly this failure did not result in a decrease and thus, with regards to Serranidae, the MPA can be seen as maintaining the *status-quo* of productivity. This is further highlighted by the abundance of Serranidae outside of the MPA displaying no declines in their respective abundance also. It is possible to suggest that a spill-over effect (McClanahan & Mangi 2000) is taking place, though, unlike Scaridae species, Serranidae are mobile fish with some species (e.g. *Plectropomus leopardus*) exhibiting home ranges of over 1.8ha, equating to 36% of the established Napantao MPA, whilst being found to travel up to a distance of 2km (Samoilys 1997a; Samoilys 1997b; Zeller, 1997; Unsworth *et al.*, 2007). The implications of species with large home-ranges, in respect

to the size of the MPA have previously been discussed, and although there appears to be a greater density of Serranidae within the MPA boundaries, it cannot be concluded that the same trends observed inter-boundary are not a result of survey error through multiple-counts of the same individuals. The size-class of Serranidae outside of the MPA increased in their variation, with an even *f* recorded across sizes from 0 to 30cm in 2015, from a population holding a higher smaller-sized cohort in 2013. Although *f* values were lower, supported by the recorded density, it is indicative of a population that is maturing. A maturer population indicates increased survivorship (Unsworth *et al.*, 2007) and could offer a justified reasoning for the stable biomass recorded outside of the MPA. Inside of the MPA in 2015, Serranidae within the 31-40cm size class were recorded, although in relatively small abundance, further indicating the presence of maturer adults, contributing to the increase in biomass observed. In contrast, between 2013 and 2015, the *f* of individuals occupying the size-class 0-10cm increased to become the dominant size-class. Although species-specific methodology was not undertaken, it can be assumed that a large proportion of these sized individuals are sexually immature and thus do not hold the morphological abilities to reproduce. The other proportion of these small-sized individuals will be small Serranidae species, such as *Cephalopholis argus*. Despite contributing to the standing biomass to a lesser extent, these smaller species will reach sexual maturity at a reduced length in comparison to their larger species counterparts (Froese and Pauly 2000), and therefore their significance within coral reef ecosystems cannot be under estimated. Many smaller Serranidae species are important food items (Unsworth *et al.*, 2007) to local communities as well as other fishes that reside on the reef, with their presence rendered as positive. These smaller species hold more restricted home-ranges (Stewart & Jones 2001) and thus their presence to surveyors is as expected due to an

increased probability of being recorded. Serranidae hold high trophic levels on coral reefs and in combination with their slow growth and tendency to aggregate, they are highly subject to unsustainable removal (Colin 1992; Sadovy & Colin 1995; Unsworth *et al.*, 2007). As a result, the trends observed throughout this study for Serranidae are not surprising, with a lack of larger, mature individuals and no increase in productivity. Thus, alongside the aforementioned natural justification, the probability of illegal poaching within the MPA cannot be ignored. Therefore, it is of high importance that continued monitoring on Serranidae communities is established that also explores species populations, their behavioural traits and ecology.

It has been demonstrated that initial declines following protection in the abundance of Serranidae are common and that numbers increase as a subsequent result of NTA protection, suggesting that after three years, populations become stable (Russ & Alcala 1998). The results presented, demonstrate stable populations, however, due to the lack of detailed results on species, greater resolution is needed to recommend directed, specific ordinance.

4.3 Benthic Substrate and Scleractinian Hard Coral Composition on Napantao Coral Reef

The benthic composition of HC inside and outside of the MPA exhibited no significant temporal changes over the sample period. However, on a spatial scale, HC held the greatest composition inside of the MPA. Conversely, HC was dominated by *Acropora*-branching sp. each sample year with the dominant lifeform outside of the MPA boundaries varying. Branching coral lifeforms are associated with coral reef complexity (Edinger & Risk 2000; Graham & Nash 2012). Coral cover, in particular branching coral cover, has been shown to positively correlate with fine-scale structural complexity (Chabanet *et al.*, 1997; Graham & Nash 2012), with further studies highlighting its importance to fish and invertebrates (Wilson *et al.*, 2006; Pratchet *et al.*, 2008; Stella *et al.*, 2011). The importance of structural complexity has been well documented on coral reefs (Risk 1972; Luckhurst & Luckhurst 1978; Grigg 1994; Edinger & Risk 2000; Graham & Nash 2012) as well as adjacent coastal systems such as seagrass beds. Many studies have found the strongest positive correlations between coral complexity and the abundance, diversity and biomass of reef associated fishes (Luckhurst & Luckhurst



1978; Grigg 1994) and equally, correlations between loss of complexity and the subsequent detrimental impact on coral reef associated communities (Gardener *et al.*, 2003; Alvarez-Filip *et al.*, 2009). Therefore, the results observed throughout the sample period on the Napantao coral reef, both inside and outside of the MPA offer further support of such conclusions.

The anecdotal complexity observed inside of the MPA, as a result of the dominance of branching corals, could be a key driving force in the diversity of communities due to the provision of niche space (Graham & Nash 2012). As a result, despite minimal significant temporal trends, the preliminary trends observed are of decreasing HC cover, and therefore, the abundance and diversity of fishes as well as biomass of commercially important families could well be driven by a decreasing structural complexity. This is further highlighted by an increase in stress-tolerant corals inside of the MPA boundaries. Edinger and Risk (2000) highlight that stress tolerant corals, composed of multi-lobate, massive and large foliose massive forming colonies, hold a lower structural complexity to their *Acropora*-branching and competitor coral counterparts. The high variability in coral reef associated fish abundance for both inter-boundary locations, specifically those recorded outside of the MPA, is possibly also a result of the strong relationship with coral reef complexity. A combination of reduced complexity and fishing activity has been shown to elicit a prey-release response in smaller-sized species as larger, high level trophic predators are removed, resulting in an increase in the abundance and diversity of smaller-sized fishes (Graham *et al.*, 2003; Dulvy *et al.*, 2004). This reaction can then justify the relatively respectable fish abundances outside of the MPA, however, for this to be concluded, species-specific size estimates will be required.

Coral morphology categories were defined as outlined in Edinger and Risk (2000) through Ternary diagrams. The coral reefs inside of the MPA were recorded as

mixed morphology, of which would be assigned the category CC=4 (Conservation Class 4) (Edinger & Risk 2000). CC=4 coral reefs were shown to hold the highest species richness of coral and morphological diversity, which is further corroborated by the results found within this study inside of the MPA. As a result, protection must be maintained due to the coral reef's morphological characteristics conferring a high conservation value. For coral reefs to be classed as stress-tolerant corals dominated, such life traits must hold a prescribed 60% composition, as they are often abundant in all communities but dominate in those subject to environmental stress (Piggot & Grime 1980). Therefore, their recorded increase calls for continued monitoring efforts. Although Edinger and Risk's (2000) study and use of Ternary diagrams is directly to related land-based pollution, other studies highlight the morphological lifeforms within this category's response to other perturbations such as increased SST and ocean acidification (Hennige *et al.*, 2010). The respective increase of stress-tolerant coral composition, although not high enough to class the coral reef of Napantao inside the MPA as stress tolerant dominated, is suggestive of local and far-field stressors impacting the study site. In 2014, outside of the MPA, the coral reef could be considered competitor dominated (>50%), however, its respective reduced dominance in 2015 does not call for great concern. The coral reef community located outside of the MPA is still of high conservation value, due to the relatively proportional distribution and abundance of each morphological category. However, due to the lower abundance of fast-growing, *Acropora*-branching sp. it can be justifiably argued that this site is in need of greater conservation and thus an increased need of protection.

It was recorded over the sample period that there was a significant reduction in silt across both sites, which is suggestive of decreased sedimentation. Previous studies have linked higher sedimentation rates to increased land-based pollution (e.g Rogers

1990) and have demonstrated the relationship with reef building corals and their respective communities with high sedimentation rates (Risk 2014). Rogers (1990) reports that an influx in sedimentation can have serious detrimental impacts on coral reef building corals, such as *Acropora* sp. and therefore the observed stability in their composition throughout the sample period at both inter-boundary locations may have been a result of observed reduction in sedimentation rates.

In addition to the impacts structural complexity can have on coral reef associated communities, such driving factors also dictate the coral reef's social and tourism value, along with the provision of ecosystem services. Extending beyond the ecological context, coral reefs that hold a greater complexity are an attractive commodity to eco-tourists. Divers will preferentially choose to dive on sites that are in a better ecological condition (Graham & Nash 2012), conferring higher fish densities making the protection of complexity a critical driving force in conservation led directives. Furthermore, it's well known that coral reefs act as an important natural barrier to coastal erosion (Sheppard *et al.*, 2005). As a result of the previously discussed points in this section, in context with the ecological status of the Napantao reef, it is thought that the MPA is providing adequate refugia for marine organisms such as *Acropora* sp.. However, the preliminary trends of HC composition decreasing is of concern and further highlights the need for a continuation in monitoring efforts.

4.4 The Ecological Status of the Napantao MPA, its Implications and Recommendations for Future Direction

The results portrayed in this study are indicative of an MPA that is buffering against the decline of coral reef associated fish communities, although it is failing to protect populations as declines in abundance were observed. Furthermore, the MPA has failed in its objectives of increasing the productivity of the present

fishery with regards to Scaridae, Serranidae and Lutjanidae. Instead, the MPA is exhibiting signs of maintaining the *status-quo* of productivity, however due to the small temporal scale of which this study reports, further monitoring is required in support of populations and standing biomass reaction-times and lag-phase to protection. Finally, the coral reef present inside the MPA is perceived as more complex than areas that are unprotected, holding true to the MPA's objectives but further failing to protect against relative composition due to preliminary analysis indicating that future monitoring will demonstrate significant negative trends.

CCC adapts an ecosystem approach to fisheries (EAF) management. As a result, the Napantao MPA acts as good example of a working EAF model in theory. The practicing EAF model by CCC integrates the 12 key points to successful EAF as given by Pomeroy *et al.* (2013) (Fig. 27). However, the current ecological status of the Napantao coral reef clearly demonstrates that fractures are present in the holistically developed model. The scale of which governance is practiced is at the local user-group level, with ordinance and directives unique to those of Barangay Napantao, however, it is important to note that fish, unlike fisher folk, are not bound to these boundaries. Resultantly, despite jurisdiction also in place at a regional level, there is a greater call for an increase in MR reserve boundaries to cover larger sections of Sogod Bay that protect areas of ecological significance such as spawning sites (Gruss *et al.*, 2014), nursery habitats (Nagelkerken



et al., 2012) and aggregation sites. Due to the topography of Sogod Bay, such areas are difficult to identify with minimal coverage of seagrass meadows and mangrove forests, acting as prospective nursery habitats, including the lack of lagoon and back reefs. It is recommended that not only are further studies conducted to identify such sites, but increases in scale on a bilateral basis between Barangays is addressed. By increasing the overall hectareage of protected reef from fishing along the eastern coastal line of Panoan Island, local resource managers should hope to include unidentified spawning sites as well as areas characterised by CCC baseline surveys (Longhurst *et al.*, 2013) and nursery areas of coral-reef associated fishes. This should also include protecting larger, commercially important spawning stocks that exhibit larger home ranges. Edgar *et al.*, (2014) offers further key elements required for the successful management of MPAs and their respective resource dependent communities. Contrastingly, many of the points argued in their study are not applicable to small-scale tropical fisheries that are governed at lower levels. Nevertheless, enforcement holds a significant role in any conservation management design, and CCC's EAF management. In combination with the bilateral increase in scale, a multilateral increase must also be implemented. The development of ternary-based consortiums between local stakeholders, scientific NGOs and governments will be crucial to further increase protection. Enabling transparent policy making whilst involving local stakeholders in the decision making process ultimately empowering them is highlighted as a key element to successful fishery management (Ferse *et al.*, 2010; Edgar *et al.*, 2014). The study of the Napantao MPA from 2013 to 2015 emphasised the impact of overfishing within the region, whilst also hinting that illegal poaching was being conducted. Illegal activities with regard to the MPA is a clear sign of low levels of compliance in the community and as such, this must be addressed. Low levels of compliance can

often be attributed to a top-down approach to management, and although CCC has established recommendations for the use of co-management, there is potential for delineation of MPA establishment justification to be resulting in local stakeholders not accepting the Napantao MPA (Ferse *et al.*, 2010). By conducting community outreach and educational programmes throughout Napantao, CCC addresses these levels of compliance that fluctuate dependent on individuals and hierarchy. Raising awareness of the issues faced with unsustainable exploitation to younger generations, CCC combats the associated restrictions of culture and traditions in older generations. Thus sustainable practices become integrated into future generations in the hope that these practices will become the 'norm'. Capacity building initiatives practiced throughout Napantao and Sogod Bay aim to provide local resource managers with the ability to practice adaptive management, whilst managing for resilience (to local and far-field stressors) and establishing their own objectives and outcomes. In combination with holding the necessary tools for scientific monitoring, autonomous MPA management should be aimed for.

The points and recommendations discussed above must be considered as short-term targets and solutions to the current ecological status of the Napantao MPA. As a result, CCC calls for the Napantao MPA to become part of a greater conservation led effort for the protection of resources in Sogod Bay. It is proposed that Sogod Bay is established as a MR that carries forward CCC's EAF to management, building upon and utilising the capacity (both scientific and local) that has been built throughout the bay. As current efforts are concentrated on a local scale, there will be need for a dramatic, standardised approach facilitated from the aforementioned ternary consortiums to elicit wholesale change and opinions. By establishing Sogod Bay as an MR that protects areas of ecological significance

and practices a multiple-use zonation spatial design (Appendix C), it is predicted that the productivity of fishery's, status of coastal systems and ecosystem services will improve on a regional scale; setting a precedent for global coral reef conservation initiatives.



Figure 27. Schematic diagram representing the 12 key points that must be incorporated into each ecosystem approach to fisheries (EAF) management plan to achieve management aims. The schematic demonstrates that Coral Cay Conservation combines all 12 into their approach to fisheries management with regards to the Napantao reef, its MPA and local stakeholders. EAF key points presented by Pomeroy et al. (2013).

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Appendix A

Table A1. Table containing the target benthic substrates Coral Cay Conservation surveyors record during point-intercept (PIT) SCUBA transects.

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

Table A2. Table containing the target invertebrate organisms Coral Cay Conservation surveyors record during underwater visual census (UVC) SCUBA transects.

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

Table A3. Table containing the target fishes Coral Cay Conservation surveyors record during underwater visual census (UVC) SCUBA transects.

Common Name	Latin Name	Visayan Name
Angelfish	Pomacanthidae	Adlo
Barracuda	Sphyraenidae	
Blenny	Blenniidae	
Butterflyfish*	Chaetodontidae	Alibangbang
Cardinalfish	Apogonidae	
(Damselfish)	(Pomacentridae)	
Anemonefish	<i>Amphiprion</i> sp.	
Sergeant Damselfish	Pomacentridae	
Emperor	Lethrinidae	Katambak
Filefish	Monacanthidae	Ilak
Fusilier	Caesionidae	Dalagang bukid
Goatfish	Mullidae	Timbongan
Groupers	Serranidae	Lapu-lapu
Jack/Trevally	Carangidae	
Lionfish	Scorpaenidae	
Lizardfish	Synodontidae	
Moorish Idol	<i>Zanclus cornutus</i>	
Moral Eel	Muraenidae	
Parrotfish	Scaridae	Talakitok
Porcupinefish	Diodontidae	
Pufferfish	Tetraodontidae	
Rabbitfish	Siganidae	Sanggowanding
Ray	Rajiformes	Mulmul
Sandperch	Pinguipedidae	
Snapper	Lutjanidae	
Spinecheeks	Nemipteridae	
Squirrelfish/Soldierfish	Holocentridae	
Surgeonfish	Acanthuridae	
Unicornfish	<i>Naso</i> sp.	
Sweetlips	Haemulidae	Silay
Toby	Tetraodontidae	
Triggerfish	Balistidae	
(Wrasse)	(Labridae)	
Crescent Wrasse	<i>Thalassoma lunare</i>	
Humphead Wrasse	<i>Cheilinus undulatus</i>	Lipti
Red Breasted Wrasse	<i>Cheilinus fasciatus</i>	

Appendix B

Table B1. Spearman's Rank Correlation coefficient table indicating the respective r_s and p -values for each community variable: Fishes; Chaetodontidae; Invertebrates; Serranidae (Grouper); Scaridae (Parrotfishes); Lutjanidae (Snapper); Benthic Substrate; Fast-Growing Corals; Competitor Corals; and Stress-Tolerant Corals. Within each community, the inter-boundary location and community characteristic were correlated over a tri-annual period between 2013 and 2015 within the Napantao marine protected area (MPA), southern Leyte, the Philippines. The following community characteristic factors are given: abundance (500m^{-3}) (N); Species Richness (500m^{-3}) (S); Shannon-Wiener Diversity Index (500m^{-3}) (H'); Biomass ($\text{kg}/500\text{m}^{-3}$) (B); Individual Weight ($\text{g}/500\text{m}^{-3}$) (W); Hard Coral (HC); Soft Coral (SC); Sponge (SP); Recently Killed Coral (RKC); Rock (RC); Silt (SI); Rubble (RB); Sand (SD); Nutrient Indicator Algae (NIA); Blue Coral (Heliporidae) (BC); Fire Coral (Milleporidae) (FC); Organ Pipe Coral (Tubiporidae) (OC).

*Confidence limits of 95% (0.05) are indicated.

Variable	Inter-boundary Location	characteristic Factor	r_s	p -value
Temperature ($^{\circ}\text{C}$)	N/A	SST	-0.05	0.52
		3m	-0.12	0.10
		10m	-0.27	0.00 *
Fishes	Inside	N	-0.29	0.01 *
		S	-0.14	0.23
		H	0.03	0.81
	Outside	N	-0.12	0.33
		S	-0.15	0.20
		H	-0.27	0.02 *
	All	N	-0.20	0.02 *
		S	-0.12	0.15
		H	-0.07	0.43
Chaetodontidae	Inside	N	-0.28	0.02 *
		S	0.10	0.41
		H	0.14	0.23
	Outside	N	-0.24	0.04*
		S	-0.10	0.41
		H	-0.04	0.71
	All	N	-0.25	0.00 *
		S	0.01	0.87
		H	0.06	0.46
Invertebrates	Inside	N	-0.06	0.63
		S	0.16	0.18
		H	0.10	0.38
	Outside	N	-0.09	0.43
		S	0.07	0.58
		H	0.01	0.93
	All	N	-0.08	0.35
		S	0.10	0.23
		H	0.06	0.48
Grouper	Inside	N	0.02	0.90
		B	0.02	0.84
		W	-0.05	0.63

Parrotfish	Outside	N	0.01	0.93
		B	0.01	0.96
		W	-0.03	0.87
	All	N	0.03	0.69
		B	0.01	0.88
		W	-0.05	0.87
	Inside	N	-0.17	0.16
		B	0.04	0.71
		W	-0.02	0.85
	Outside	N	-0.30	0.01*
		B	-0.10	0.41
		W	-0.04	0.63
	All	N	-0.23	0.01*
		B	-0.03	0.74
		W	-0.04	0.85
Snapper	Inside	N	-0.14	0.23
		B	-0.05	0.66
		W	0.16	0.29
	Outside	N	-0.39	0.00*
		B	-0.30	0.01*
		W	-0.03	0.85
	All	N	-0.27	0.00*
		B	-0.18	0.03*
		W	0.11	0.33
Substrate	Inside		-0.18	0.12
	Outside	HC	0.04	0.73
	All		-0.05	0.52
	Inside		-0.10	0.42
	Outside	SC	0.05	0.70
	All		-0.02	0.83
	Inside		0.22	0.06
	Outside	SP	-0.26	0.03*
	All		-0.03	0.76
	Inside		-0.05	0.68
	Outside	RKC	-0.22	0.06
	All		-0.14	0.09
	Inside		0.18	0.14
	Outside	RC	0.02	0.84
	All		0.09	0.26
	Inside		-0.38	0.00*
	Outside	SI	-0.30	0.01*
	All		-0.34	0.00*
	Inside		0.07	0.55
	Outside	RB	-0.08	0.50
	All		0.00	1.00
	Inside		0.05	0.65

	Outside	SD	0.01	0.95
	All		0.02	0.81
	Inside		0.06	0.64
	Outside	NIA	0.10	0.41
	All		0.08	0.35
Fast-Growing Corals	Inside		-0.08	0.53
	Outside		0.03	0.80
	All		-0.03	0.77
Competitor Corals	Inside		-0.06	0.60
	Outside	HC, BC, FC, OC	-0.07	0.56
	All		-0.06	0.47
Stress-Tolerant Corals	Inside		0.12	0.33
	Outside		0.01	0.92
	All		0.07	0.40

Appendix C

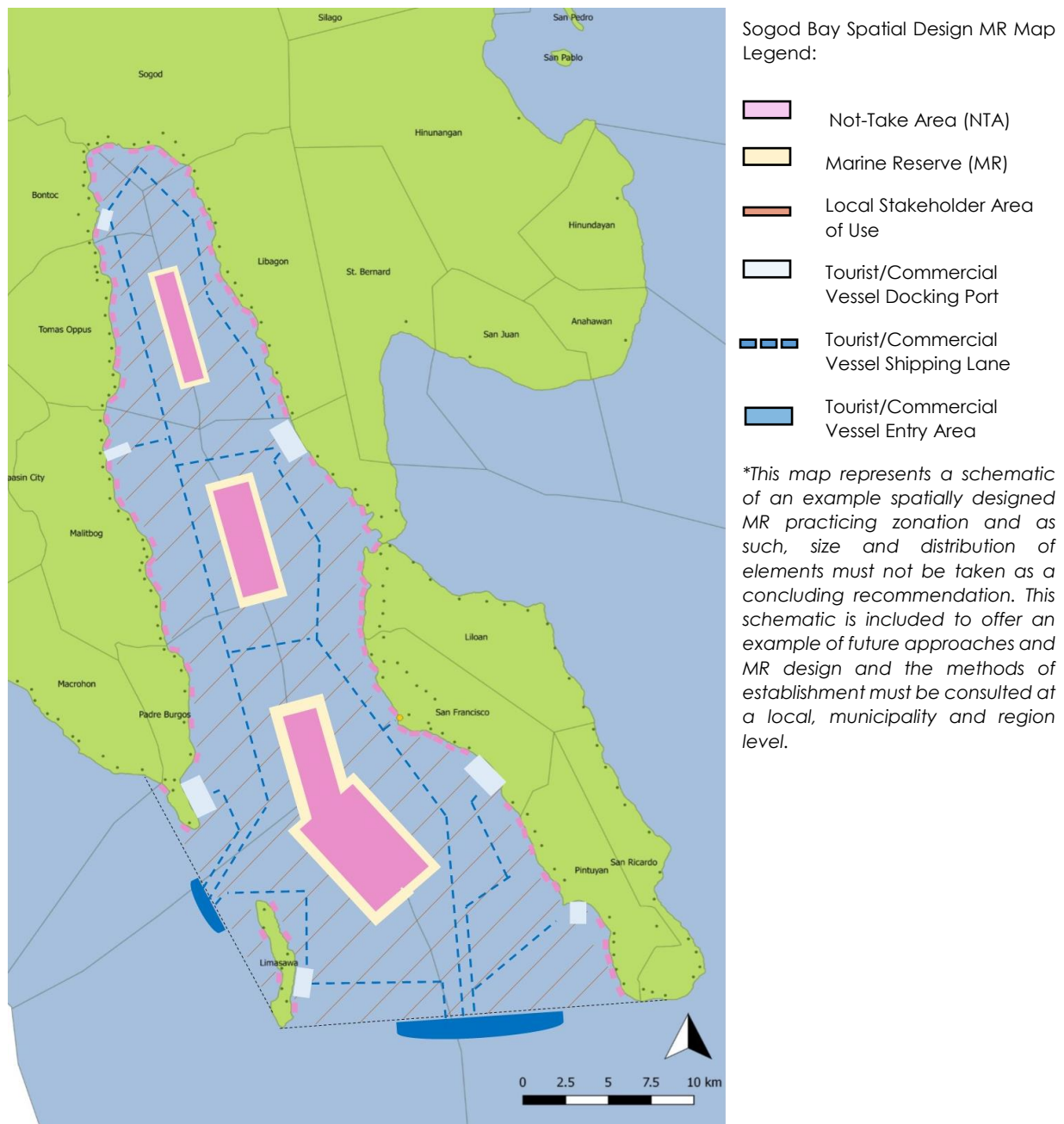


Figure C1. A schematic presented as an example and future possible approach to designating Sogod Bay, southern Leyte, Philippines as a marine reserve (MR). The example provides a basic zonation plan that incorporates local stakeholders and tourists whilst taking into account the ecological benefits of protecting areas of ecological significance. It is recommended that an abundance of small-scale marine protected areas (MPAs) be established within the coastal zone around Sogod Bay, of which will practice the accepted spatial design of a not-take area (NTA) surrounded by a 50m buffering zone or MR. In order to protect pelagic species and larger charismatic mega-fauna, three large MPAs are established within the centre of the MR. These three large MPAs will practice the same basic by-laws adopted by small-scale, coastal MPAs such as no access to boats and other vessels. By designating specified vessel routes, the adoption of this MR design will reduce shipping strikes of large mega-fauna as well as protect spawning species and resident, aggregating species from noise pollution and direct other forms of anthropogenic pollution. Such mitigation is also adopted for the designation of docking ports allowing large vessels to access the bay through designed ports, limiting traffic and pollution. In order for tourists to access MPA sites, permission will need to be received from the specified directing parties; this will still enable economic input to Barangays.