



School of Applied Sciences

A Comparison in the biodiversity of a tropical reef, between a Marine Protected Area, no-take zones and the adjacent area outside the designated MPA in Napantao, South Leyte, Philippines.

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Abstract

This research investigated the biodiversity difference between inside a Marine Protected Area (MPA), and the adjacent area outside the MPA. Using the Reef Check Worldwide recommended surveying method of reef surveying, data was collected on fish and invertebrate abundance, and coral cover. The Shannon-Weiner diversity index was used to establish the biodiversity for fish and invertebrates for the Napantao MPA, Philippines, Sogod Bay. Results show that there was no statistically significant difference in fish biodiversity between inside (1.67 ± 0.35) and outside (1.41 ± 0.5) the MPA. Invertebrates show a similar result with biodiversity inside (1.83 ± 0.21) to biodiversity outside (1.82 ± 0.22) the MPA not significantly different; however there is a slight increase inside the MPA. Evidence was established for the MPA providing spill over, indicating a positive outcome in the allocation of an MPA by allowing sustainable use of an ecosystem service. This was established by using a One-way ANOVA, looking at the biodiversity as surveying moved away from the MPA, indicating a decline in fish biodiversity (1.66 ± 0.31 to 1.41 ± 0.5), and a decline in invertebrate biodiversity (1.92 ± 0.28 to 1.72 ± 0.16), but not statistically significant. Evidence also indicated there is a correlation in live coral cover to fish and invertebrate biodiversity.

Contents Page

	Page
Acknowledgement	i
Abstract	ii
Content Page	iii
Tables	iv
Figures	v
1.0 Chapter 1: Introduction	1
1.1 Overview	2
1.2 Background	5
1.3 Study Location	9
1.4 Rational	10
1.5 Aims	13
1.6 Objectives	14
2.0 Chapter 2: Literature Review	15
2.1 Introduction	16
2.2 Marine Protection	17
2.3 Availability of Marine Data	18
2.4 Threats to Coral Reefs	19
2.5 Functional Diversity	22
2.6 Ecosystem Services & Processes	23
2.7 Determining Coral Reef Conservation Location	25
2.8 Surveying	27
2.9 The Philippines Marine Protected Areas (MPAs)	29
3.0 Chapter 3: Methodology	32
3.1 Introduction	33
3.1.1 Benthic Survey	34
3.1.2 Fish Survey	35
3.1.3 Invertebrate and Impacts Survey	36
3.2 Analysis	37
3.2.1 Hypotheses	38
3.3 Testing Hypotheses	39
4.0 Chapter 4: Findings & Discussion	40
4.1 Introduction	41
4.2 Independent-samples t-test	42
4.2.1 Calculating Effect Size (d)	46
4.3 One-way ANOVA	48
4.4 Pearson's Correlation Analysis	52
4.5 Analysis of Results	55
4.5.1 Biodiversity difference between inside and outside MPA (HA1)	55
4.5.2 Biodiversity difference between transects outside the MPA (HA2)	58
4.5.3 Correlation in coral cover with fish and invertebrate biodiversity (HA3)	61
5.0 Chapter 5: Conclusion	63
5.1 Summary of Results	64
5.2 Strengths of Research	65
5.3 Recommendations for Future Research	65
6.0 Chapter 6: References	66
7.0 Chapter 7: Bibliography	74
8.0 Chapter 8: Appendices	78

Tables

	Page
Table 1 Example of projects performed within Sogod Bay, Southern Layte by Coral Cay Conservation.....	6
Table 2 Example of literature demonstrating the importance of ecosystem services.....	24
Table 3 Test of Normality.....	43
Table 4 Group Statistics.....	44
Table 5 Independent Samples Test.....	45
Table 6 Effect Size.....	46
Table 7 Test of Normality.....	50
Table 8 Descriptives.....	50
Table 9 Test of Homogeneity of Variances.....	51
Table 10 ANOVA.....	51
Table 11 Test of Normality.....	54
Table 12 Correlations.....	54
Table 13 Coefficient Value.....	55

Figures

		Page
Figure 1	Map showing the location of Santa Paz Sur Marine Protected Area.....	8
Figure 2	Map showing the location of Napantao Marine Protected area.....	9
Figure 3	Survey plan of MPA assessment performed in Santa Paz Sur.....	12
Figure 4	Survey plan for MPA assessment for Napantao MPA.....	12
Figure 5	Illustration of full transect line setup.....	33
Figure 6	Illustration of benthic survey setup.....	34
Figure 7	Illustration to demonstrate the fish visual census, recording data 2×2.5m wide by 5m high along the 20m transect.....	35
Figure 8	Illustration of invertebrate surveying setup. Recording target species and impacts 2×2.5m along the 20m transect.....	36
Figure 9	Boxplot of mean fish biodiversity inside and outside the MPA.....	42
Figure 10	Boxplot of mean invertebrate biodiversity inside and outside the MPA...	43
Figure 11	Boxplot of mean fish biodiversity for each transect outside the MPA...	48
Figure 12	Boxplot of mean invertebrate biodiversity for each transect outside the MPA.....	49
Figure 13	Scatter graphs for fish biodiversity inside and outside the MPA.....	53
Figure 14	Scatter graphs for invertebrate biodiversity inside and outside the MPA.....	53
Figure 15	Bar graph of mean fish biodiversity inside and outside the MPA.....	57
Figure 16	Bar graph of mean invertebrate biodiversity inside and outside the MPA.....	57
Figure 17	Bar graph of mean fish biodiversity per transect for outside the MPA...	60
Figure 18	Bar graph of mean invertebrate biodiversity per transect for outside the MPA.....	60
Figure 19	Plot graph for fish biodiversity values and coral cover per 20m transect.....	62

1.0 Chapter 1 - Introduction

1.1 Overview

Concerns in the health of coral reefs have increased as a result in proliferation of coral degradation and mortality, associated with the increasing anthropogenic influence on the natural world (Randall 1972; Santer et al. 2013). Within literature, a notable increase in crown-of-thorns sea star populations in 1969 raised the concern in anthropogenic influences affecting the health of the marine environment (Randall 1972). Subsequently, the same proposals occur on why the coral degradation and mortalities were taking place, such as increased pollution, changes in water quality from an inland source, outbreaks of disease (White 2008), and the increasing concern of over fishing (Wilson 2006).

An understanding of the ecosystem processes and services that the marine environment provides is now being recognised as a powerful tool in the conservation of biodiversity (Cimon-Morin 2014). With new ecosystem services being discovered from organisms associated with the coral reef habitat (Craik 2014; ASBMB 2014), this demonstrates that unprotected marine areas may still hold new ecosystem services that mankind could benefit from.

The functional diversity of a community within an ecosystem has demonstrated the need to conserve the biodiversity in association with the organisms that provides the ecosystem service (Micheli & Halpern 2005). With evidence that there is little functional redundancy within the marine environment, this leads to the need to conserve the biodiversity beyond a community of the ecosystem service provider (Micheli & Halpern 2005). The potential for the marine environment to still provide mankind with undiscovered ecosystem services, demonstrates the need for marine protection, as loss of undiscovered ecosystem services

may arise from the increasing anthropogenic influences on the marine and terrestrial environment (Santer et al. 2013).

Coral reefs play a significant role in marine and terrestrial ecosystems (White 2008), a habitat for thousands of marine species (Knudby et al. 2007), and providing temporary shelter for juvenile pelagic species, to a more permanent habitat for unique species that have evolved within the coral reef habitat. Corallivores for example, with diets consisting of up to 80% live coral (Cole 2008). Coral reefs are also recognised as a building block for tropic islands (White 2008). Structure size does not overall equate to that of a rainforest, however due to the species diversity per unit area on a reef they are described as the rainforest of the ocean (Goreau 1994). This makes coral reefs one of the most diverse habitats overall (Goreau 1994), providing a habitat to one-third of all known marine species (White 2008).

Corals have a way of dealing with degradation threats that is a precaution that helps on a long term scale, by means of reproduction, producing coral larvae capable of settling in a more suitable environment. However, the successful assemblage of coral species takes many years to reform the reef structure needed to accommodate the variety of marine species as that of the coral larvae spawning location (Hughes 2003). Due to the increasing threats influencing coral degradation this impacts the capability for the coral reef habitat to recover, demonstrating a need for protection against anthropogenic impacts.

Reef surveying is now a common way of assessing the health of a reef by means of identifying species of fish, invertebrates and coral, taking into account the reef location and keystone species that should be present (Arias-González et al. 2012). Assessing many reef structures within a location allows for comparisons to be made, and the impacts of man can then be taking into consideration (Barbosa 2009). Such areas that are recognised as

significant to a species that is under threat, such as an ecosystem service provider, or of rare value, can be allocated as a marine protected area (MPA) no take zone, where fishing is prohibited. Assessing these coral reef structures and areas of local fishing can determine whether the local fishermen should relocate. This recommendation may come from assessments providing evidence in a decreasing area of biodiversity, and would be in the best interest of the local fishermen and the health of the reef if that area was now allocated as a MPA no take zone. This would allow the reef to regain species abundance and biodiversity (Robbins 2006).

1.2 Background

Coral Cay Conservation (CCC) is an example of a non-government organisation (NGO) that is working to provide evidence for the protection of the marine and terrestrial environment. Focusing on developing community-based coral reef and tropical forest conservations programmes, involving local community capacity building to allow future management of their own natural resources. Offered to host Governments and other NGO's to provide expertise and manpower to increase the awareness and importance of sustainable management of coral reefs and tropical forests for future prosperity to the indigenous communities in developing countries (³Coral Cay Conservation 2012).

“Using the best science, Coral Cay provides the resources the help sustain livelihoods and alleviate poverty through the protection of coral reefs & tropical forests” (³Coral Cay Conservation 2012)

The Philippines archipelago is an example of a country that heavily relies on the sustainability of coral reefs. The majority of the population (approximately 92 million) (Longhurst et al. 2013) is concentrated along the coastlines, further putting strain, via anthropogenic influence, on the narrow ecosystem requirement for coral reefs to be established and maintained (Knudby et al. 2007). The primary source of protein for most Filipinos comes from the fish obtained from the surrounding reefs (Doyle et al. 2003). Other services such as tourism and commercial harvesting provide an income to the locals, while the reef structure provides coastal protection (White 2008; Doyle et al. 2003). This demonstrates the need to protect the coral reefs in the best interest for the indigenous human populations within the Philippines.

Southern Leyte is an area where CCC has been invited by the Philippines Reef and Rainforest Conservation Foundation Inc. (PRRCFI) and the Provincial Government of Southern Leyte (PGSL), to perform surveys to gain data on fish abundance and biodiversity within Sogod Bay, Southern Leyte, and develop capacity building for the local communities. Recognising the need to conserve and develop sustainable management of the bay the Southern Leyte Coral Reef Conservation Project (SLCRCP) was initiated in September 2002 (Doyle et al. 2003). CCC was given objectives to undertake marine habitat assessments for the designations of MPAs. Provide education and capacity building for the locals to increasing awareness in the need for sustainable use of the coral reefs habitat, and demonstrating the beneficial economic importance of MPAs (Doyle et al. 2003).

Table 1

Example of projects performed within Sogod Bay, Southern Layte by Coral Cay Conservation

Author	Credentials
Doyle et al. 2003	First Bi-Annual Report of Sogod Bay, Southern Layte
Taylor et al. 2004	Second year report and coral species list for Sogod Bay, Southern Leyte
⁴ Coral Cay Conservation 2005	Results of community and scientific work
O’Ferrel et al. 2006	Whale Shark photo-identification project, Sogod Bay, Southern Leyte
Aeby & Fenner 2007	A preliminary study of coral disease on reef in Sogod Bay, Southern Leyte
Longhurst & Van De Geer 2013	Marine protected area assessment report, Santa Paz Sur MPA
¹ Longhurst & Ferguson 2013	Crown of Thorns Se Star (<i>Acanthaster planci</i>) assessment report, Limasawa, Southern Layte

CCC has supplied valuable data in the support of conservation of the marine habitat within Southern Layte, providing education to the local communities and capacity building through scholarships to prepare and increase confidences in individuals to carry on in the maintenance of designated MPAs.

Marine protected area assessment reports are useful indicators in the evaluation of MPAs. Assessments allow for the observation, via reef surveying, in species assemblage and reef health, taking into account any further degradation, coral disease and pollutants. Although the assessments look into the abundance of species and diversity, an assessment on the influence the designation of an MPA has on the surrounding marine environment has yet to be looked into for the Napantao reef, by CCC within Sogod Bay, Southern Layte. A similar assessment has been performed by Longhurst & Van De Geer (2007) for the Santa Paz Sur MPA.

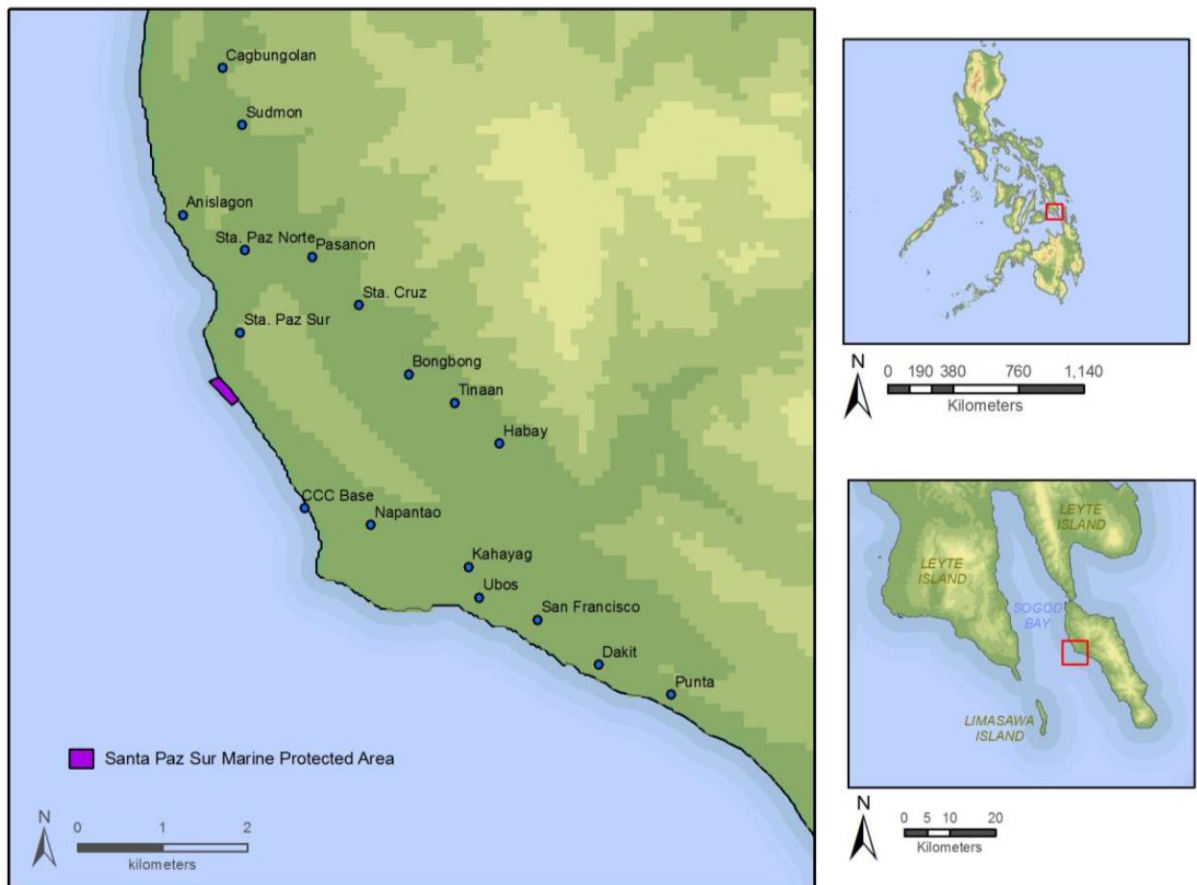


Figure 1 – map showing the location of Santa Paz Sur Marine Protected Area. (Longhurst & Van De Geer 2013)

Longhurst & Van De Geer (2013) found that there was no statistically significant difference in biodiversity between inside the MPA and outside the MPA, although fish biodiversity was overall higher within the MPA. Abundance in fish and invertebrate assemblage showed that both were lower within the MPA, but not statistically significant. Longhurst & Van De Geer (2013) indicated that the high abundance outside the MPA occurred within the deeper transects surveying of 12m, suggesting that highly mobile pelagic schooling fish were recorded due to chance occurrence within transect locations, reflected with no statistical significance with inside the MPA (Longhurst & Van De Geer 2013).

1.3 Study Location

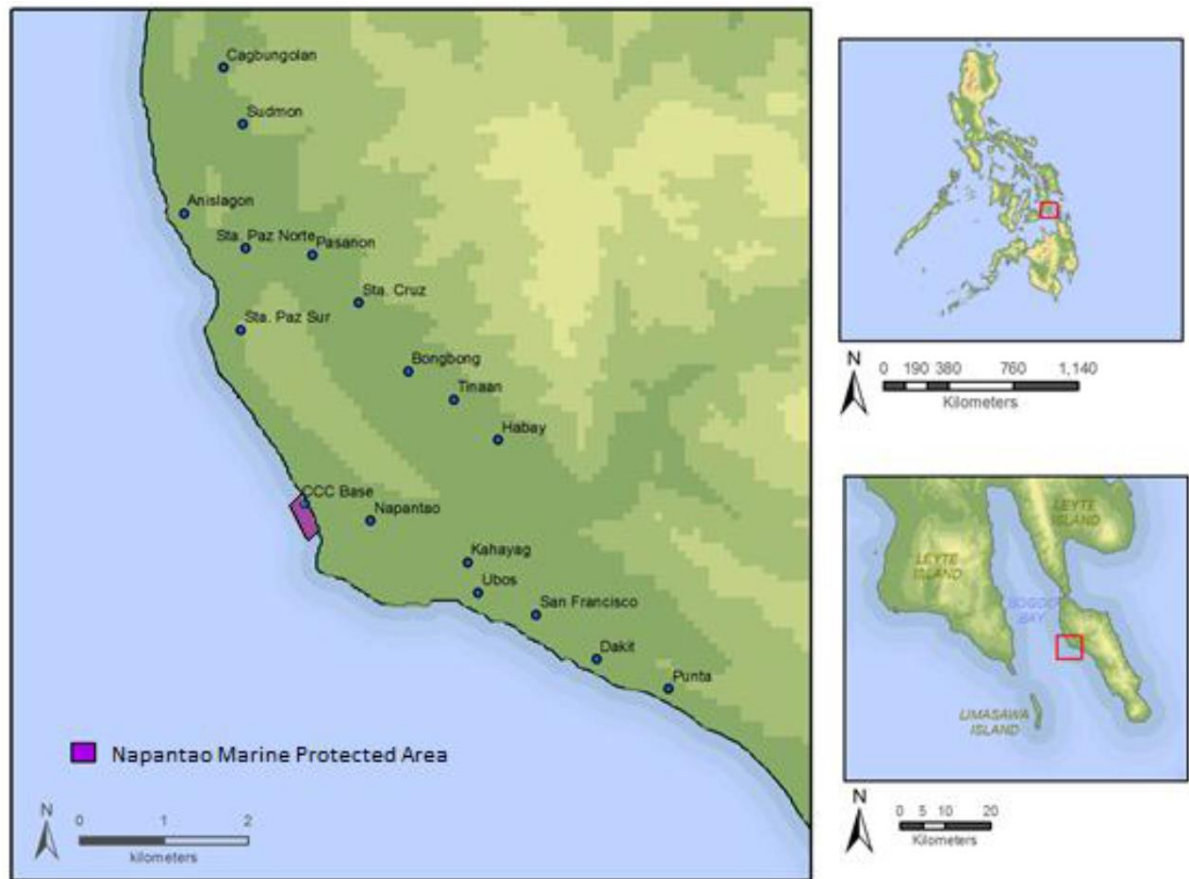


Figure 2 – map showing the location of Napantao Marine Protected area. (²Longhurst & Ferguson 2013)

The Napantao MPA covers 5 hectares within the Municipality of San Francisco. Currently there are 23 established MPAs within Sogod Bay with a mean average at 8.7 hectares (± 2.1). Napantao was established in 1996, CCC began survey working within Sogod bay in September 2002 (²Longhurst & Ferguson 2013).

1.4 Rational

The reef surveying data that will be gathered is of significant value as the Philippines falls into the area of top 10% species richness (Roberts et al. 2002). Monitoring this area will be vital to show any signs of change in biodiversity on a long term scale and will become apparent when showing signs of a decline in biodiversity due to the anthropogenic influences of pollution, increased global warming (Santer et al. 2013), and over fishing (Knudby et al. 2007).

CCC has been providing marine assessment data on Sogod Bay, Southern Layte, since 2002, after an invitation from the PRRCFI to provide education and capacity building for the local communities'. Plans to demonstrate the importance in maintaining the coral reef habitat and the economic importance of MPAs were implemented (Doyle et al. 2003).

From a look at the current marine assessment reports, there has only been one report looking into the difference in biodiversity within an MPA and areas outside the MPA, with no statistically significant difference found (Longhurst & Van De Geer 2013). To date there has not been a similar assessment performed on the Napantao MPA. As found within literature there is significance important in maintaining the biodiversity to ensure a functionally biodiversity within an ecosystem remains (Micheli & Halpern 2005). With little functional redundancy within the marine environment, this increases the risk of loss in functional biodiversity due to reduced ecosystem resilience to intervening circumstances (Micheli & Halpern 2005). Anthropogenic influences put the ecosystem under increasing pressure, and so the need to monitor the biodiversity is vital for the observation in coral reef health. The need to maintain the health of the reef is vital if ecosystem services that it provides are to be sustainable.

The previous assessment performed at Santa Paz Sur MPA (figure 1), was assessed using the standard up to date approach to marine surveying, outline line by Reef Check Worldwide (Longhurst & Van De Geer 2013; Reef Check 2007). Due the topography of the Napantao MPA this surveying method needed to be adapted due the reef structure (²Longhurst & Ferguson 2013). In doing so an additional observation could be made into looking at the influence the allocation of an MPA has on the surrounding reef habitat outside of the MPA.

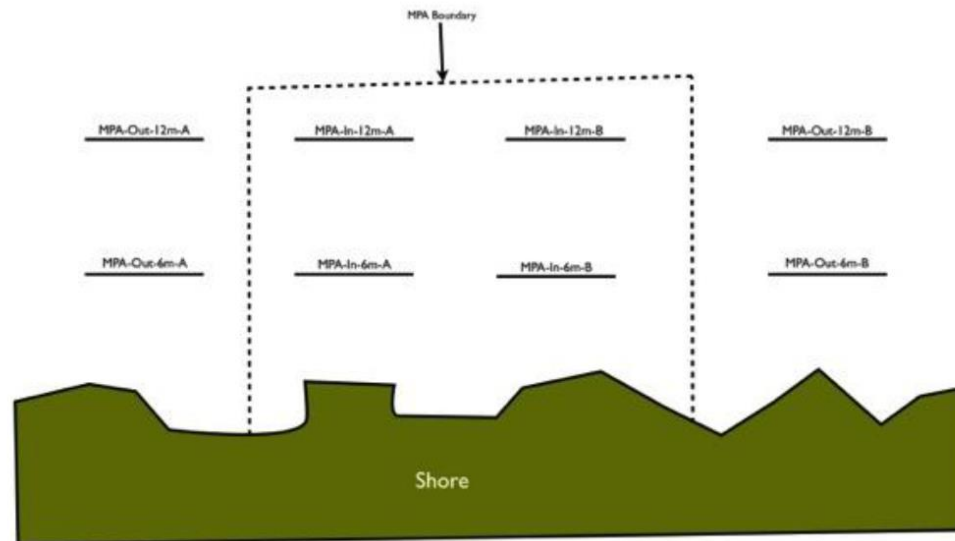


Figure 3 – survey plan of MPA assessment performed in Santa Paz Sur (Longhurst & Van De Geer 2013)

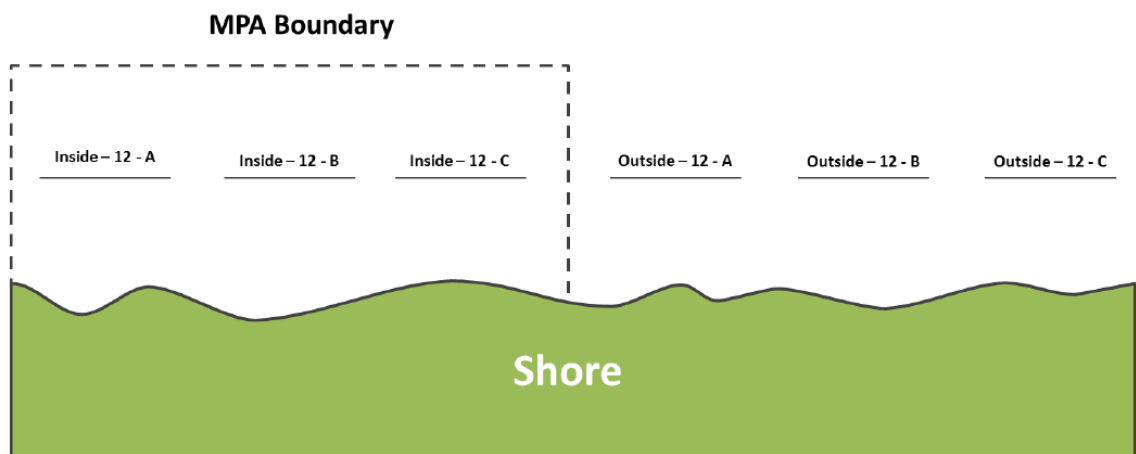


Figure 4 – survey plan for MPA assessment for Napantao MPA (²Longhurst & Ferguson 2013)

1.5 Aims

The aim of this research is to determine any statistically significant difference in the biodiversity between a MPA no-take zone and adjacent areas outside the MPA.

By performing the up to date reef surveying on fixed transects recording fish and invertebrate species abundance, this will allow for the area richness to be established, which can then be applied to the Shannon-Weaver diversity index to establish the biodiversity of the area surveyed (Arias-González et al. 2012). Coral cover will also be recorded in order to establish any correlations with fish and invertebrate biodiversity.

Surveys will be performed with Coral Cay Conservation on a reef site within a MPA no-take zone to gain the data needed to estimate the biodiversity of that reef. The same surveying technique will be performed on a reef site outside of the MPA no-take zone to gain the data needed to estimate the biodiversity of that reef. With a sufficient number of diversity values for the MPA no-take zone and areas outside the zone a comparison can be made as to whether there is any statistically significant difference in the biodiversity.

This research will provide evidence that will allow for observations to be made on the effects of allocating a MPA no-take zone within a coral reef location, and the influences a MPA has on the marine biodiversity surrounding that MPA (figure 2).

1.6 Objectives

- Perform Reef Check surveys within a MPA no-take zone and adjacent areas outside the zone using the up to date MPA surveying technique outline by Reef Check Worldwide (Reef Check 2007).
- Establish biodiversity values from the surveying data using Shannon-Weaver diversity index.
- Establish any significant difference in biodiversity between a MPA no-take zone and the adjacent areas outside the MPA

2.0 Chapter 2 - Literature Review

2.1 Introduction

This chapter of the research project reviews the literature that presents an understanding for the need to conserve coral reefs. A strong relationship is found for the environment to provide mankind with useful resources or process, to support conservation efforts. The challenges that the marine environment faces due to anthropogenic influences, and the challenges it presents to establish the protection are outlined within literature. The technique used to establish the areas in need for coral reef conservation is established, and an example of a method in reef surveying is explained. Finally this review touches on the current MPAs within the country that the research project was performed, the Philippines. This resulted in literature demonstrating the conflicting idea for the recommended MPA size with regards to the requirements in resources it provides.

2.2 Marine Protection

With the inevitable increase in anthropogenic impacts upon the natural world, directly or indirectly as a result of the resources provided by ecosystem processes (Cimon-Morin et al. 2014; David 2014), the need to protect these potentially effected natural habitats is increasing (Hopper et al. 2005). Protection of the natural world will trend along the basis of the environment providing mankind with a useful resource or service, and so the assumption can be made that allocation of environmental protection strongly needs to fall within the categories of an ecosystem service or process that benefits mankind's needs (Worm et al. 2006). After a four year assessment by the Millennium Ecosystem Assessment (MEA) (MEA 2005) considering the benefits of supporting, provisioning, regulating and the cultural services provided by the marine environment, it is in mankind's best interest to protect this 'last great living wilderness' (Culliney 1976). The need to protect the marine environment can also be supported by the human desire for exploration (Worm et al. 2006).

With limited knowledge of the services that the oceans can provide, this draws up the consideration of unprotected areas to potentially provide a service that mankind can benefit from obtaining (Danovaro et al. 2008).

2.3 Availability of Marine Data

In order to gain a better understanding of these services provided by the marine environment, an approach is needed to assess the diversity and how the marine species interact with one another and their environment. Knowledge of this enables us to predict outcomes in species populations with changes to the marine environment or interactions between populations. This is an important area to start with as in order to do further research into the potential services that the marine environment could provide there needs to be the protections of the natural state the marine species and environment require for optimal function. It also enables us to see the influence of anthropogenic effects occurring within the marine environment.

Due to the difficulty and high risk resulting in higher expense needed in order to study the deep oceans (Danovaro et al. 2008), an area that can be accessed more easily and with little expense, are the reefs within shallower waters, above the continental ridges on the continental shelves (Worm et al. 2006). This area still provides a great level of information on the intricate and delicate ecosystem processes and services provided by the marine environment.

2.4 Threats to Coral Reefs

White (2008) outlines several damaging factors that threaten the global coral reef formations. There is a strong indication that anthropogenic threats have a large part to play in the degradation in the coral reef ecosystem. Over fishing impacting on the ecosystem dynamics in altering the established food webs by removal of key stone species (White 2008; Valentine & Heck 2005), is just one of the examples in how over fishing is damaging marine life beyond the coral reef ecosystem. Furthermore, sedimentation due to poorly managed farming, construction and forestry from inland sources ultimately impedes the coral polyps from the sunlight needed for the symbiotic relationship with zooxanthellae algae to photosynthesis (White 2008; Bartley 2014; Nakajima et al. 2013). This can result in effecting goral growth or ultimately encourage coral bleaching, decreasing the effected corals immune system, and increasing susceptibility to coral disease (Bruno et al. 2007; Nakajima et al. 2013). These anthropogenic impacts add to the natural disasters that can occur such as Typhoons, further increasing the degradation of the coral reef habitat. The Global Coral Reef Monitoring Network (GCRMN) found that up to 20% of the global coral reefs have virtually been destroyed, and show no sign of recovery (GCRMN 2013). While a prediction by the National Ocean and Atmospheric Administration (NOAA) suggested that by 2028, 40% of global coral reefs could be eliminated (NOAA 2014).

It is argued and recognised within literature that anthropogenic influences on the environment has increased the rate of global warming (Santer et al. 2013). Consequently due to the increase in ocean temperatures, this is causing the phenomena of mass coral bleaching when temperatures exceed an increase of 1.5 °C (Frieler et al. 2013). Frieler et al. (2013) demonstrates that this phenomenon is likely to increase in frequency and

intensity and in order to preserve >10% of the global coral reefs there is a limit to this increase in average ocean temperature that should not exceed a raise of 1.5°C. Bruno et al. (2007) demonstrates that the increase in ocean temperatures is also strongly linked to the outbreak of coral 'white syndrome disease'. Bruno et al. (2007) shows that there is a correlation between areas of high coral density and 'white syndrome disease' proliferation. This suggests that not only will coral reefs come under the threat of coral bleaching from increasing temperatures, areas of high coral density will become more susceptible to diseases, such as the 'white syndrome disease' outbreak (Bruno et al. 2007). Frieler et al. (2013) recognises that even with new optimum emission scenarios, one-third of the Worlds coral reefs are predicated to be subjected to global warming, leading to the consequent effect of long-term coral degradation.

A possible outcome from the increase in average ocean temperatures is that of high-latitude reefs potentially acting as a refuge for tropical, sum-tropical and temperate reef species (Beger et al. 2013). With the increasing temperatures, species assemblage may naturally migrate to higher global latitudes where temperatures become more suitable. This may benefit species with greater requirements in seasonal compositions (Beger et al. 2013). As suggested by Knudby et al. (2007), there are strong correlations in coral species to fish species. This demonstrates that although high-latitude reefs may act as natural surrogates for some tropical, sum-tropical and temperate reef species, some may have unique phenotypical adaptations in relation to evolved symbiotic relationships with coral species. This potentially produces the requirement for specific coral species to migrate to higher latitudes. Multiple abiotic influences stated by Knudby et al. (2007) outline some of the unique environmental requirements for coral reefs to be established and maintained, such as distance between land masses, availability of shallow clear waters, to direction and income of ocean currents. These abiotic requirements may further narrow the capability for

coral species to migrate to higher latitudes, ultimately threatening the endemic species and species with strong symbiotic relationships within an existing ecosystem community.

Allocations of no-take reserves can be implemented to reduce the anthropogenic impacts, but as suggested by Beger et al. (2013) climate change is still likely to have an impact on the endemic species and strong seasonality in species composition. There are significantly many other considerations to protect areas of coral reef as mentioned by Hopper et al. (2005), White (2008) and supported by MEA (2005). These supportive considerations for conservation of coral reefs strongly demonstrate the increasing understating in the ecosystem services that the marine environment has to offer. Loss in biodiversity due to anthropogenic impacts will ultimately reduce these ecosystem services, and potentially remove services that still remain undiscovered.

2.5 Functional Diversity

Functional diversity of an ecosystem is the range of species within that ecosystem that share similar functional traits (Micheli & Halpern 2005). Understanding the functional diversity of an ecosystem provides greater insight into the areas that require conservation when considering the protection of the ecosystem service. Cimon-Morin (2014) states that when considering the conservation of a species due to its ecosystem system contribution, an understanding of the ecosystem community and species assemblage is required in order to determine how the species contributes to that ecosystems functional diversity. Micheli & Halpern (2005) presents that there is a low level of redundancy in functional species traits across many marine ecosystems. This demonstrates that a loss in biodiversity has an increased effect in reducing the functional biodiversity of an ecosystem. When a minimal functional diversity arises due to a sudden loss in biodiversity, this reduces the ecosystems resilience to intervening disturbances, threatening the loss of the remaining functioning species within that ecosystem (Micheli & Halpern 2005). A loss of these remaining functional species could potentially alter the ecosystem resulting in loss of the provided ecosystem services. Cimon-Morin (2014) argues that an understanding of how the marine environment can be used to gain ecosystem services becomes a powerful tool in the conservation of biodiversity. Delieg & Neuteleers (2014) expresses a concern to how using the ecosystem services argument will focus on conserving target species:

“useful species or ecosystems, so that useless or non-functional biodiversity can be extinguished” (Delieg & Neuteleers 2014)

Whereas Cimon-Morin (2014) states how by understanding the functional biodiversity of a community towards that of the species in consideration in providing the ecosystem service, can be used as an extension in biodiversity conservation.

2.6 Ecosystem Services & Processes

The coral reef ecosystem is increasingly being recognised for the ecosystem services and processes it provides (White 2008). This ultimately strengthens the understanding to conserve the associated biodiversity. As stated by Micheli & Halpern (2005), the functional biodiversity within many marine ecosystems shows a low level of redundant functional species. This further demonstrates the understanding in the need to conserve the biodiversity beyond the associated community of specific ecosystem service providers. Existing understanding within literature has already demonstrated the significance of coral reef formations and the dependant ecological communities.

Table 2*Example of literature demonstrating the importance of ecosystem services*

Author	Credentials
White 2008	Outlining uses derived from the coral reef ecosystem: food, coastal protection, tourism, gauge water quality, environmental indicators, potential to provide pharmaceutical.
Craik 2014	Local anaesthetic produced from the cone shell.
ASBMB 2014	Coral reef providing a potential potent anti-HIV protein.
Cimon-Morin et al. 2014	Synergy between ecosystem services and conservation plans.
Danovaro et al. 2008	Loss in biodiversity might impair the functioning and sustainability of ecosystems in deep-sea ecosystems.
Worm et al. 2006	Biodiversity loss effecting marine ecosystem services.

A significant service that is providing vital evidence for the need to conserve marine ecosystem is that demonstrated by Craik (2014) & the ASBMB (2014). This literature demonstrates that even in the 21st century, pharmaceuticals are still being discovered within the natural world that may hold solutions to some of the most biologically threatening diseases to humans. An example is the discovery of a potent anti-HIV protein, capable of binding to the HIV virus to inhibiting the virus capability to fuse with T-cell membranes (ASBMB 2014).

2.7 Determining coral reef conservation locations

Roberts et al. (2002) has demonstrated a way in which this can be done by using existing data on the distribution of 3235 species from four phylum: 1700 reef fish species, 804 species of coral, 662 species of snail and 69 species of lobster, in relation to their geographical range to establish areas that may be under threat of coral degradation. Throughout the tropics, areas containing coral reefs show a similar pattern of hot spots of diversity with species richness peaking around the coral-triangle in Southeast Asia (Roberts et al. 2002; Knudby et al. 2007). Roberts et al. (2002) established this by using the four taxa chosen, as they show a relatively equal level of distribution across the geological mapped area of the tropics (50,000-km² per cell), pairwise Spearman's rank correlations range was used to gain this information. These four taxa were also chosen as they are good surrogates for reef diversity overall (Roberts et al. 2002). There are strong correlations with the biodiversity of coral species to fish species, which form the areas of hot spots for species richness; this makes a good indicator of biodiversity using the distribution of fish. However as mentioned by Knudby et al. (2007), remote sensing on fish cannot be done, so environmental variables can be used to map out the likely spatial distribution of biodiversity. The locations of coral reefs are down to several geographical factors that have helped to form these areas of species richness and biodiversity, and provide the coral with essential abiotic and biotic requirements that they need to establish and be maintained (Knudby et al. 2007). These three factors covered by Knudby et al. (2007) are the distribution of land masses between the Atlantic and Indo-Pacific Ocean in relation to the dominant equatorial current flowing east to west, which brings an upwell of cold nutrient rich water ideal for coral growth. The closing of the Isthmus of Panama 3.5 million years ago separating the Atlantic and Pacific Ocean resulting in species isolation

and the evolution of new marine species, and the relatively shallow tropical waters surround the island clusters and land masses within Indo-West Pacific seas. In order to gain the understanding of where to focus conservation efforts Roberts et al. (2002) explains how by determining the mapped out cells that contain endemism species, these areas are to be considered more vulnerable to the effect of coral degradation as the species within these cells have a lower distribution range, so come under greater threat of extinction, these cells are referred to as centres of endemism (Roberts et al. 2002). 58 coral species (7.2%), 26.5% fish species, 28.7% snails species and 53.6% of lobster species all have restricted-ranges, and the cells within Southern Philippines and Central Indonesia are recorded to be in the top 10% for species richness (Roberts et al. 2002).

2.8 Surveying

Remote sensing is a sufficient and inexpensive way of mapping out coral reef areas that can then be used towards coral reef conservation, such as analysing the rate of coral growth and area size of annual bleaching (Knudby et al. 2007). When performing a biodiversity assessment over a large reef area there is essential data that needs to be collected and recorded by means of Geographic Information System (GIS), remote sensing and information on environmental variables, along with species abundance and richness (Arias-González et al. 2012). Knudby et al. (2007) argues that just using environmental variables to predict biodiversity is more of a species specific approach to measuring the variables to a habitat and requirements of a species which can be done on a local scale for the species known.

“with approximately 10,000 species of described fish, and a total of one million species in all taxonomic groups estimated to exist on coral reefs, a species-specific approach is unfeasible for studies of general biodiversity patterns” (Knudby et al. 2007).

To obtain the biodiversity of a large area, some habitat variables are essential as habitat surrogates i.e. coral cover and depth. With the strong correlation of coral species to fish species, remote sensing can be used to map out the area of Live Coral Cover (LCC) and Reef Area (RA) to give likely spatial distribution of biodiversity in that area, and with the occurrence of catastrophic disasters i.e. hurricane or coral bleaching, this will help towards establishing any estimated decrease in biodiversity (Knudby et al. 2007). The use of Global Positioning System (GPS) is essential when performing reef habitat checks to ensure the desired area to be surveyed is located. Arias-González et al. (2012) demonstrated that the

biodiversity of a reef can be assessed by means of reef surveying using line transects to gather data on species richness and abundance. By using the Shannon-Weiner diversity index, a diversity value can be established for the area surveyed. However in order to produce the biodiversity of an entire reef site there needs to be the use of additional software. Arias-González et al. (2012) used General regression analysis and spatial prediction v.2.5 (GRASP) to establish spatial prediction. An understanding of the spatial difference of an entire reef structure is vital as different species require different environmental variables.

Marine conservation has many more barriers than that of terrestrial conservation due to the restriction of enabling us to record and observe the marine biome. With remote sensing this allows for areas within the marine environment to be recorded and data to be added with the use of software such as GIS to gradually present an accurate assessment of an area within the marine environment (Knudby et al. 2007). One way this is achieved is by that of reef surveying over a GPS marked reef (Knudby et al. 2007).

2.9 The Philippines Marine Protected Areas (MPAs)

The Philippines Marine Sanctuary Strategy (2004) aims to establish approximately 10% of all coral reef area in the Philippines to be within a no-take MPA by 2020 (Weeks et al. 2010). While the Fishers Code Legislation (1998) called for 15% of coastal municipal waters within 15km of the Philippines coastline to be within a no-take MPA (Weeks et al. 2010). Weeks et al. (2010) established that the current numbers of MPA no-take zones within the Philippines are not adequate enough in comparison to the biodiversity. To the date of the research Weeks et al. (2010) performed, only 0.5% of coastal municipal water and between 2.7% and 3.4% of coral reef areas in the Philippines are protected, falling short of both The Philippines Marine Sanctuary Strategy 10%, and the Fisheries Code Legislations of 15%. The 15% target is suggested by (Weeks et al. 2010) to be originally determined most likely due to political convenience for the Fisheries Code Legislation, given that 15% of municipal waters are approximately twice the area of coral reefs within Philippines waters (Weeks et al. 2010). As for The Philippines Marine Sanctuary Strategy, a more solid scientific based assessment, with a series of expert workshops, helped define an achievable target of 10% of coral reefs to be within no-take MPAs (Weeks et al. 2010). Even the 10% of coral reef protection falls short of the recommended 20%, with an optimum target of 30%-50% set aside as marine reserves (Roberts et al. 2002). Current MPAs represent the social and academic needs, not localised where greatly needed. Distributions of MPAs may reflect the increased biodiversity due to the current influence on biodiversity of existing MPAs, where allocation of an MPA is based on biodiversity data sets, not due to the distribution needs of the marine species (Weeks et al. 2010). Roberts et al. (2002) recommends a patchy distribution of MPAs as oppose to random or uniform focusing on habitat types, will reduce overall impact from fishing as the fishing

impacts are greater than subsequent impacts. Small MPAs within the Philippines with a median size of just 0.12km², are too small for the intermediate recommend size of 10-100km² (Weeks et al. 2010; Roberts et al. 2002), but these MPAs still provide relative protections and species recruitment (Roberts et al. 2002). Distance between MPA should allow for natural larval dispersal distances, which vary depending on geology and tidal patterns. Within the Philippines MPAs consist of an average distance of 1-5km apart (Weeks et al. 2010; Roberts et al. 2002). These small MPAs are unlikely to provide the protection for the larger mobile species, and do not meet the regional conservation objectives. Roberts et al. (2002) indicates that the MPAs will be impacted by edge effect, with larger MPAs protecting more than smaller. However the allocation of one large MPA as oppose to a few small MPAs impacts on the fisherman capability. This may result in an advantage to those living closer to the large MPA perimeters with the knowledge of the spill over effect, as oppose to those living further away, requiring greater distance to travel to benefit from the MPA allocation (Roberts et al. 2002). There is a lack of scientific knowledge on the effects of pressure displacement on non-target population, resulting form when fishermen simply move to a different location when target species stock is low (Roberts et al. 2002).

Weeks et al. (2010) demonstrated that previous assessment of current MPAs networks over looked the MPAs that fell short of the recommended >1km², such as that of Rodrigues (2004), which is the equivalent of excluding 93% of the data sets that Weeks et al. (2010) used.

Philippines need to move away from the small community based MPAs in order to achieve the conservation targets, such as Tubbataha Reef National Park and Apo Reff Natural Park, that together comprise more than 85% of Philippines total no-take area of MPAs (Weeks 2010). But socioeconomic constraints due to the high dependence of local communities on

marine resources and low spatial mobility of fishers, adds to the constraint in increasing the no-take areas of MPAs (Weeks et al. 2010).

3.0 Chapter 3 - Methodology

3.1 Introduction

Using the up to date MPA surveying technique (Reef Check 2007) a 100m full surveying transect is placed along the reef at a constant depth parallel to the shore, depending on the reef topography the transect is placed at a shallow depth of 2-6m or a deep depth of 6-12m. 4×20m transects are performed along the 100m full transect line with 5m between each along the 100m to complete one survey. 3x100m full survey transects are performed within an MPA and then repeated outside of the MPA, the depths that the surveys were performed at will be mirrored to reduce bias.

Each 20m transect will allow data to be collected on the benthic substrate type, recording hard coral species, fish abundance for families that are of relative importance to that area, invertebrate species abundance, and notes on any human impacts and abiotic factors. See appendix 1 for tables on substrate and target species recorded during surveying.

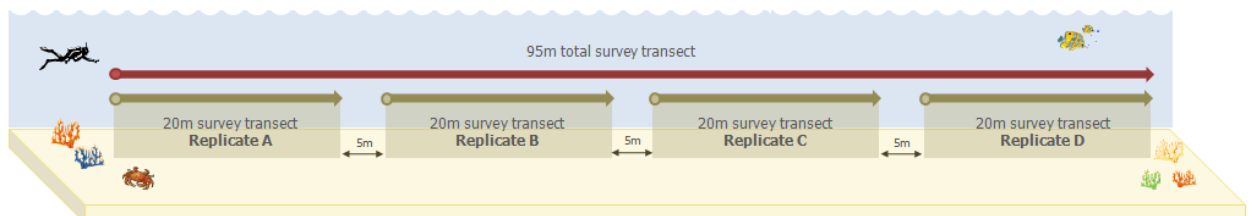


Figure 5 - illustration of full transect line setup (²Coral Cay Conservation 2013)

3.1.1 Benthic Survey

A 20m transect line is laid out at a continuing depth along the full 100m transect line. Every 50cm a record of substrate type is recorded using a plum line dropped vertically down from the 50cm mark. There will be a total of 40 points of record to give a % of relative abundance of living and non-living benthic cover along that 20m transect.

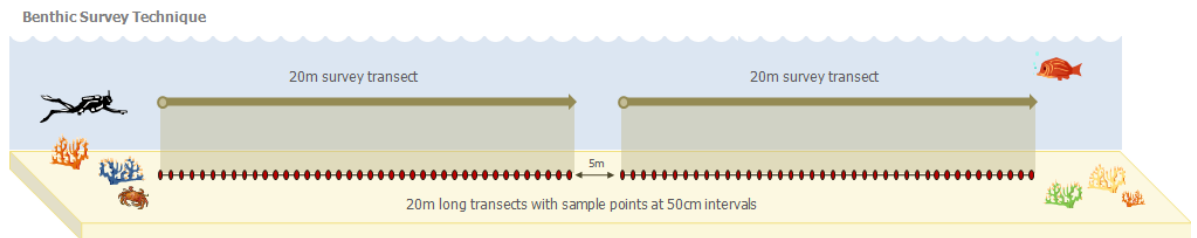


Figure 6 - illustration of benthic survey setup (²Coral Cay Conservation 2013)

3.1.2 Fish Survey

Two divers will swim at a controlled speed either side along the transect recording and abundance of target fish species 2.5m either side of the transect line and 5m above. Target species are selected based on them being a good reef health indicator, or species locally consumed to show signs of fish recovery or over fishing. The size of each fish is also recorded to give indication of a healthy fish stock, size is recorded by class: 1-10cm, 11-20cm, 21-20cm or >30cm.

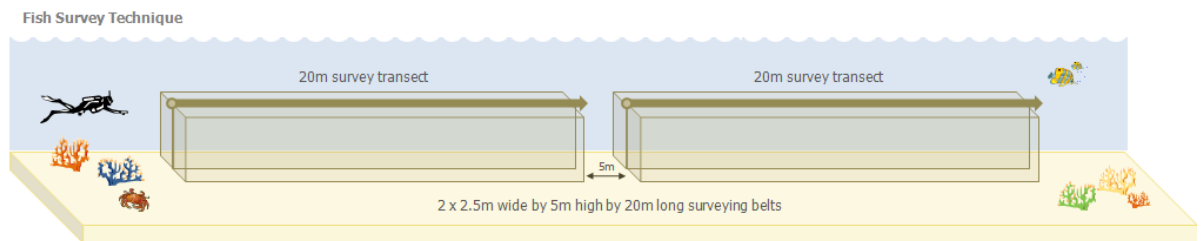


Figure 7 - illustration to demonstrate the fish visual census, recording data 2×2.5m wide by 5m high along the 20m transect (²Coral Cay Conservation 2013)

3.1.3 Invertebrate and impacts survey

A total area of 250m² is used to record invertebrate species. Two divers swim in an ‘S’ shape 2.5m either side to cover the area along the 20m transect recording target invertebrate and impacts on the reef. Similar to the target fish species, the invertebrates recorded are those that may indicate the health of the reef and are of commercial importance (¹Coral Cay Conservation 2013).

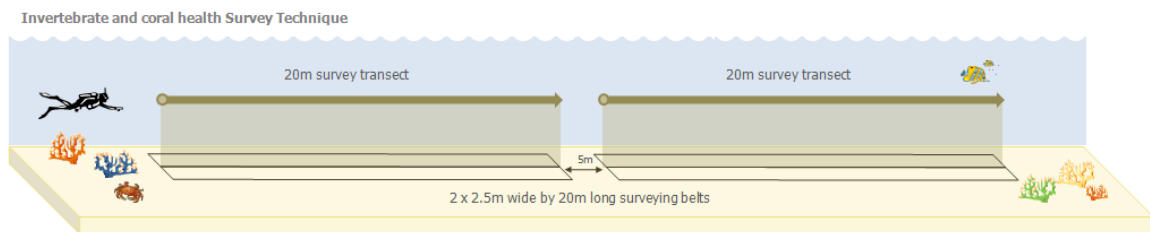


Figure 8: Illustration of invertebrate surveying setup. Recording target species and impacts 2×2.5m along the 20m transect. (²Coral Cay Conservation 2013)

3.2 Analysis

The data collected will be allocated a biodiversity value by applying the results to the Shannon-Wiener diversity index. This diversity index is chosen based on previous use by the author and evidence within literature when deriving the biodiversity from marine transects surveying (Arias-González et al. 2012).

$$H = - \sum_{i=1}^s p_i \ln p_i$$

Note. where p_i is the proportion of individual within a population belonging to the i^{th} species.

If sufficient data is collected per transect then each transect will be allocated a biodiversity value. This will allow observation in changes in biodiversity based on distance from the MPA within the non MPA zones, potentially giving evidence of spill over. If not enough data is collected per transect then the biodiversity value will be allocated per completed survey ($4 \times 20\text{m}$ transects).

3.2.1 Hypotheses

- (HA1) There is a statistically significant difference in biodiversity between inside the MPA and the adjacent area outside the MPA.
- (HN1) There is no statistically significant difference in biodiversity between inside the MPA and the adjacent area outside the MPA.
- (HA2) There is a statistically significant decrease in biodiversity as you move away from the MPA.
- (HN2) There is no statistically significant decrease in biodiversity as you move away from the MPA.
- (HA3) There is a correlation between percentage coral cover and fish/invertebrate biodiversity.
- (HN3) There is no correlation between percentage coral cover and fish/invertebrate biodiversity.

3.3 Testing Hypotheses

In order to perform further analysis to establish hypotheses Statistical Package for the Social Sciences (SPSS) will be used. SPSS will establish if the data meets the assumptions in order for a specific analysis to produce a reliable result.

In order to determine HA1 an independent samples t-test will be used to establish any statistically significant difference in fish and invertebrate biodiversity between inside the MPA and outside the MPA. Assumption that the data need to meet are no outliers in the data, data is normally distributed and there is homogeneity of variance.

HA2 will be established with the use of a one-way analysis of variances (ANOVA). This will allow for the observation in difference in biodiversity values for fish and invertebrate, per transect for the areas surveyed outside of the MPA. This will establish any difference in biodiversity when moving away from the MPA, potentially providing evidence for spill over. Assumption that the data need to meet are no outliers in the data, data is normally distributed and there is homogeneity of variance.

HA3 requires the observation in population correlations to establish if there is any correlation between fish and invertebrate biodiversity with percentage coral cover, Pearson's Correlation Analysis is used. Assumptions that the data needs to meet are no outliers in the data and data is normally distributed.

Additional analysis will be conducted on effect size to establish Null Hypothesis Significance Testing (NHST). This will allow for the observation in significance of the null hypothesis for HN1 and HN2 are accepted (Dunst & Hamby 2012).

4.0 Chapter 4 - Findings & Discussion

4.1 Introduction

The research data was gathered during a 6 week expedition in the Philippines based at Napantao Dive Resort on the eastern side of Sogod Bay (figure 2). The data gathering needed to fit in with Coral Cay Conservation's on going surveying effort; this means that although the data gathered will be used by Coral Cay Conservation, it can also be used by independent research students to facilitate their research. This chapter shows the analysis of the data using SPSS to establish hypotheses. Three forms of analysis were performed to establish HA1, HA2 and HA3. Within each analysis the data sets needed to pass assumptions in order for the result to be accurate, these assumptions are also shown.

4.2 Independent-samples t-test

Hypothesis

- **(HA1)** There is a statistically significant difference in biodiversity between inside the MPA and the adjacent area outside the MPA.
- **(HN1)** There is no statistically significant difference in biodiversity between inside the MPA and the adjacent area outside the MPA.

Results:

There were no outliers in the data, as assessed by inspection of the boxplots for values greater than 1.5 box-lengths from the edge of the box.

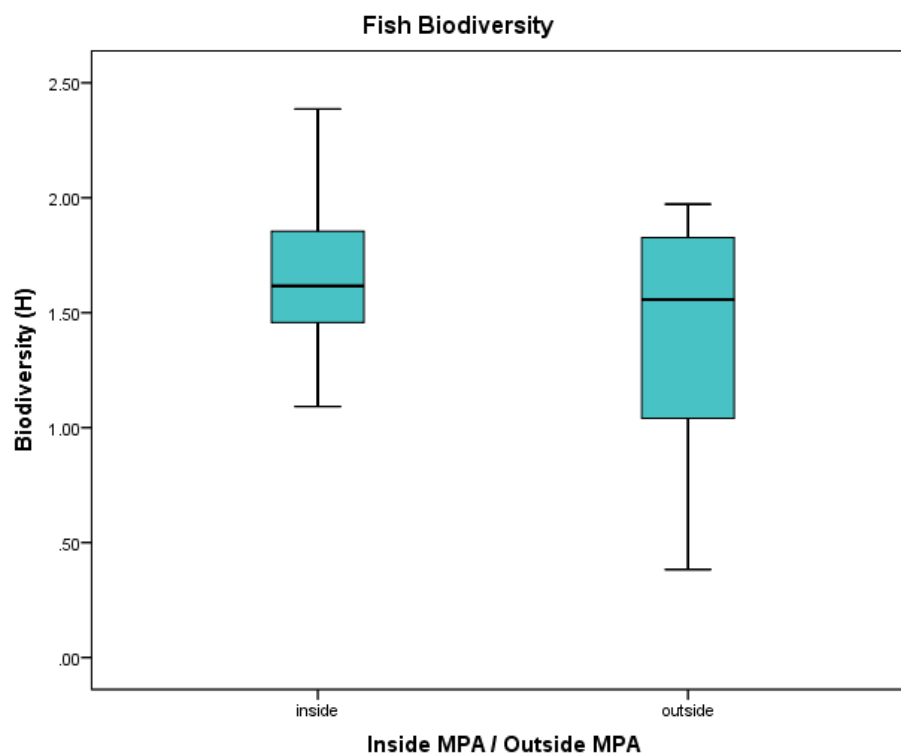


Figure 9 – boxplot of mean fish biodiversity inside and outside the MPA

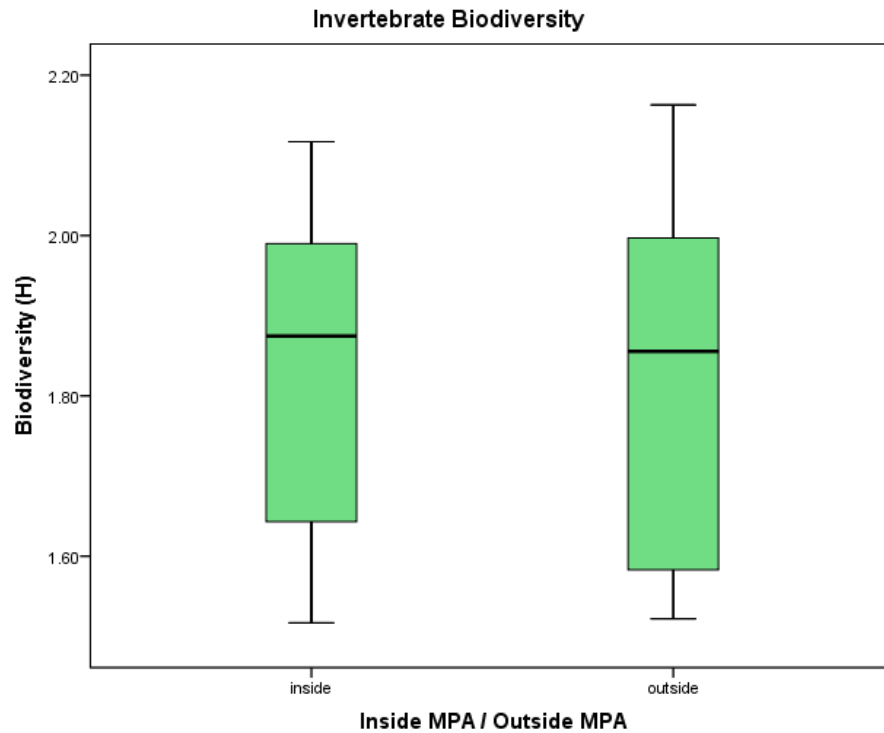


Figure 10 – boxplot of men invertebrate biodiversity inside and outside the MPA

Fish and invertebrate biodiversity for inside MPA and outside MPA were normally distributed, as assessed by Shapiro-Wilk's test ($p > 0.05$).

Table 3

Test of Normality

		Shapiro-Wilk's		
		Statistic	df	Sig
Fish Biodiversity	Inside	.976	12	.962
	Outside	.922	12	.305
Invertebrate Biodiversity	Inside	.937	12	.465
	Outside	.923	12	.308

Note. Inside = inside the MPA, Outside = adjacent areas outside the MPA.

Data are mean $\pm$ standard deviation, unless otherwise stated. There were 12 inside MPA and 12 outside MPA biodiversity values.

Mean fish biodiversity inside MPA (1.67 ± 0.35) was higher than mean fish biodiversity outside MPA (1.41 ± 0.5).

Mean invertebrate biodiversity inside MPA (1.83 ± 0.21) was higher than mean invertebrate biodiversity outside MPA (1.82 ± 0.22).

Table 4

Group Statistics

		N	Mean	Std. Deviation	Std. Error Mean
Fish Biodiversity	Inside	12	1.6673	.34739	.10028
	Outside	12	1.4119	.49555	.14305
Invertebrate Biodiversity	Inside	12	1.8327	.20941	.06045
	Outside	12	1.8193	.22041	.06363

Note. Inside = inside the MPA, Outside = adjacent areas outside the MPA.

There was homogeneity of variances, as assessed by Levene's test for equality of variances, for fish biodiversity ($p = 0.125$) and invertebrate biodiversity ($p = 0.773$).

There was no statistically significant difference in mean fish biodiversity between inside MPA and outside MPA, with inside MPA fish biodiversity occurring higher than outside MPA fish biodiversity, 0.26 ± 0.17 , $t(22) = 1.462$, $p = 0.125$.

There was no statistically significant difference in mean invertebrate biodiversity between inside MPA and outside MPA, with inside MPA invertebrate biodiversity occurring higher than outside MPA invertebrate biodiversity, 0.13 ± 0.09 , $t(22) = 0.153$, $p = 0.773$.

There was no statistically significant difference between means for fish and invertebrate biodiversity ($p < .05$), and therefore, we can accept the null hypothesis (HN1) and reject the alternative hypothesis (HA1).

Table 5

Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Fish Biodiversity	2.544	.125	1.462	22	.158	.25533	.17470
Invertebrate Biodiversity	.086	.773	.153	22	.880	.01342	.08777

4.2.1 Calculating effect size (d)

$$d = \frac{|M_1 - M_2|}{s_{pooled}}$$

$$s_{pooled} = \sqrt{\frac{s_1^2(n_1 - 1) + s_2^2(n_2 - 1)}{n_1 + n_2 - 2}}$$

Note. Where n = number of participants in first independent, M = mean, S = std. deviation.

Table 6

Effect Size

	Strength
.2	small
.5	medium
.8	large

(Cohen 1988)

Fish biodiversity:

$$s_{pooled} = \sqrt{\frac{0.2919^2(12 - 1) + 0.39339^2(12 - 1)}{12 + 12 - 2}} = 0.346$$

$$d = \frac{1.6673 - 1.4119}{0.346} = 0.738$$

Invertebrate biodiversity:

$$s_{pooled} = \sqrt{\frac{0.20941^2(10 - 1) + 0.22041^2(12 - 1)}{12 + 12 - 2}} = 0.215$$

$$d = \frac{1.8327 - 1.8193}{0.215} = 0.062$$

4.3 One-way ANOVA

Hypothesis

- (HA2) There is a statistically significant decrease in biodiversity as you move away from the MPA.
- (HN2) There is no statistically significant decrease in biodiversity as you move away from the MPA.

Results:

There were no outliers in the data, as assessed by inspection of the boxplots for values greater than 1.5 box-lengths from the edge of the box.

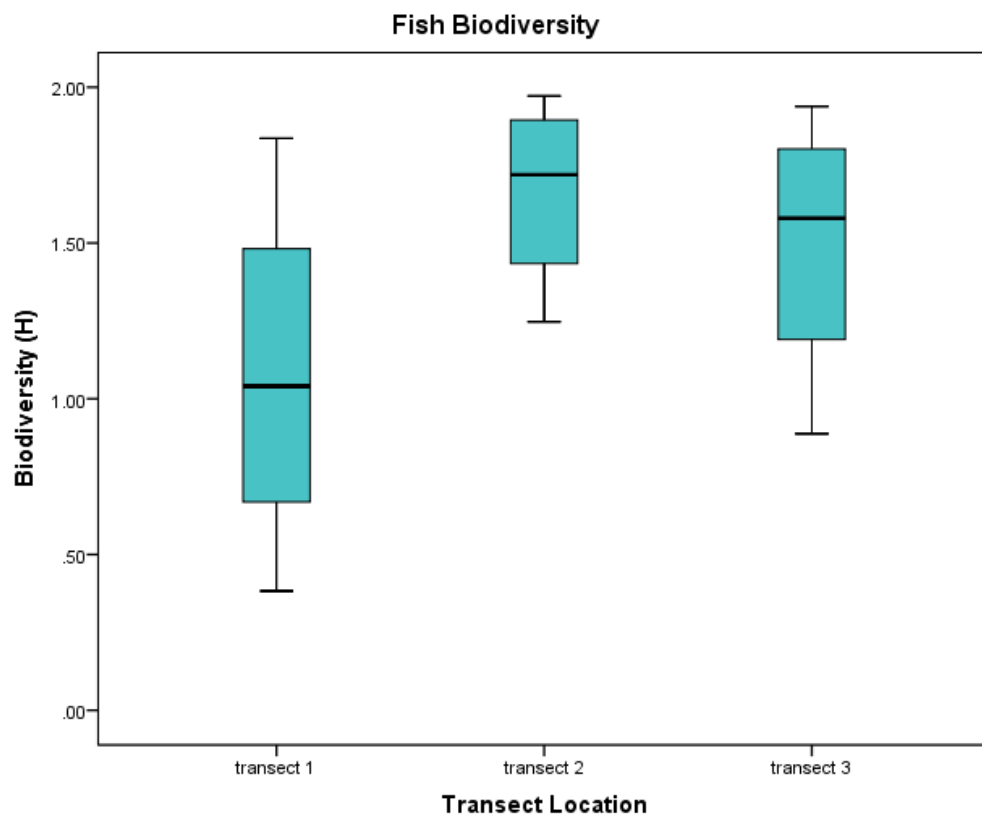


Figure 11 – boxplot of mean fish biodiversity for each transect outside the MPA

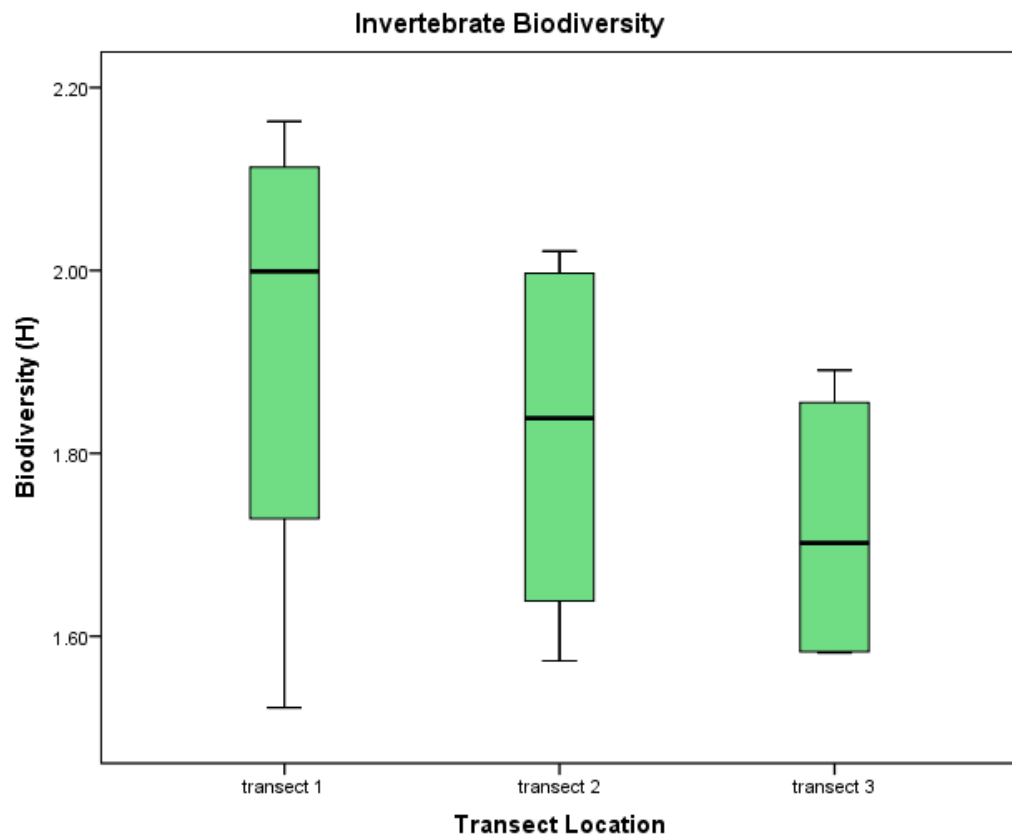


Figure 12 - boxplot of mean invertebrate biodiversity for each transect outside the MPA

Fish and invertebrate biodiversity for transect 1, 2 & 3 were normally distributed, as assessed by Shapiro-Wilk;s test ($p > 0.05$).

Table 7*Test of Normality*

		Shapiro-Wilk's		
		Statistic	df	Sig.
Fish Biodiversity	T 1	.982	4	.911
	T 2	.958	4	.767
	T 3	.948	4	.704
Invertebrate Biodiversity	T 1	.896	4	.410
	T 2	.899	4	.428
	T 3	.825	4	.154

Note. T1 = transect 1, T2 = transect 2, T3 = transect 3.

Data is presents as mean $\pm$ standard deviation. The fish biodiversity increased from transect 1 (1.08 ± 0.6), to transect 2 (1.66 ± 0.31), then decreased to transect 3 (1.41 ± 0.5), in that order.

Invertebrate biodiversity decreased from transect 1 (1.92 ± 0.28), to transect 2 (1.81 ± 0.21), then decreased to transect 3 (1.72 ± 0.16), in that order.

Table 8*Descriptives*

		N	Mean	Std. Deviation	Std. Error
Fish Biodiversity	T 1	4	1.0750	.59870	.29935
	T 2	4	1.6645	.31322	.15661
	T 3	4	1.4963	.44495	.22247
	Total	12	1.4119	.49555	.14305
Invertebrate Biodiversity	T 1	4	1.9208	.28174	.14087
	T 2	4	1.8173	.21467	.10734
	T 3	4	1.7193	.15998	.07999
	Total	12	1.8193	.22041	.06363

Note. T1 = transect 1, T2 = transect 2, T3 = transect 3.

There was homogeneity of variances, as assessed by Levene's test for equality of variances, for fish biodiversity ($p = 0.185$) and invertebrate biodiversity ($p = 0.340$).

Table 9

Test of Homogeneity of Variances

	Levene Statistic	Sig.
Fish Biodiversity	.392	.687
Invertebrate Biodiversity	.410	.676

The fish biodiversity was not statistically significantly different between transect 1, 2 & 3, $F(2, 9) = 1.691$, $p = 0.238$.

The invertebrate biodiversity was not statistically significantly different between transect 1, 2 & 3, $F(2, 9) = 0.807$, $p = 0.476$.

Table 10

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Fish Biodiversity	Between Groups	.738	2	.369	1.691	.238
	Within Groups	1.964	9	.218		
	Total	2.701	11			
Invertebrates Biodiversity	Between Groups	.081	2	.041	.807	.476
	Within Groups	.453	9	.050		
	Total	.534	11			

4.4 Pearson's Correlations Analysis

Hypothesis:

- (HA3) There is a correlation between percentage coral cover and fish/invertebrate biodiversity.
- (HN3) There is no correlation between percentage coral cover and fish/invertebrate biodiversity.

Results:

Two cases were removed from the data as they appeared as outliers when testing for linearity. Although outliers only appeared in the 'fish biodiversity' to '% coral cover' linear chart, the case was removed over all ($H = 1.36$, $CC\% = 58$ & $H = 0.38$, $CC\% = 12.5$). These two cases were removed as it would compromise the result in the Pearson's Correlations Analysis. With the aim to establish a correlation, the cases removed will not affect the accuracy of the result.

As assessed by the scatter graphs, there is a positive linear relationship between fish biodiversity and coral cover percentage, and a negative linear relationship between invertebrate biodiversity and coral cover percentage.

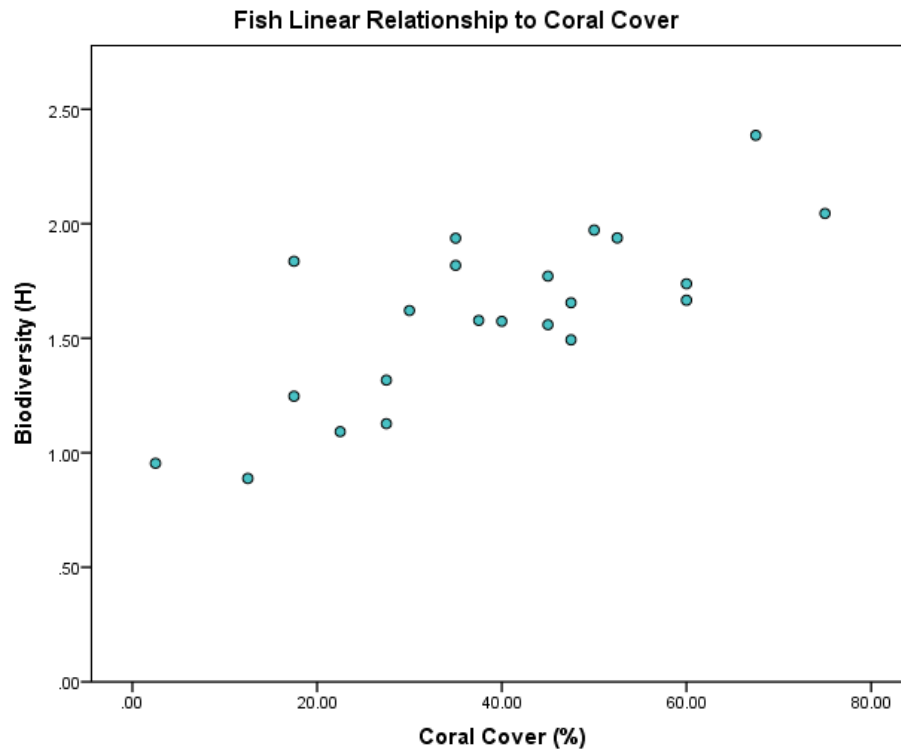


Figure 13 – scatter graphs for fish biodiversity inside and outside the MPA

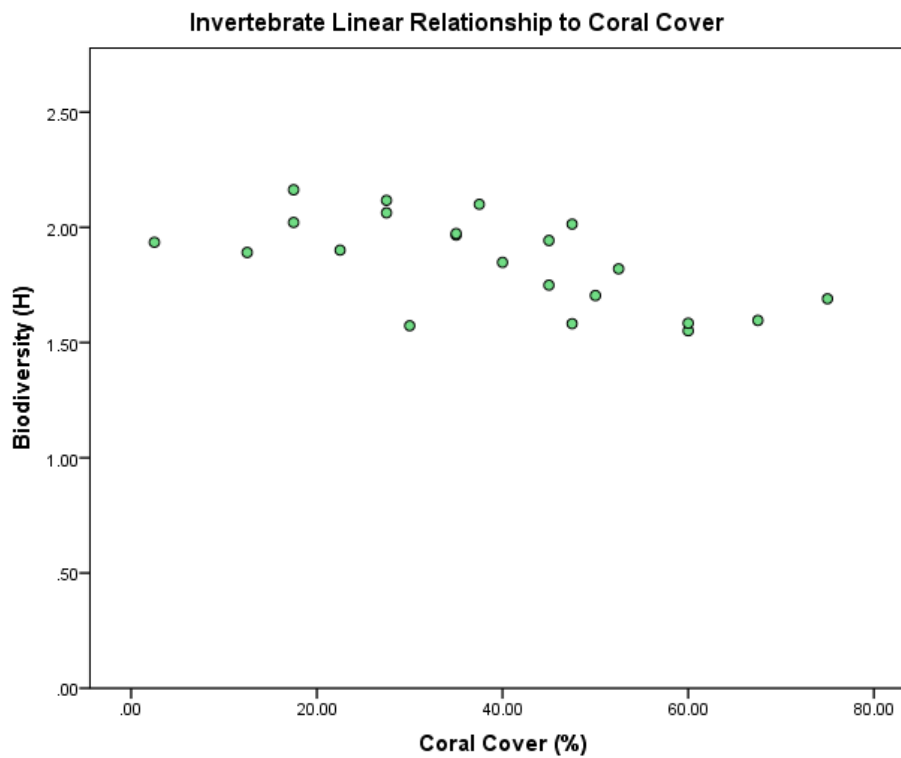


Figure 14 - scatter graphs for invertebrate biodiversity inside and outside the MPA

All variables were normally distributed, as assessed by Shapiro-Wilk's test ($p > 0.05$).

Table 11

Test of Normality

Shapiro-Wilk's			
	Statistic	df	Sig.
Fish Biodiversity	.971	22	.736
Coral Cover	.991	22	.998
Invertebrate Biodiversity	.931	22	.128

There was a strong positive correlation between coral cover percentage and fish biodiversity, $r(20) = 0.776$, $p < 0.0005$.

There is a strong negative correlation between coral cover percentage and invertebrate biodiversity, $r(20) = -0.625$, $p = 0.002$

Table 12

Correlations

		Fish Biodiversity	Invertebrate Biodiversity
Coral Cover	Pearson Correlation	.766**	-.625**
	Sig. (2-tailed)	.000	.002
	N	22	22

Note. ** = correlation is significant at the 0.01 level (2-tailed).

Coral cover percentage statistically explained 60% of the fish biodiversity and 40% of the invertebrate biodiversity.

There was a statistically significant relationship between coral cover percentage and fish biodiversity, and coral cover percentage and invertebrate biodiversity, so we can reject the null hypothesis (HN3) and accept the alternative hypothesis (HA3).

Table 13

Coefficient Value

	Strength of Association
$0.1 < r < 0.3$	small correlation
$0.3 < r < 0.5$	medium/moderate correlation
$ r > 0.3$	large/strong correlation

Note. r = Pearson Correlation Coefficient. (Cohen 1988)

4.5 Analysis of results

4.5.1 Biodiversity difference between inside and outside MPA (HA1)

There were 12 biodiversity values for fish and invertebrate inside the MPA, and 12 biodiversity values for fish and invertebrates outside the MPA. An independent-samples t-test was run to determine if there was difference in fish and invertebrate biodiversity between inside an MPA and the adjacent area outside the MPA. As the author stated previously, the data needed to meet assumption in order for the result of the test to be accurate. There were no outliers in the data, as assessed by inspection of the boxplots meeting the first assumption (Figure 9 & 10). Fish and invertebrate biodiversity values for inside MPA and outside MPA were normally distributed, as assessed by Shapiro-Wilk's test ($p > 0.05$) (Table 3), indicating the second assumption is met. Finally there was homogeneity of variances, as assessed by Levene's test for equality for fish biodiversity ($p = 0.125$) and invertebrate biodiversity ($p = 0.773$) (Table 5), stating that all assumptions about the data set are met. Results from the independent-samples t-test indicated that fish biodiversity was higher inside MPA (1.67 ± 0.35) than outside MPA (1.41 ± 0.5), with no

statistically significant difference of 0.13 ± 0.09 , $t(22) = 0.153$, $p = 0.773$, $d = 0.738$.

Invertebrate biodiversity was also higher inside MPA (1.83 ± 0.21) than outside MPA (1.82 ± 0.22), with no statistically significant difference of 0.13 ± 0.09 , $t(22) = 0.153$, $p = 0.773$, $d = 0.062$ (Table 5). This results indicates that although there is no statistically significant difference in the biodiversity between inside and outside the MPA, biodiversity is still higher inside the MPA, therefore the null hypothesis (HN1) is accepted, and the alternative hypothesis is rejected (HA1). This is a similar result gained by Longhurst & Van De Geer (2013), when biodiversity comparisons were performed on the Santa Paz Sur MPA (Figure 1), an MPA within close proximity to the Napantao MPA (Figure 2). This can lead to evidence that there is spill over actively in progress, resulting in the biodiversity outside the MPA improving due the population capacity within the MPA overflowing into the surrounding reef. Alternatively, as established by Weeks et al. (2010) the Napantao MPA may be too small to fully protect the biodiversity that is associated within the Philippines, therefore the variation between inside the MPA and outside the MPA will not be significant, as the results suggest.

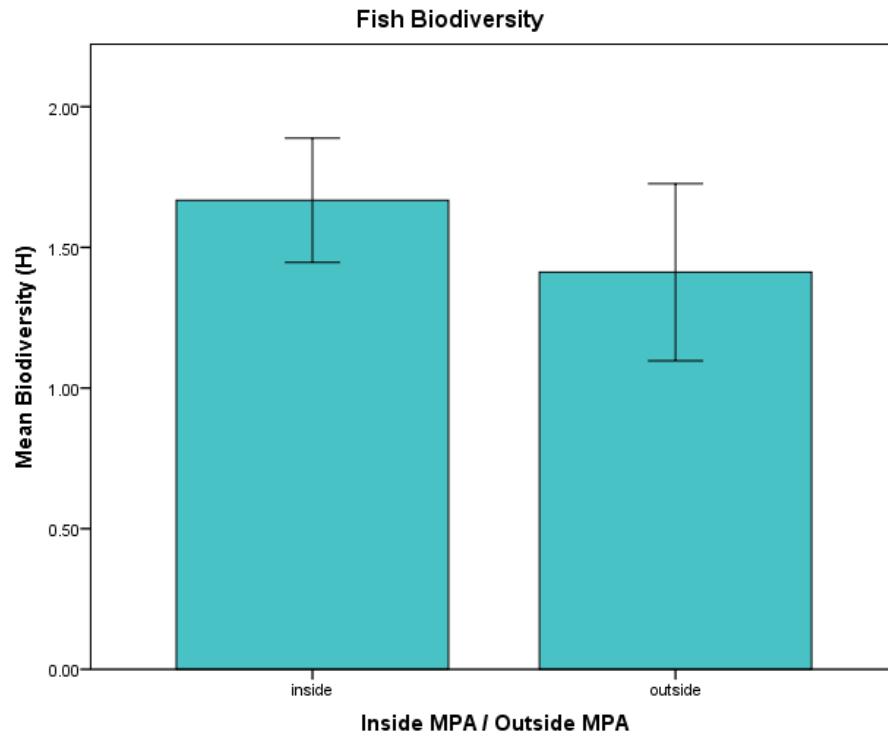


Figure 15 – bar graph of mean fish biodiversity inside and outside the MPA

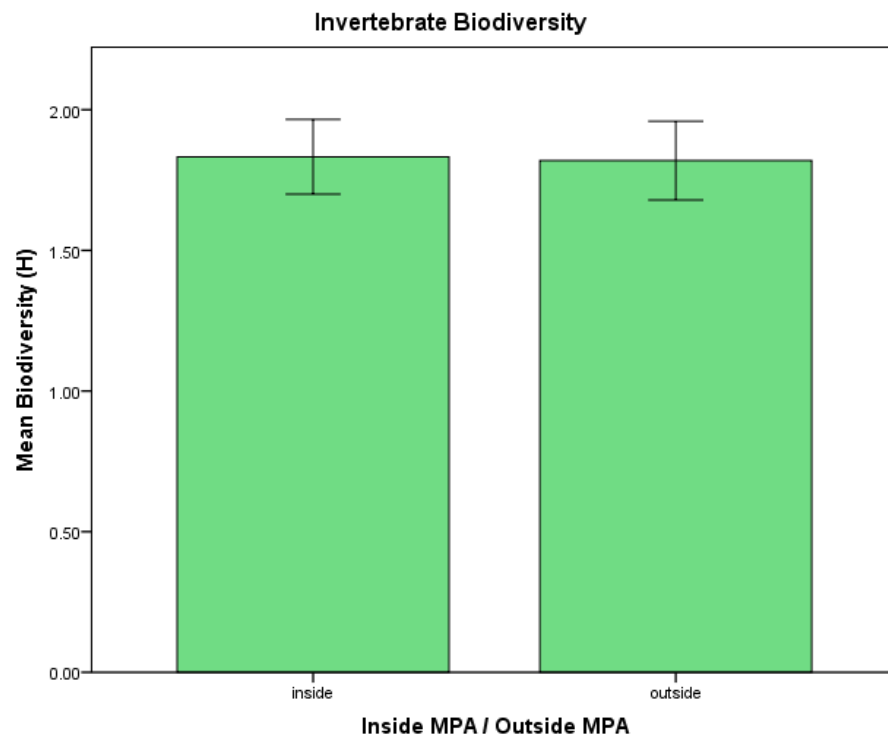


Figure 16 – bar graph of mean invertebrate biodiversity inside and outside the MPA

4.5.2 Biodiversity difference between transects outside the MPA (HA2)

Follow on for the previous analysis where no statistically significant difference in biodiversity for fish and invertebrate was established between inside the MPA and outside the MPA, a look into the changes in biodiversity can now be established when moving away from the MPA. As the author mentioned, the topography of the Napantao MPA required the Reef Check surveying method (Reef Check 2007) to be adapted to allow for data gathering (Figure 3 & 4). This opened up the opportunity to observe the biodiversity for fish and invertebrates as the surveying moved away from the MPA (Appendix 4). For this a one-way ANOVA was conducted. Transects were classified into three groups: transect 1 ($n = 4$), transect 2 ($n = 4$) and transect 3 ($n = 4$) (Appendix 5). Again, the data needed to meet assumptions in order for the results to be accurate. There were no outliers, as assessed by the boxplots (Figure 11 & 12); data was normally distributed for each transect, as assessed by Shapiro-Wilk's test ($p > 0.05$) (Table 7); and there was homogeneity of variance, as assessed by Levene's test of homogeneity of variances for fish biodiversity ($p = 0.392$) and invertebrate biodiversity ($p = 0.41$) (Table 9). Data is presented as mean $\pm$ standard deviation. Fish biodiversity was not statistically significantly different between transect 1, 2 & 3, $F(2, 9) = 1.691$, $p = 0.238$. Invertebrate biodiversity was also not statistically significantly different between transect 1, 2 & 3, $F(2, 9) = 0.807$, $p = 0.476$. The fish biodiversity increased from transect 1 (1.08 ± 0.6), to transect 2 (1.66 ± 0.31), then decreased to transect 3 (1.41 ± 0.5), in that order (Table 8). Invertebrate biodiversity decreased from transect 1 (1.92 ± 0.28), to transect 2 (1.81 ± 0.21), decreasing further to transect 3 (1.72 ± 0.16), in that order (Table 8). From the results there is evidence that suggests spill over is occurring, positively affecting the biodiversity. As the analysis

indicated that there was no statistically significance in fish and invertebrate biodiversity between all three transect, the alternative hypothesis (HA2) is rejected, and the null hypothesis (HN2) is accepted. Although there was no statistical significance, both fish and invertebrate biodiversity decreasing within transects 3. This suggests that the increased biodiversity associated with transect 1 for invertebrates, and transect 2 for fish and invertebrates, is evidence towards the Napantao MPA providing spill over. This evidence supports the literature to indicate the benefits in MPAs, to ensure the biodiversity remains in order to maintain function diversity within the ecosystem (Cimon-Morin 2014; Micheli & Halpern 2005). This also provides evidence in the benefits in of an MPA for the local fishermen, when the functional biodiversity remains this ensures the ecosystem service that the coral reef is providing, is sustainable (White 2008; Weeks et al. 2010).

To understand the low fish biodiversity in transect 1, the following analysis looks into the correlation between coral cover and biodiversity for fish and invertebrate. This may indicate the associated low fish biodiversity within transect 1, and the subsequent raise in transect 2.

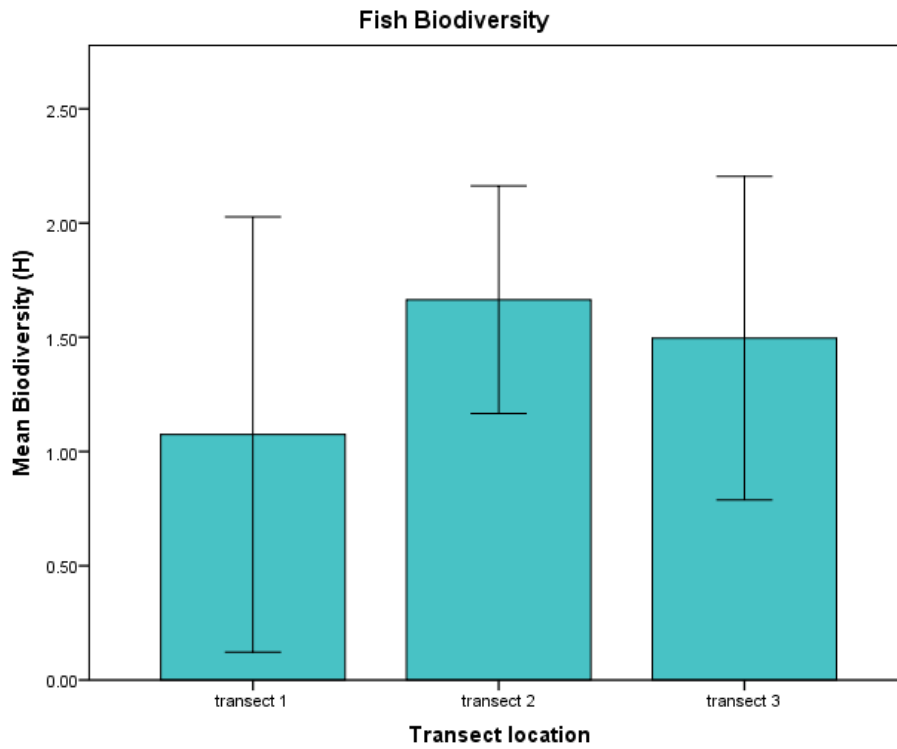


Figure 17 – bar graph of mean fish biodiversity per transect for outside the MPA

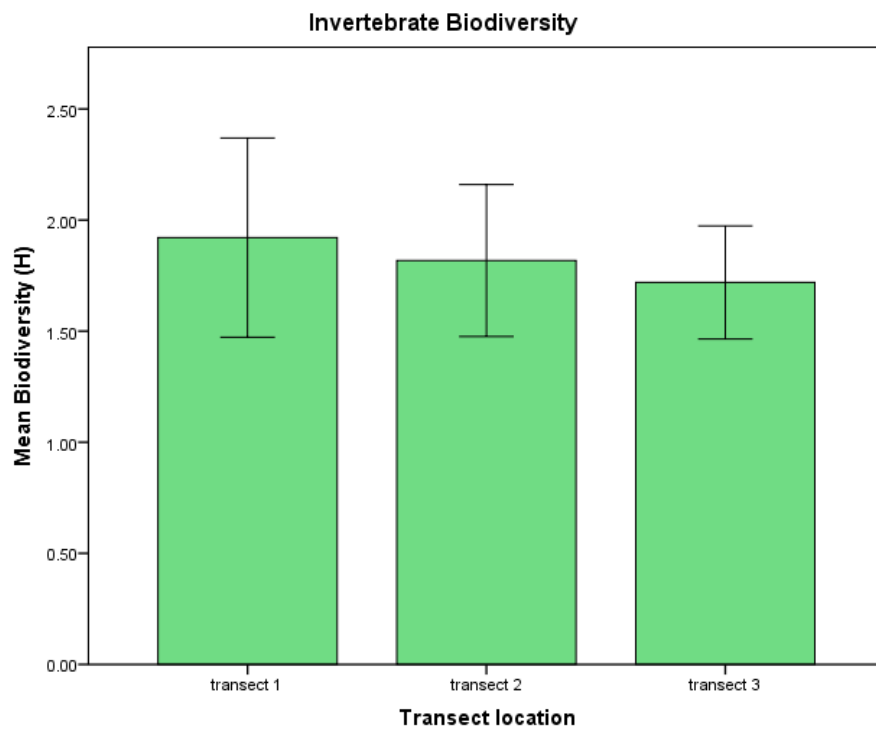


Figure 18 – bar graph of mean invertebrate biodiversity per transect for outside the MPA

4.5.3 Correlation in coral cover with fish and invertebrate biodiversity (HA3)

A Pearson's product-moment correlation was run to assess the relationship between coral cover and biodiversity for fish and invertebrates. Preliminary analysis showed the relationships to be linear with all three variables normally distributed, as assessed by Shapiro-Wilk's test ($p > 0.05$), there were two outliers removed within the data as it would have compromised the result, but removal did not affect the accuracy. There was a strong positive correlation between coral cover percentage and fish biodiversity, $r(20) = 0.776$, $p < 0.0005$, with coral cover percentage explaining 60% of the fish biodiversity. There was a strong negative correlation between coral cover percentage and invertebrate biodiversity, $r(20) = -0.625$, $p = 0.002$, with coral percentage cover explaining 40% of the invertebrate biodiversity. This is supportive evidence towards the literature that there is a correlation in coral cover to biodiversity for fish and invertebrates (Knudby et al. 2007). This is also evidence for the lower fish biodiversity value within transect 1, as assessed during the one-way ANOVA analysis. Figure 19 shows the correlation, as coral cover declines fish biodiversity shares a very similar level of decline and inclines.

Fish Bioiversity & Coral Cover Outside MPA



Figure 19 – plot graph for fish biodiversity values and coral cover per 20m transect. **Note.**

0-20m, 25-45m, 50-70m, & 75-95m is one complete 100m survey transect.

5.0 Chapter 5 - Conclusion

5.1 Summary of results

From the results it has established that there is no statistically significant difference in fish and invertebrate biodiversity between the Napantao MPA and the adjacent area outside the MPA. This is evidence that the smaller MPAs as suggested by Weeks et al. (2010), are not adequate enough to protect the biodiversity associated with the Philippines. However there is evidence of spill over which suggest the MPA is still maintaining the functional biodiversity of the coral reef to allow fishermen so exploit an ecosystem service sustainably.

This research has demonstrated that the allocation of an MPA has the capability in protecting the coral reef biodiversity; the size needs to be considered if it is adequately protect the biodiversity associated with the marine ecosystem. Protection of the marine environment due to the ecosystem services and processes it can provide is a valuable consideration for biodiversity conservation. Spill over of biodiversity into the areas outside of the MPA is just one example of an ecosystem service that the local fishermen exploit. There is many more consideration for the allocation of MPAs in order to protect the biodiversity in association of the ecosystem service providers, outlined within literature. This research can be used to help towards reaching the target of 10% of all coral reefs within the Philippines to be within an MPA no-take zone by 2020, set by The Philippines Marine Sanctuary Strategy (Weeks et al. 2010), providing evidence towards the benefits in allocating MPAs to conserve the biodiversity, with the best interest in the Filipinos that rely on the coral reef ecosystem for ecosystem services.

5.2 Strengths of research

The research method used during surveying was developed by Reef Check Worldwide (Reef Check 2007). This ensures that the data gathered is of significant use and shared on a global scaled to develop an overall assessment of the coral reefs Worldwide. As the research was conducted within the Philippines, this area is considered to falls into the top 10% in marine species richness (Roberts et al. 2002). Data on the coral reef formations in this area may provide vital evidence worldwide.

5.3 Recommendations for future research

Additional data could be recorded on the rugosity of the survey transects locations. This would allow for the rugosity index to be established for the area surveyed. This data could then be used to determine significant in rugosity to coral species and diversity, and also invertebrate species and biodiversity. Further investigation can be done once significant data is gathered on with the Napantao MPA, to establish change of biodiversity over time. This will further allow for the observation of the designations of an MPA.

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8.0 Chapter 8 - Appendices

Appendix 1

Substrate and target species recorded during surveys (²Coral Cay Conservation 2013)

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> massive
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		

Target Invertebrates		
Feather duster worms	Christmas tree worms	Flatworms
TARGET HARD CORALS		
Brain small	Brain medium	Brain large
<i>Ctenactis echinata</i>	<i>Diploastrea heliopora</i>	<i>Echinopora</i>
<i>Euphyllia</i>	<i>Favia</i>	<i>Favites</i>
Foliose <i>Montipora</i>	<i>Galaxea</i>	<i>Goniopora/Alveopora</i>
<i>Herpolitha limax</i>	<i>Hydnophora</i>	<i>Lobophyllia</i>
Massive <i>Porites</i>	<i>Montipora digitata</i>	<i>Mycedium elephantotus</i>
<i>Pachyseris rugosa</i>	<i>Pachyseris speciosa</i>	<i>Pavona clavus</i>
<i>Pectinia lactuca</i>	<i>Plerogyra</i>	<i>Pocillopora</i> small
<i>Pocillopora</i> medium	<i>Pocillopora</i> large	<i>Polyphyllia talpina</i>
<i>Porites cylindrica</i>	<i>Porites nigrescens</i>	<i>Porites rus</i>
<i>Seriatopora hystrix</i>	<i>Tubastrea micrantha</i>	<i>Turbinaria</i>
Upside-down Bowl		

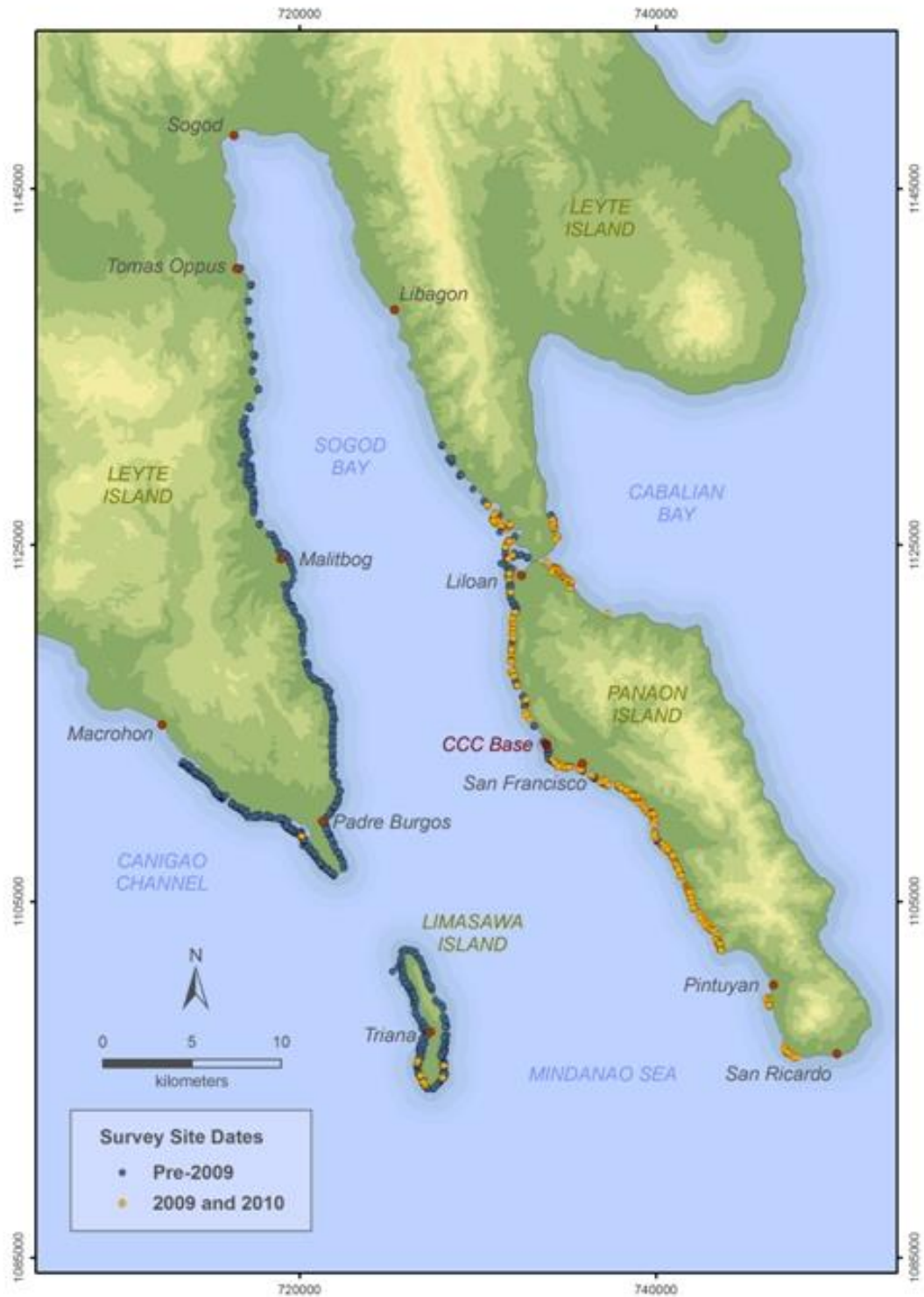
Crabs	Shrimps	Banded coral shrimp
Lobsters	Nudibranch	Abalone
Conch	Cowrie	Triton's trumpet
Cone shell	Drupella	Top shell
Other gastropod	Giant clam	Octopus
Cuttlefish	Squid	<i>Acanthaster planci</i>
<i>Linkia laevigata</i>	<i>Culcita novaeguineae</i>	<i>Protoreaster nodosus</i>
<i>Choriaster granulatus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

Target Fish		
Butterflyfish*	Snapper	Gobies
Angelfish	Black and White Snapper	Blennies
Surgeonfish	Checkered Snapper	Sandperch
Unicornfish	Two-Spot Snapper	Lizardfish
Moorish Idol	Emperors	Scorpionfish/Stonefish
(Wrasse)	Sweetlips	Lionfish
Crescent Wrasse	Triggerfish	Barracuda
Red Breasted Wrasse	Filefish	Pipefish
Humphead Wrasse	Goatfish	Squirrelfish/Soldierfish
(Damselfish)	Fusilier	Sweeper
Anemonefish	Rabbitfish	Spadefish/Batfish
Sergeant Damselfish	Virgate Rabbitfish	Moray Eels
Grouper	Spinecheeks	Rays
Barramundi Cod	Twoline Spinecheek	Sharks
Peacock Grouper	Cardinalfish	Turtles
Flagtail Grouper	Jack/Trevally	Manta Rays
Honeycomb Grouper	Pufferfish	Sea Snakes
Lyretail Grouper	Toby	
Parrotfish	Porcupinefish	
Bumphead Parrotfish	Trunk/Box/Cowfish	
*Target Butterflyfish		
Vagabond Butterflyfish	Spot-Banded Butterflyfish	Merten's Butterflyfish
Klein's Butterflyfish	Dot and Dash Butterflyfish	Chevroned Butterflyfish
Latticed butterflyfish	Singular Bannerfish	Threadfin Butterflyfish
Eastern Triangle Butterflyfish	Longfin Bannerfish	Teardrop Butterflyfish
Redfin Butterflyfish	Masked Bannerfish	Spot-Nape Butterflyfish
Pyramid Butterflyfish	Pennant Bannerfish	Lined Butterflyfish

(Big) Long-Nosed Butterflyfish	Raccoon Butterflyfish	Yellow-Dotted Butterflyfish
Copper-Banded Butterflyfish	Dotted Butterflyfish	Black-Backed Butterflyfish
Orange-Banded Butterflyfish	Ovalspot/Mirror Butterflyfish	Spot-Tail Butterflyfish
Humphead Bannerfish	Bennett's/Eclipse Butterflyfish	Panda Butterflyfish
Asian Butterflyfish	Bluespot Butterflyfish	Eight-Banded Butterflyfish
Burgess' Butterflyfish	Highfin Coralfish	Reticulated Butterflyfish
Ornate Butterflyfish	Two-Eyed Coralfish	Saddled Butterflyfish
Meyer's Butterflyfish	Brown Banded Butterflyfish	Spotted Butterflyfish
Speckled Butterflyfish	Ocellate Coralfish	Yellowtail Butterflyfish
Pacific Double-Saddle Butterflyfish		

Appendix 2

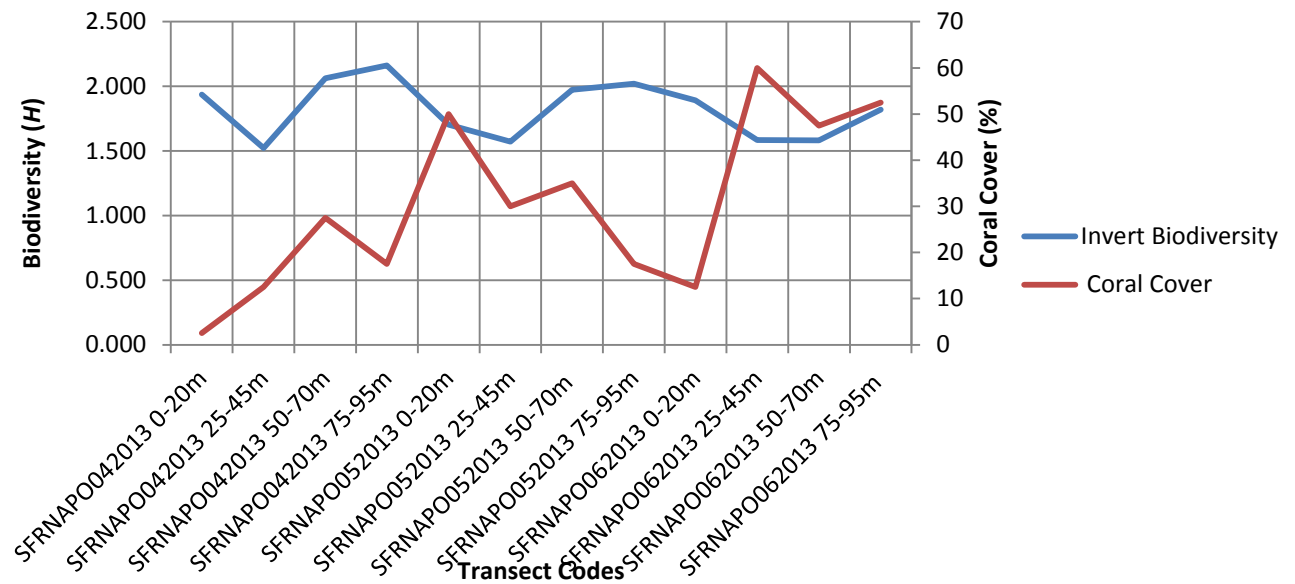
Map of Sogod Bay, illustrating areas of pre 2009 reef surveys and 2009-2010 reef surveys (¹Coral Cay Conservation 2012).



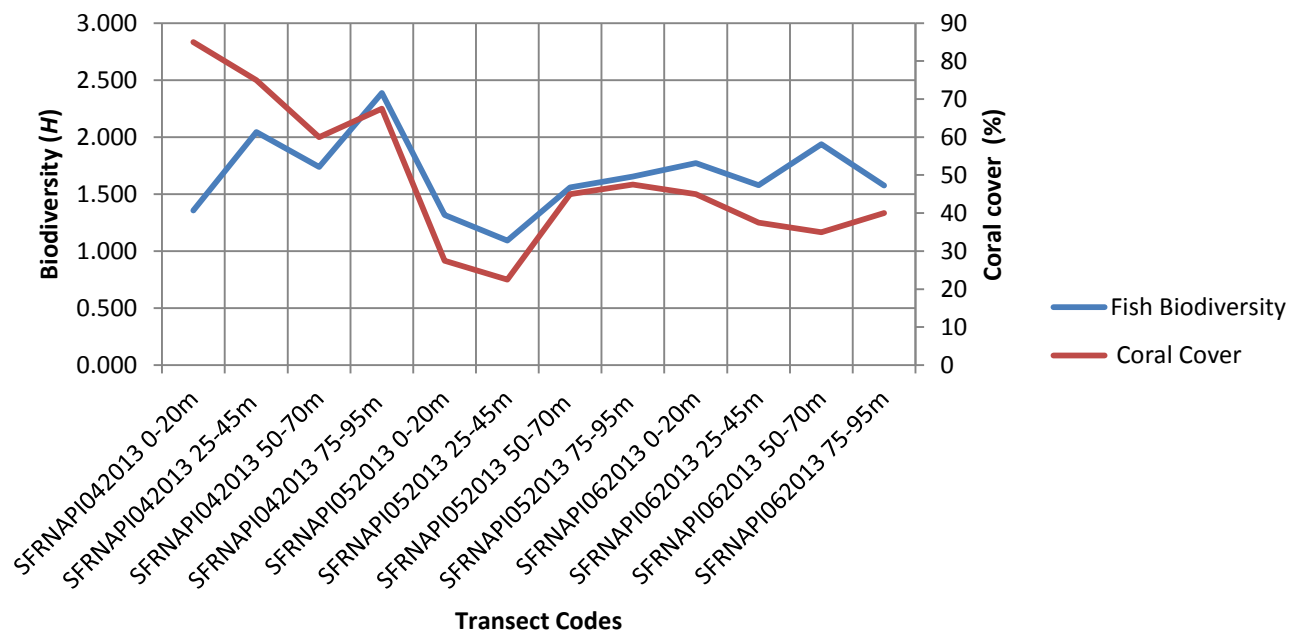
Appendix 3

Graph plots showing correlation in biodiversity and coral cover

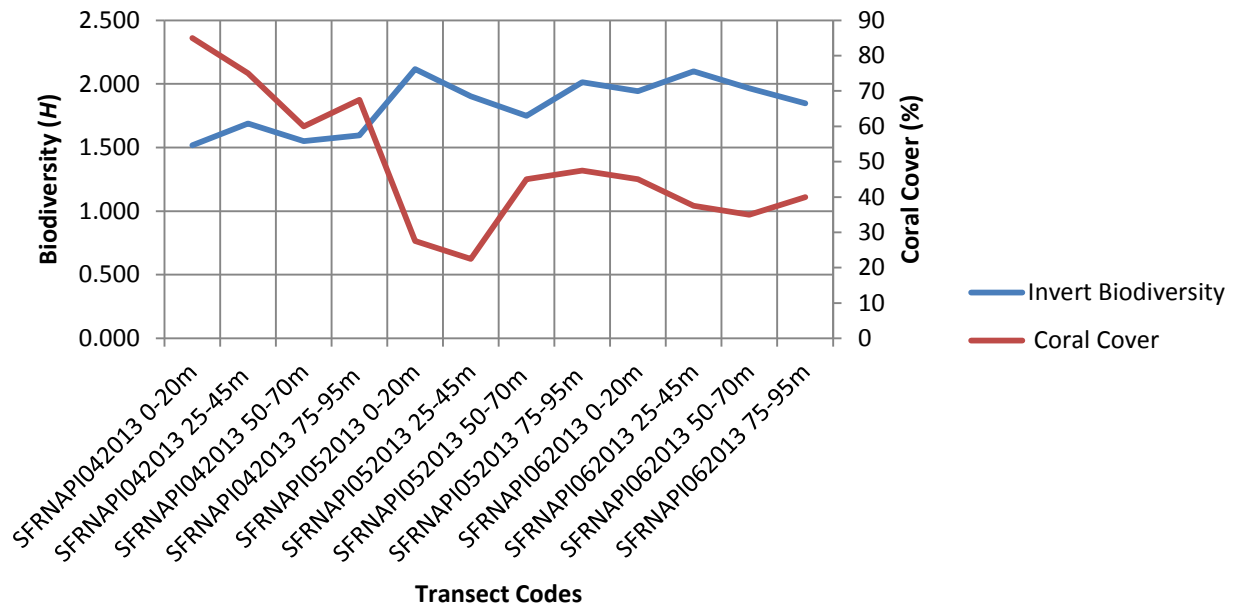
Invertebrate Bioiversity & Coral Cover Outside MPA



Fish Bioiversity & Coral Cover Inside MPA

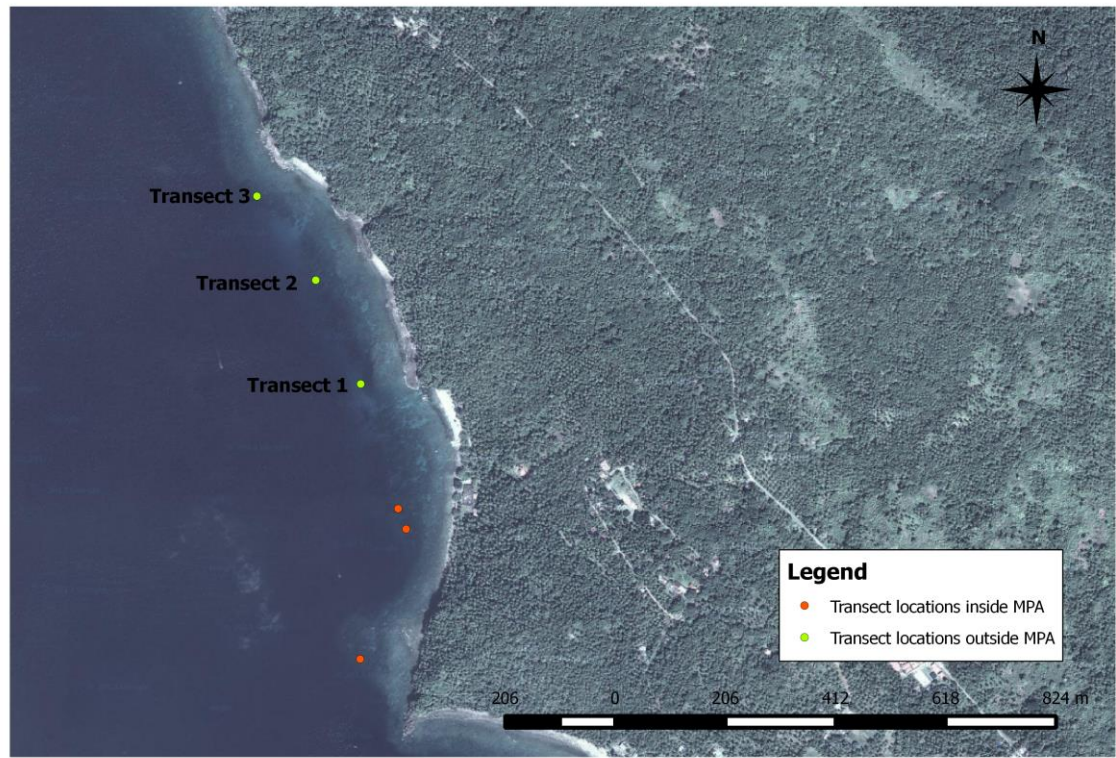


Invertebrate Bioiversity & Coral Cover Inside MPA



Appendix 4

Transect locations



Appendix 5

Full transect Easting and Northing

Survey ID	Inside or outside MPA?	Easting (0-20)	Northing (0-20)
SFRNAPI042013	Inside MPA	733901	1113091
SFRNAPI052013	Inside MPA	733987	1113334
SFRNAPI062013	Inside MPA	733972	1113372
SFRNAPO042013 (T1)	Outside MPA	733902	1113605
SFRNAPO052013 (T2)	Outside MPA	733818	1113799
SFRNAPO062013 (T3)	Outside MPA	733708	1113956

Appendix 6

Biodiversity values and substrates for each transect

Site ID	Inside_Outside MPA	Fish Diversity	Invert Diversity	% Coral Cover	% Sand Cover	% Rubble Cover	% Rock Cover
SFRNAPI042013 0-20m	Inside	1.355	1.517	85	0	0	7.5
SFRNAPI042013 25-45m	Inside	2.045	1.690	75	0	2.5	15
SFRNAPI042013 50-70m	Inside	1.738	1.551	60	0	10	17.5
SFRNAPI042013 75-95m	Inside	2.386	1.596	67.5	0	2.5	17.5
SFRNAPI052013 0-20m	Inside	1.317	2.117	27.5	2.5	2.5	40
SFRNAPI052013 25-45m	Inside	1.092	1.901	22.5	20	20	17.5
SFRNAPI052013 50-70m	Inside	1.559	1.749	45	12.5	2.5	25
SFRNAPI052013 75-95m	Inside	1.655	2.014	47.5	0	7.5	35
SFRNAPI062013 0-20m	Inside	1.771	1.943	45	5	17.5	12.5
SFRNAPI062013 25-45m	Inside	1.578	2.100	37.5	22.5	7.5	15
SFRNAPI062013 50-70m	Inside	1.937	1.966	35	7.5	22.5	17.5
SFRNAPI062013 75-95m	Inside	1.574	1.848	40	7.5	25	15
SFRNAPO042013 0-20m	Outisde	0.954	1.935	2.5	70	25	2.5
SFRNAPO042013 25-45m	Outisde	0.383	1.522	12.5	55	27.5	5
SFRNAPO042013 50-70m	Outisde	1.127	2.063	27.5	22.5	12.5	27.5
SFRNAPO042013 75-95m	Outisde	1.836	2.163	17.5	25	10	25
SFRNAPO052013 0-20m	Outisde	1.972	1.704	50	0	5	2.5
SFRNAPO052013 25-45m	Outisde	1.621	1.573	30	7.5	5	30
SFRNAPO052013 50-70m	Outisde	1.818	1.973	35	2.5	15	35
SFRNAPO052013 75-95m	Outisde	1.247	2.021	17.5	27.5	17.5	10
SFRNAPO062013 0-20m	Outisde	0.888	1.891	12.5	57.5	17.5	7.5
SFRNAPO062013 25-45m	Outisde	1.666	1.584	60	0	5	15
SFRNAPO062013 50-70m	Outisde	1.493	1.582	47.5	7.5	5	22.5
SFRNAPO062013 75-95m	Outisde	1.938	1.820	52.5	0	0	30

Appendix 7

Student Research Project Interview - Agreed Comments Form

Student Name Aaron Harper	Programme BSc EWC
Date 12/11/2013	DRP IRP ✓
Supervisor Name Kathy Hodder	

Overview

You have a complete data set for your survey. The spread sheet would benefit from some reorganisation to enable data manipulation, graphing and analysis. The main points to address include ensuring that you have a more complete understanding of the rationale behind the original siting of the MPA. You also require some additional data in order to complete your analysis but showed a good understanding of this requirement.

Actions advised

- Contact CCC to request data from the first survey of the MPA. Prior to doing this make sure that you can specify the exact data required.
- Contact CCC to clarify the rationale for the designation of the site.
- Consider comparing the inside and outside MPA after removal of boundary (sand area) transect.
- Arrange a meeting with me to finalise plans for analyses.

Two copies of this form are needed – student to retain one copy the other to be deposited and retained in the Student Office

Student Signature	
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