THE EFFECTIVENESS OF MARINE PROTECTED AREAS

In the south-eastern part of Negros Oriental, Philippines

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Abstract

The loss of biodiversity worldwide results in a big negative impact on ecosystem services and therefore on human well-being. The Philippines is positioned in the heart of the coral triangle, an area which contains nearly 30% of the world's coral reef and has the highest diversity of species in the world. The majority of the coral reefs in the Philippines are threatened by human activities. Reducing human activities and thereby protecting the marine biodiversity can be achieved by creating marine protected areas (MPA's). Research shows that MPA's are able to increase the health of a coral reef resulting in an increase of fish abundance and diversity. This study looks at the effectiveness of those MPA's in the south-eastern part of Negros Oriental in the Philippines. For gathering information about the fish diversity and abundance, surveys were performed for the chosen indicator fish species with a fish belt transect method. Data was collected at nine different sites located in the municipalities Dauin, Zamboanguita and Siaton. The diversity and abundance is compared between the different sites with the status of protection and environmental features taken into account. The environmental features that are included are, percentage life coral cover, reef rugosity, distance to mangrove forests and seagrass beds, water clarity and water temperature. This study showed significant higher diversity at sites with higher protection ($p<0.05$). Diversity also increased with a higher percentage life coral cover and reef rugosity ($p<0.05$). However, diversity is higher at sites with a high protection status and low rugosity compared to sites with lower protection status and high rugosity ($p<0.05$). Protection has a positive influence on the abundance of herbivorous fish and a small number of predators, especially at the site Dauin poblacion where diversity is significantly higher compared to all other sites ($p<0.05$). A small number of species that rely on seagrass beds for their juvenile phase showed a negative effect on their presence with a further distance to seagrass. Water clarity didn't show any differences between sites and was not taken into account. Thus, protection is more important than habitat and shows that protection is therefore effective. However, for further research algal communities, biomass and sediment measurements should be taken into account and the amount of surveys should be induced as well as the amount of experience of observers.

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1. Introduction

One of the most beautiful things in the world is the existence of life and its diversity. When the interest in biodiversity research grew to a major international level, the understanding of how biodiversity loss might affect the dynamics and the functioning of ecosystems increased. We understand that biodiversity loss will affect the supply of goods and services the earth has to offer. One of the most important functions of ecosystems is the efficiency by which ecological communities capture biological essential resources, produce biomass[1], decompose and recycle biologically essential nutrients. Biodiversity loss reduces all the functions ecosystems have to offer and this has resulted in a big negative impact on ecosystem services[2] and therefore on human well-being (Cardinale et al., 2012; Haines-Young & Potschin, 2010).

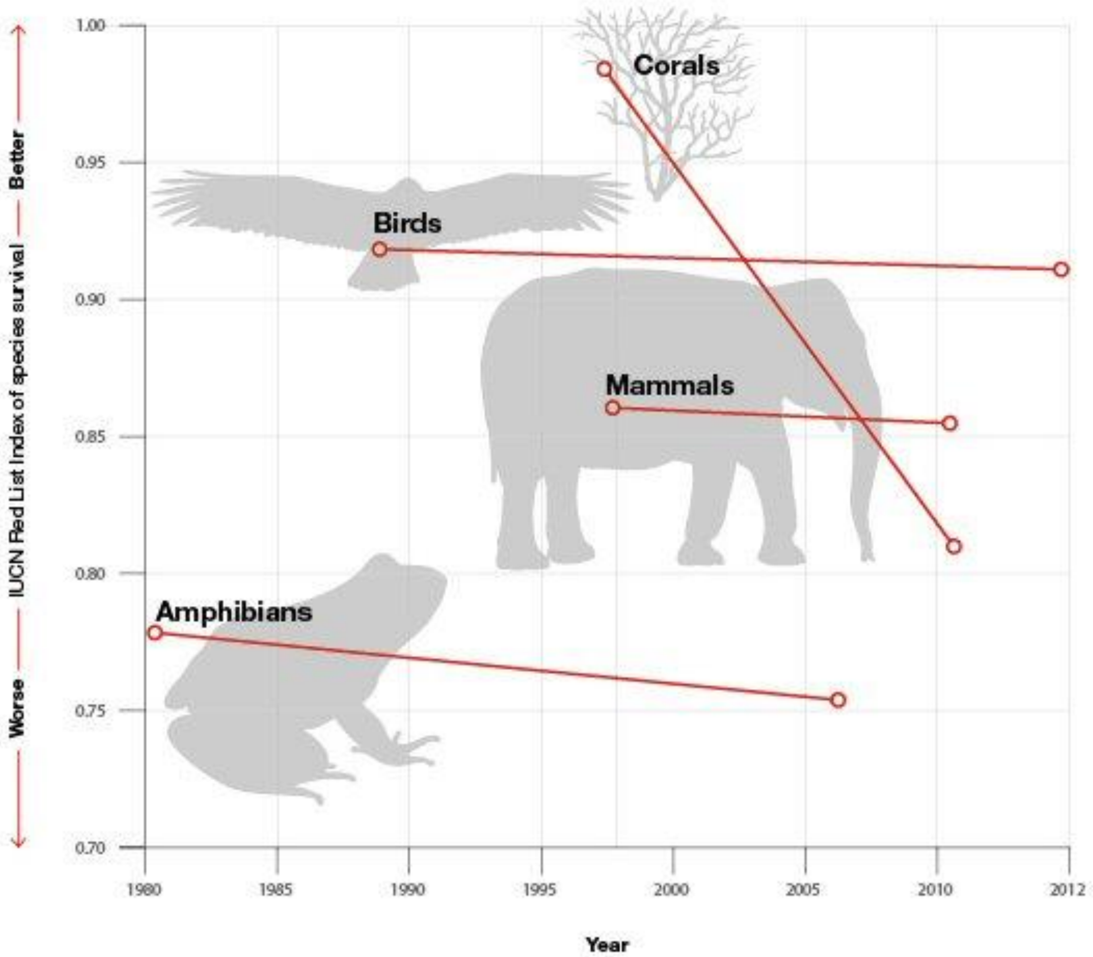

Figure 1.1: RLI value of 1.0 equates to all species qualifying as Least Concern. An RLI value of 0 equates to all species having gone Extinct. A constant RLI value over time indicates that the overall extinction risk for the group is constant. Reef-forming coral species are moving towards increased extinction risk most rapidly (obtained from IUCN, 2015).

[1] Biomass production: How much new living stuff grows each year (Pimm, 2001)
[2] Ecosystem services: all services ecosystems have to offer like, provisioning services (e.g. food and water), regulating services (e.g. climate regulation and water purification), cultural services (e.g. recreational and education) and supporting services (e.g. soil formation and nutrient cycling) (Haines-Young & Potschin, 2010)

Although ecosystem services are mostly thought to be related to terrestrial biodiversity, marine biodiversity provides also important ecological services, such as a vital food resource for millions of people, pharmaceutical products, biogeochemical processes[3] and protection for coastal areas like mangrove forests (Beaumont et al., 2007; Worm et al., 2006; Kathiresan & Rajendran, 2005). Biodiversity loss in marine ecosystems are mostly caused by human impacts like exploitation (e.g. destructive fishing and overfishing), habitat destruction by coastal development and pollution and indirectly by climate change (Burke et al., 2012; Worm et al., 2006). Currently 27-44% of all reef-forming corals are on the list of threatened species and the prediction is that this trend will continue (Figure 1.1) [IUCN, 2015; Burke et al., 2012].

Nearly 30% of the world's coral reefs are located in the coral triangle. The coral triangle, also called 'the amazon of the sea', spans the marine waters between Malaysia, Indonesia, Papua New Guinea, the Philippines, Solomon-islands and Timor-Leste. This area contains 76% of all known coral species and 37% of the world's fish species, which twice the amount found anywhere else in the world. More than 85% of the reef-forming corals in the coral triangle are at risk due to human impacts. 130 million local people and millions of humans living elsewhere are sustained by the natural resources of this diverse marine area (Burke et al., 2012). An area as important and beautiful as the marine ecosystem in the coral triangle should be conserved (Clifton et al., 2010; Burke et al., 2012).

Within the coral triangle region, the Philippines is probably the most vulnerable country because the reef is highly threatened, the economy depends very much on all marine life and the people have low capacity to adapt to the loss of products and services provided by the reefs (Burke et al., 2012; Padilla, 2008; Carpenter & Springer, 2005). The majority of the reefs in the Philippines are threatened by human activities. Nowadays, reefs with the highest and most constant levels of coral cover and high densities of fish and other reef species are most frequently found in protected areas (Alcala et al., 2005; White et al., 2006; Maliao et al., 2009). Creating a Marine Protected Area (MPA) like a sanctuary, reserve or a park is a proven method for protection of a well-defined marine area. A MPA is a non-take area and can achieve an increase in the amount of living coral and fish(species). Juvenile fish can grow up without being disturbed by fisherman in a non-take area and the damage to coral will decrease when no fishing activities occur (White et al., 2006; Wilkinson et al., 2003; Burke et al., 2012). Only 7% of all the reefs in the Philippines are inside MPA's, with less than 3% in (partially) effective MPA's (Maypaab et al., 2012).

One of the most famous examples of a successful MPA in the Philippines is Apo Island Marine Reserve in Dauin, Negros Oriental. The success of this MPA was possible because of the strong commitment to MPA management by the community. In 1986 the marine reserve was established by the municipality and in 1994 it got national protection. The fisheries yields have increased with almost 50% in the period 1998-2001 compared to the 1980's. The biomass of fish species increased and coral reefs became more healthy, resulting into a big increase of tourists that are looking for attractive, healthy reefs for diving. As a result of the increased economy due to charging entry fees for entering the MPA, a lot of local fishermen changed their employment to tourist-related activities and this resulted in a decrease of fisheries (Leisher et al., 2007; Russ et al., 2004; Burke et al., 2012; White et al., 2006).

The aim of this study is to determine if marine protected areas project a positive influence on the diversity and abundance of reef fish. Research shows an increase in life coral cover and health of a

[3] Biogeochemical processes: "The maintenance of a healthy, habitable planet is dependent on processes such as the regulation of the volatile organic halides, ozone, oxygen and dimethyl sulphide, and the exchange and regulation of carbon, by marine living organisms." (Beaumont et al., 2007)

coral reef in MPA's, resulting in an increase of fish abundance[4] and diversity[5] (Alcala et al., 2005; Burke et al., 2012; Clifton et al., 2010). This study tests that 1) The abundance of the indicator fish species is the highest in well protected and managed MPA's and 2) The diversity of the indicator fish species is highest in well protected and managed MPA's. Research is carried out at nine different sites which are located in the municipalities Dauin, Zamboanguita and Siaton, Negros Oriental, and differ in status of protection, ranging from a good enforced and managed MPA to a no protected area. To determine the abundance and diversity of fish species, a baseline survey was done from February 2015 until February 2016 at the same sites using the visual rapid census (Hill & Wilkinson, 2004). 75 indicator fish species were selected for the long term monitoring of the coastline from Dauin to Siaton.

This study will focus on the first results of the long term monitoring program. During this study maps of the bottom composition and surroundings were created, water clarity and temperature was measured and surveys for fish species were executed. During the surveys the list of indicator-species was used. The indicator-species are chosen based on the following aspects:

- Fish family
- Indicator species in similar monitoring methods like Reef Check (Hill, 2006; Reef Check, 2015)
- Commercial interest
- Functional group
- Any ecological importance other than functional group
- Diet
- Reproductive behaviour (spawning aggregations, ontogenetic shifts)
- Habitat (both as adult and as juveniles)

Butterflyfish are chosen because a large number of species are corallivores and feeds on coral (Kulbicki et al., 2005). Butterflyfish and angelfish are mainly caught for the aquarium trade, making them useful indicators for human impacts and therefore for ecosystem health (Kulbicki et al., 2005; Wabnitz et al., 2003; Hill, 2006). Indicator fish species that give an indication of overfishing are snappers, groupers, rabbitfish, emperors, fusiliers, sweetlips, batfish, parrotfish and goatfish (Alcala et al., 2008; Alcala, 1999). Some unicornfish, batfish, rabbitfish and parrotfish are important indicators because of their diet. They are herbivorous fish (eating plant material) and play an important role in reduction of coral overgrowth by algae and therefore reduces the chance on a macroalgae-dominated reef (Green & Bellwood, 2009; Guillemot et al., 2013). Such reefs are overgrown by algae that cause shading and eventually the coral will die. Corals need sunlight for the symbiotic zooxanthellae, which produce most of the food for the coral (Richmond, 2008; Green & Bellwood, 2009). Mangroves and seagrass beds are nursery habitats for some reef fish species, which move to the coral reef in a later phase in life. This is called an ontogenetic shift (Palumbi, 2004; Nagelkerken et al., 2000). Fishes with ontogenetic shifts are some species from the goatfish, snappers, parrotfishes, barracudas, surgeonfish and butterflyfish (Nagelkerken et al., 2012, 2000). These species are indicators for connectivity which is an import ecological factor to take into account for managing and designing a MPA because a lot of reef fish make use of different habitats during different life stages (Green et al., 2014; Palumbi, 2004; Honda et al., 2013). Other small ecological features are taken into account by making sure that a wide range of functional groups, habitats, different diets and species used in other monitoring programs are covered.

[4] Species abundance: the representation of a species in an ecosystem (Krebs, 1999)

[5] Species diversity: the species richness (number of species in the community), the heterogeneity (equilibrium occurrence of different species) and the evenness (quantification of (un)equal representation of species) in an ecosystem (Krebs, 1999)

Based on the preferences of different reef fish we also take a few ecological and environmental features of the nine sites into account. The five features this study will look at is live coral cover, reef rugosity, water clarity, water temperature and the distance to mangroves, seagrass beds and rivers. Percentage of live coral is one of the features of structural complexity of coral reefs together with reef rugosity (roughness of the surface) and it provides hiding places for reef fish and more attachment places for algae, invertebrates and corals (Rooney, 1993; Fuad, 2010). An increase in the percentage of live coral cover will improve the diversity of shelters and/or feeding places and is therefore strongly related with an increasing species richness, biodiversity and eveness (Bell & Galzin, 1984; Fuad, 2010). Earlier research has shown that a large declines in live coral cover is linked to a decline in reef fish populations; especially for reef fish that are strongly dependent to coral for protection and food (Graham et al., 2008; Arceo et al., 2001). Percentage live coral is highly correlated with reef rugosity, diversity and abundance (Aronson & Precht, 1995; Fuad, 2010).

Water temperature and water clarity can have a big influence on the biodiversity of a coral reef and therefore on the reef fish (Veron, 1993; Fuad, 2010). The minimum temperature for coral to survive and reproduce is 20 °C and a temperature higher than 29.5 °C for several days can cause bleaching of the coral with the possible result of permanent damage to the coral reef (Veron, 1993; McWilliams et al., 2004; Arceo et al., 2001). Temperature might also have an effect on spawning aggregations of reef fish (Claydon, 2004). E.g. some groupers spawn with a preferred temperature above 24°C and others rather around 25.5°C (Domeier & Colin, 1997). Water clarity can cause shading on corals, resulting into a reduced level of photosynthesis which will cause a decrease in survival and reproduction rates (Barnes, 1999; Richmond, 2008). Fish also show preferences for a high amount of light in the water. When water is to turbid they will move to a place with more clear water. A high amount of sediment in the water can even result in a decreased survival rate of larvae and eggs because they get covered in sediment and die for example because of an unsuccessful hatching (Clifton et al., 2010; Kerr, 1995; Auld & Schubel, 1978). The amount of sediment in the water sometimes depends on the bottom structure, e.g. varied amount of suspension through different particle sizes and low suspension because of a high reef rugosity, or on the distance to the nearest river mouth (Fuad, 2010; Kerr, 1995; Edwards, T.E., 1999). Close to a river mouth the sedimentation rate might be much higher. The distance to the nearest mangrove forest and seagrass beds is included in this research because a lot of reef fish make use of those habitats during one or more of their life stages (Nagelkerken et al., 2000, 2012; Honda et al., 2013).

2. Methods

2.1 Study area

This study was executed at nine different sites located in the municipalities Dauin, Zamboanguita and Siaton, Negros Oriental. The names of the sites are Kookoo's nest (1), Antulang (2), Andulay (3), Lutoban south (4), Lutoban pier (5), Guinsuan (6), Basak (7), Malatapay (8) and Dauin poblacion (9) (figure 2.1). Marine Conservation Philippines is based in the barangay (village, the smallest administrative division) Lutoban in the municipality of Zamboanguita. All locations are located in the central Visayas region in the Philippines. The Philippines has a tropical climate with wet and dry seasons. The central Visayas region has a dry and a wet season (figure 2.2). This study was executed from March 2016 until July 2016 and took place partly in the dry season and partly in the wet season (Grosberg et al., 2015; CLIMATE-DATA.ORG, 2016)

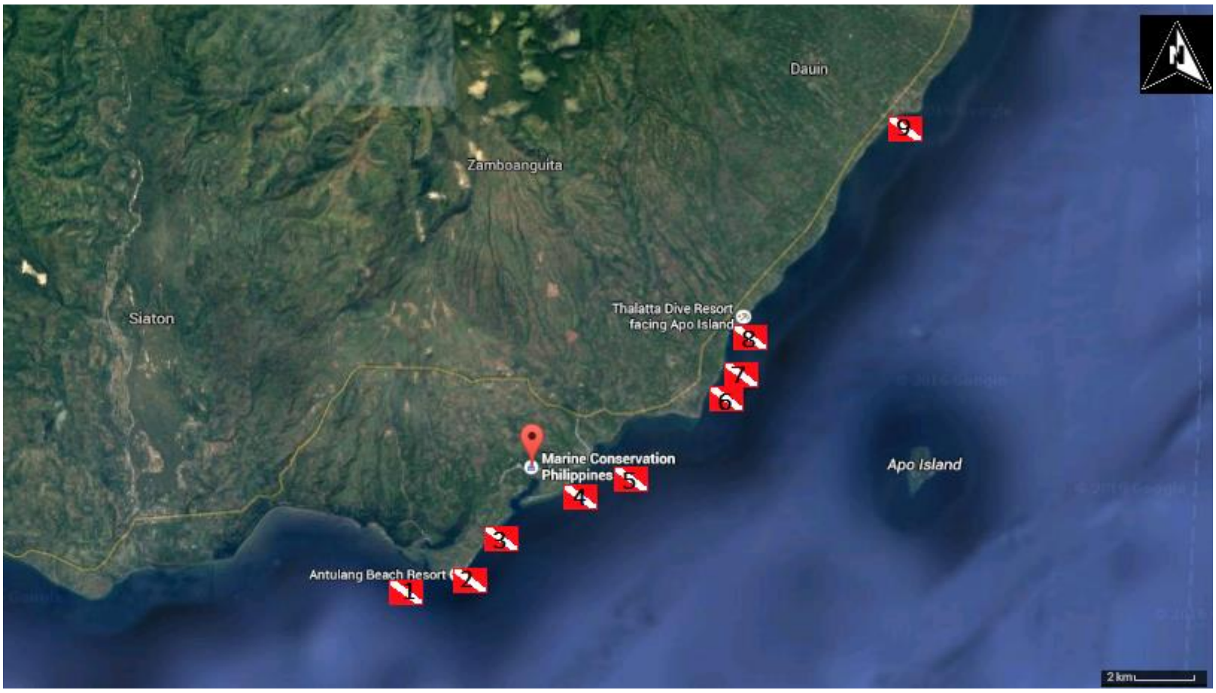

Figure 2.1: A map with all nine dive sites: 1: Kookoo's nest, 2: Antulang, 3: Andulay, 4: Lutoban South, 5: Lutoban pier, 6: Guinsuan, 7: Basak, 8: Malatapay, 9: Dauin poblacion (obtained from Google Inc. (2016)*).*

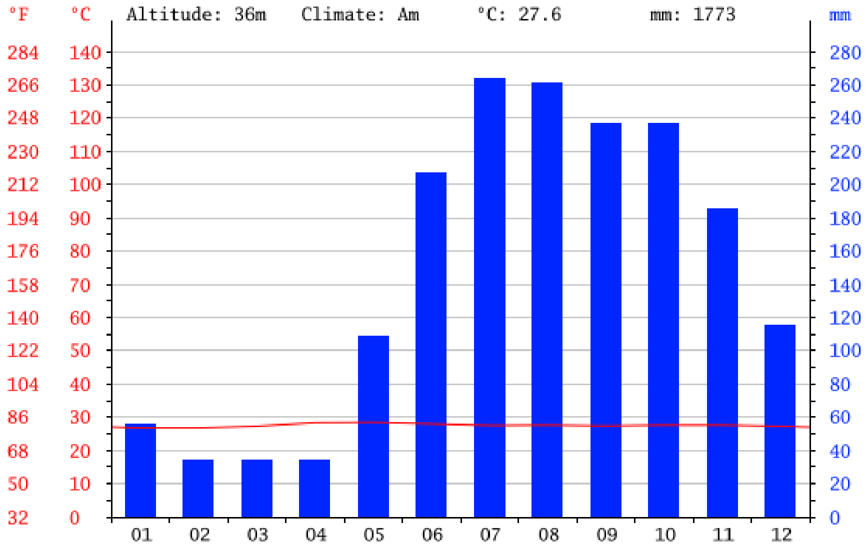

Figure 2.2: An annual schedule of average rainfall (mm) and temperature (°F/°C) per month (obtained from CLIMATE-DATA.ORG (2016)*)*

2.2 Fish surveys

All fish surveys were performed with scuba diving. Before the surveys started the transect lines were placed. Two permanent line transect of 100 meters are used at all nine sites, one between 4 and 6 meters depth and one between 9 and 12 meters depth. A dive computer was used for measuring the depth, the dive computer was hold as close to the bottom as possible and the 100 meter tape line was reeled out as straight as possible with staying at the same depth. Preferably the transect runs parallel to shore, although this is not always possible because the reef is sometimes differently shaped. Subsequently the transect line is marked with zip-ties along the whole transect line (figure 2.3) and a mini marker buoy in the water at both ends of the line (figure 2.4).

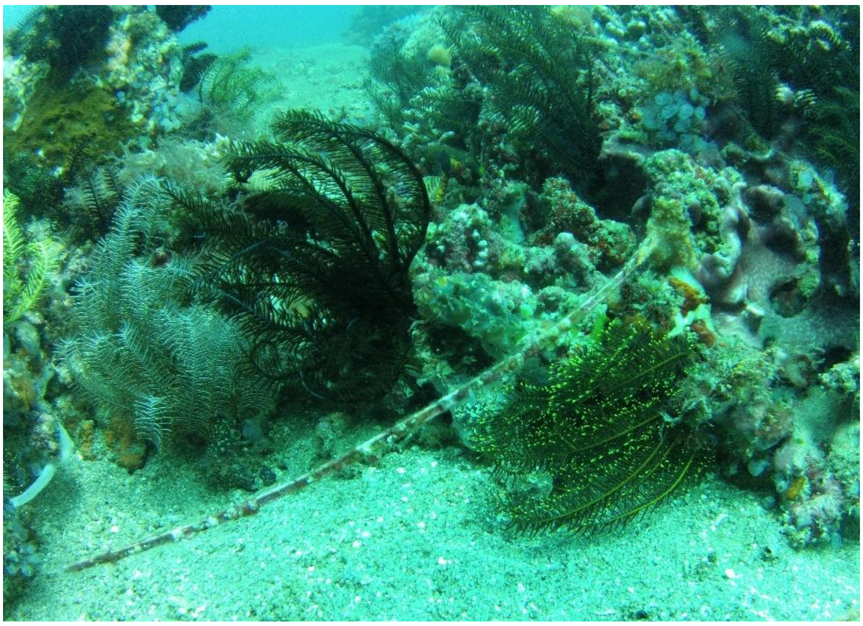

Figure 2.3: An overgrown zip-tie as a marker of the transect line.

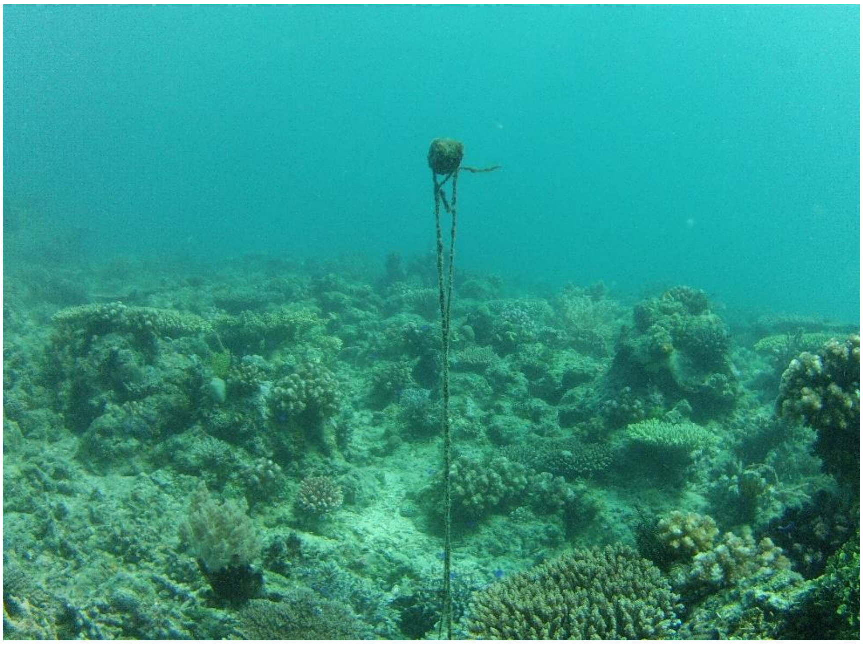

Figure 2.4: A mini marker buoy as a marker for the beginning or end of a transect line.

Before the survey started a tape line was reeled out along the permanent transect line by following the buoys and zip-ties so the same transect line was created during every survey. The 100 meter transect line exists of four 20 meter transect lines with a gap of 5 meters between each line (figure 2.5). The 5 meter gaps make sure that each 20 meter transect line can be seen as an independent transect which is necessary for statistical analysis. The Fish Belt Transect method was used for surveying the indicator fish species (Appendix 1) (Hill & Wilkinson, 2004). The surveys were executed by two observers. One observer swam slowly at the right side of the transect line and one observer swam slowly at the left side of the transect line. During the survey the observers swim through an imaginary square tunnel of 5 metres width and 5 metres high. The fish species were only tallied in this square. So each observer surveyed 2.5 metres from the reel to the left or right and 5 metres high. Both observers swam slowly at the same level along the transect line on their own side. Every 5 metres the observers stopped 1 minute so fish could settle along the transect line. All fish in the lengths of the transects were tallied continuously but in the lengths of the gaps no fish were tallied. (figure 2.7). Butterflyfish, Angelfish, Surgeonfish, Sweetlips, Snappers, Rabbitfish, Groupers and Parrotfish were also tallied at family level for keeping the data likely compatible with Reef Check (Reef Check, 2015). All nine dive sites were surveyed 5 times preferably once every 2-3 weeks in the period March 2016 and May 2016.

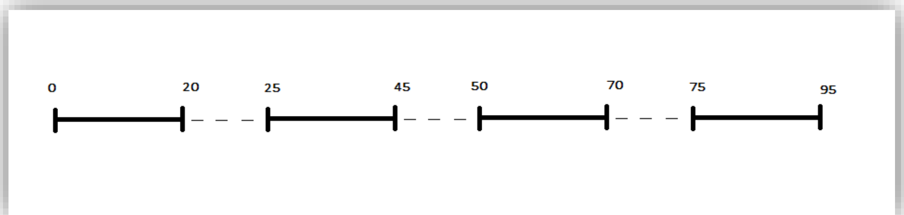

Figure 2.5: The four individual transect lines with the 5 meter gaps in between. First transect line is 0m – 20m, second transect line is 25m – 45m, third transect line is 50m – 70m and the last transect line is 75m – 95m.

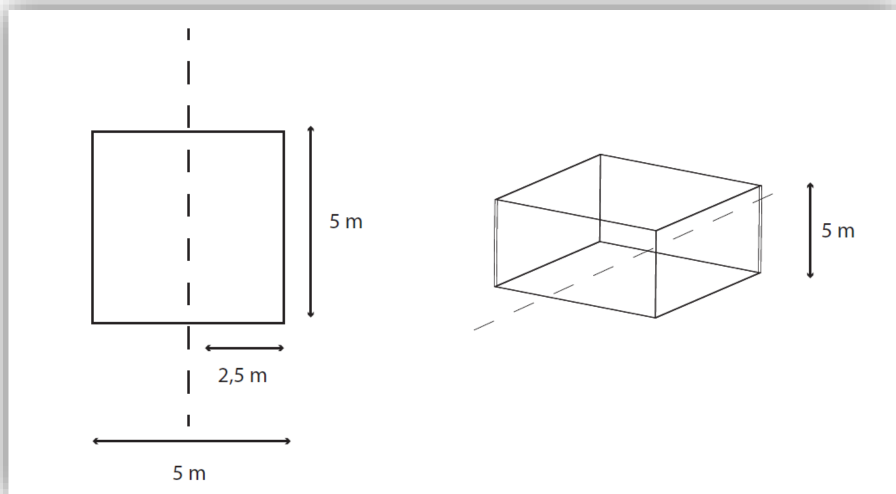

Figure 2.6: The 'belt' that was used by the observers for the survey, based on the Fish Belt Transect method. The belts width and hight is 5 meters and the length is as far the transect line reaches. This creates a 2.5 meter width for each observer.

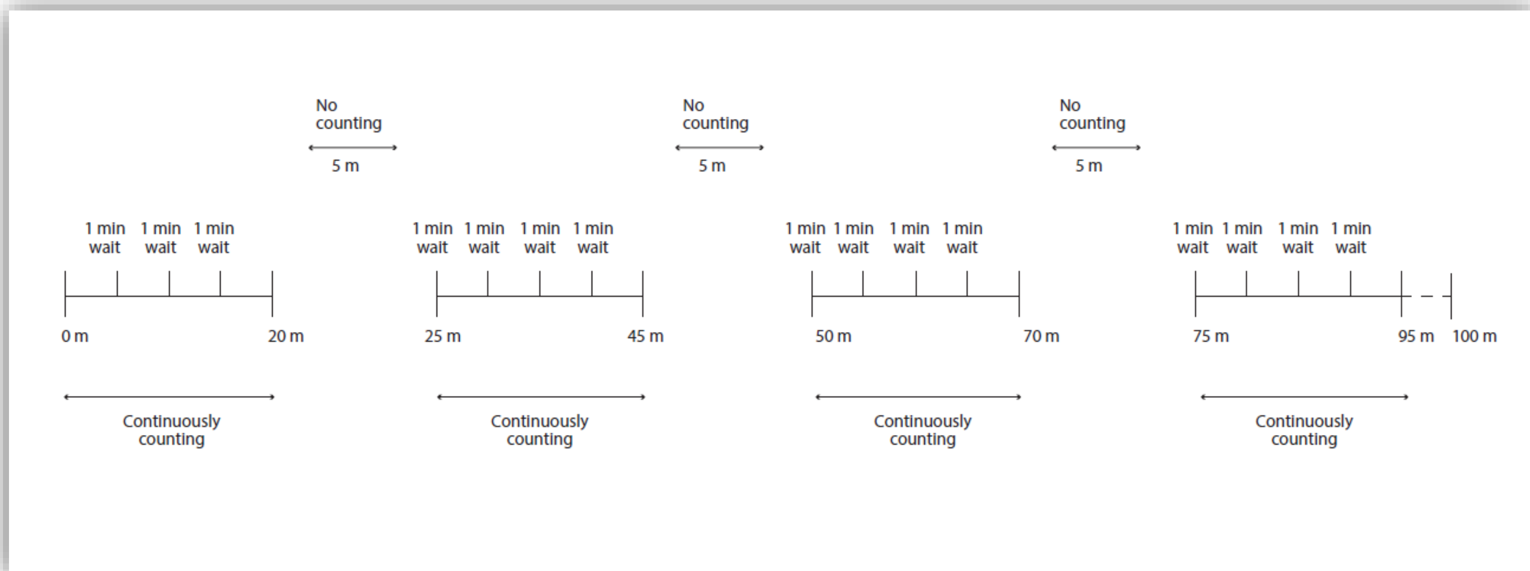

Figure 2.7: A schematic summary of how the surveys were performed.

2.3 Environmental features

2.3.1 Status of protection

The status of protection is divided in three categories. A protected MPA is an official MPA on paper and has well enforced and managed protection. A paper MPA is an official MPA on paper but there is no sign of management in this area. A no protected area is an area without protection and no registration of being a MPA.

2.3.2 Percentage of life coral

The percentage of life coral was measured by mapping the area at four different depths, 1 meter, 5 meters, 9 meters and 13 meters. Mapping at 1 meter was accomplished with snorkelling and all other depths by scuba diving. The different substrates categories are, life coral, seagrass, rubble, sand, algae and rock. First a 300 meter tape line was placed as straight as possible on the same depth parallel to the shore. Depending on the level of the reef rugosity, the depth varied. Two observers swam over the tape line. One observer held a frame of 1.0 meter by 0.5 meter over the tapeline and moved it forward slowly. Within this framework of two 0.5 square meters on both sides of the line the substrate was observed. The observer indicated with a hand signal which substrate category dominated the framework (> 50%) (figure 2.8), while the other observer wrote down the distance of the tape line and the substrate on a slate. When a change of dominant substrate category occurred, the observer with the frame gave the sign of the new substrate category. This process continued until the whole 300 meters was recorded. An observer at land determined the GPS location of the beginning and endpoint of the 300 meter line from shore with a GPS and made a track of the transect with a surface swim over the line. An observer under water registered the depths each 5 meter. All the data was collected and the percentage of coral was calculated per site.

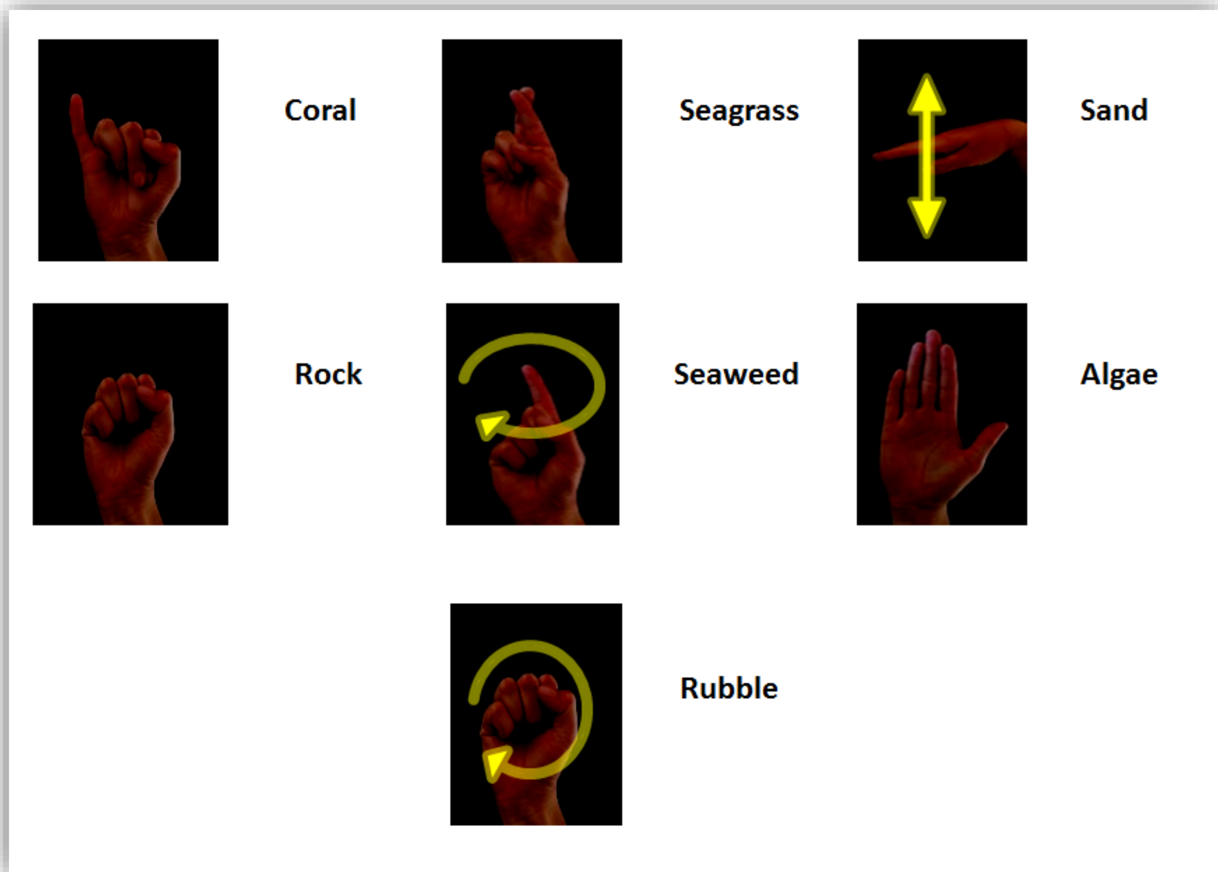

Figure 2.8: The hand signals that were used for communication during mapping.

2.3.4 Distance to mangroves and seagrass

The distance to mangroves forest and seagrass beds is specified in meters and calculated in the program QGIS.

2.3.5 Water temperature

Water temperature has been measured with the same dive computer during every dive from the period March 2016 to July 2016.

2.3.6 Water clarity

Water clarity was measured with a Secchi disk, a black and white disk with a 30 centimeter diameter. The Secchi disc measured the Secchi depth, the maximum depth the disk can be seen from the surface (figure 2.9) [Dennison et al., 1993]. The disk was lowered into the water until it was out of sight and the depth when it disappeared was marked on the rope where the surface met the rope. On land the length between the disk and the mark on the rope was measured in meters. Each site was measured in the period of May 2016 to June 2016 The measurements are divided in 3 different scales, Clear water (≥ 10.0 meters), moderate clear water (5.0 - 10.0 meters) and turbid water (≤ 5.0 meter) (De'ath & Fabricius, 2008).

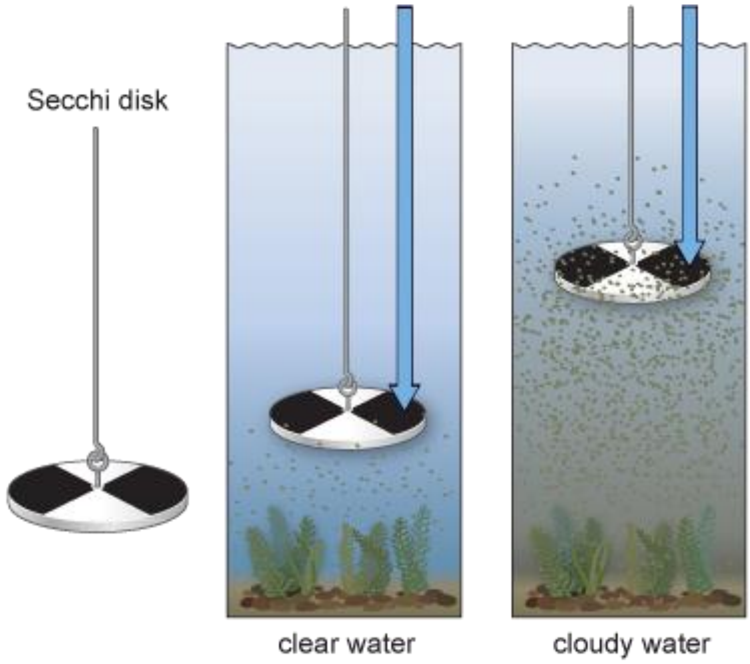

Figure 2.9: A visual example of how the Secchi disc was used (obtained form: http://www.open.edu/openlearn/science-maths-technology/science/chemistry/test-kits-water-analysis/content-section-4.1)

2.3.7 Reef rugosity

Reef rugosity, the amount of 'wrinkling' of the profile of the reef, is measured by SCUBA diving with a tapeline. The tapeline is reeled out over the exact same transect line as used for the fish survey at both 5 and 10 meters depth. The measurement is performed with a 10 meter tapeline. The first tapeline is reeled out in a straight line and functions as the official transect line. The 10 meter tapeline is weighted down with several small fishing lines with a weight on both ends (figure 2.10) and follows the exact contours of the reef. The transect line shows the distance that was covered by the 10 meter tapeline (figure 10). This measurement was repeated until the whole 100 meter transect was measured. A rugosity index, C, is calculated as $C=1-d/l$. d is horizontal distance covered by the 10 meter tapeline that follows the rugosity of the reef and l is the length that was covered by the transect line. The rugosity index is used as value and categorical divided in three scales, low rugosity index ($C \leq 0.170$), moderate rugosity index ($0.170 < C \leq 0.275$) and high rugosity index ($C > 0.275$) (Fuad, 2010).

Figure 2.10: Laying down the line for rugosity measurement using small fishing weights for keeping the line in place

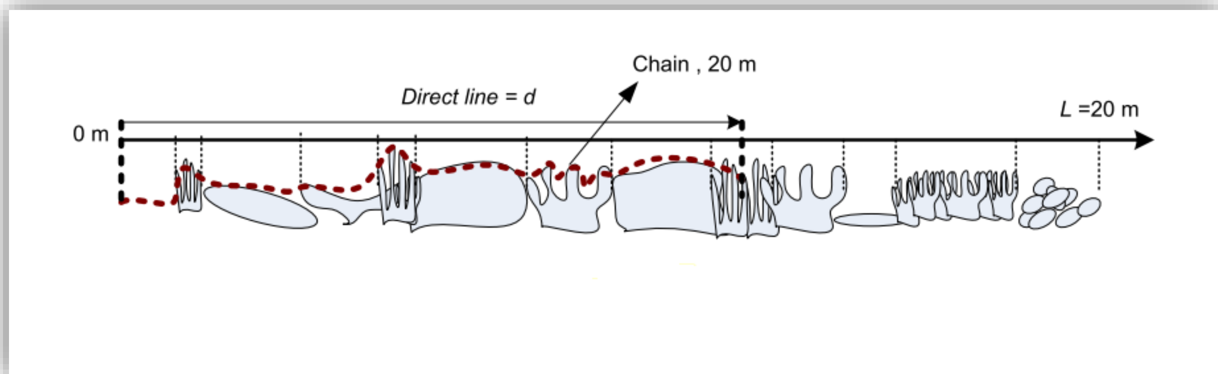

Figure 2.11: The method for measuring the reef rugosity (obtained from Fuad, 2010)

2.4 Statistical analyses

The diversity was gained by calculating the Shannon Wiener diversity index based on the obtained survey data (Krebs, 1999). Comparing the diversity of fish species between different sites and the environmental factors was statistically tested with a one-way Anova, Linear Regression and an Independent T-test. Comparing the abundance between different sites was statistically tested with a Generalized Linear Model, Kruskal Wallis and Mann-Whitney U test. The presence/absence of the fish species was statistically tested with Logistic Regression analyses. The abundance, diversity and presence/absence of the fish species are the dependent variables and the sites (nominal), depth (ordinal), percentage of life coral (%), reef rugosity (value and ordinal), distance to a mangrove forest and/or seagrass bed (meters), water clarity (ordinal) and status of protection of each site (ordinal) as the independent variables.

3. Results

In total, 23506 individuals, belonging to 78 different species in 21 families were recorded. Diversity (Shannon Wiener index), abundance and presence/absence based on those records were compared between sites and the environmental factors of those sites. Table 3.1 shows results of the environmental factors that has a significant influence on the diversity, abundance and present/absence which significantly influenced the results, protection, percentage life coral cover and reef rugosity. Other factors are water clarity, water temperature and distance to and size of mangrove forests and seagrass beds.

Table 3.1: Status of protection, percentage life coral cover and the reef rugosity index per site.

Site	Status of protection	Percentage life coral cover (%)	Reef rugosity index
Antulang	No MPA	14.5	.162
Guinsuan	No MPA	6.1	.112
Malatapay	No MPA	10.5	.124
Andulay	MPA	15.0	.121
Basak	MPA	16.9	.082
Lutoban south	Paper MPA	19.7	.211
Lutoban pier	No MPA	19.9	.215
Kookoo's nest	No MPA	44.8	.300
Dauin poblacion	MPA	13.4	.212

The fish diversity is significantly higher at Dauin poblacion and significantly lower at Guinsuan compared to all the other sites ($p<0.05$). The diversity index at Lutoban pier is significantly lower compared to Andulay and Basak ($p<0.05$) (figure 3.1).

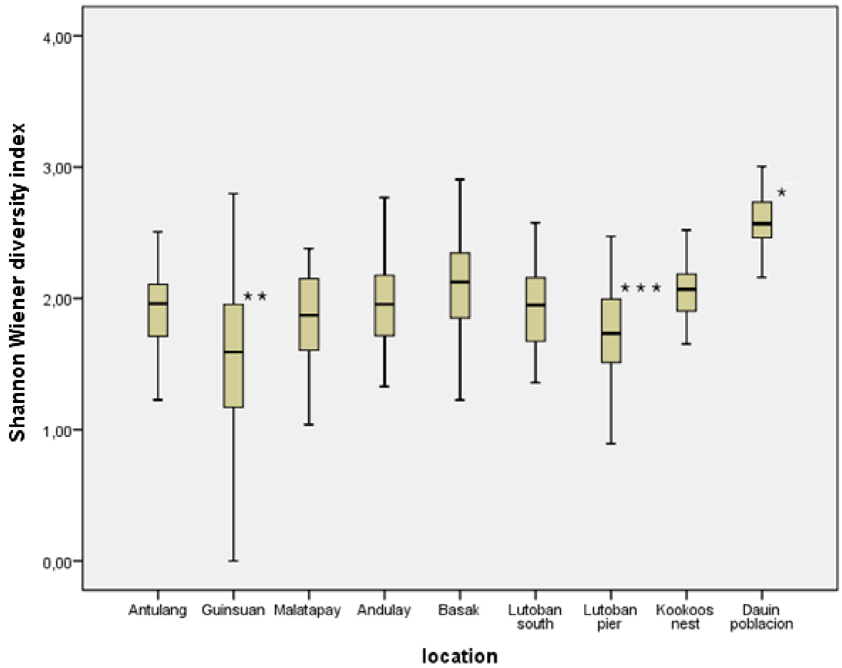

*Figure 3.1: Shannon Wiener diversity index per site. * Dauin poblacion shows significant higher diversity than every other site(p<0.05), ** Guinsuan shows significant lower diversity then every other site (p<0.05), *** Lutoban pier shows significant lower diversity than Basak and Andulay (p<0.05).*

The diversity in MPA's is significantly higher than the diversity in non MPA's and paper MPA's (figure 3.2). Table 3.3 shows the significant differences per site divided in the different protection statuses.

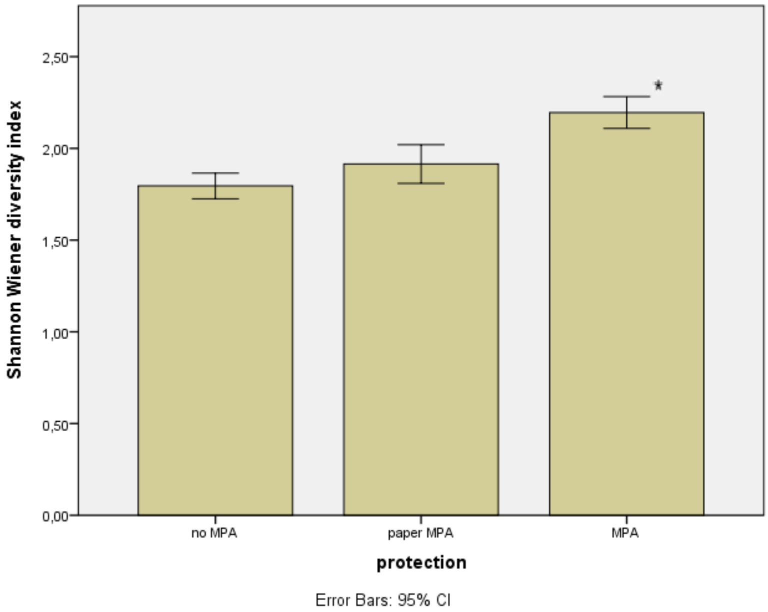

*Figure 3.2: The Shannon Wiener diversity index per protection status. * MPA has a significantly higher diversity compared to a paper MPA and non MPA (p<0.05).*

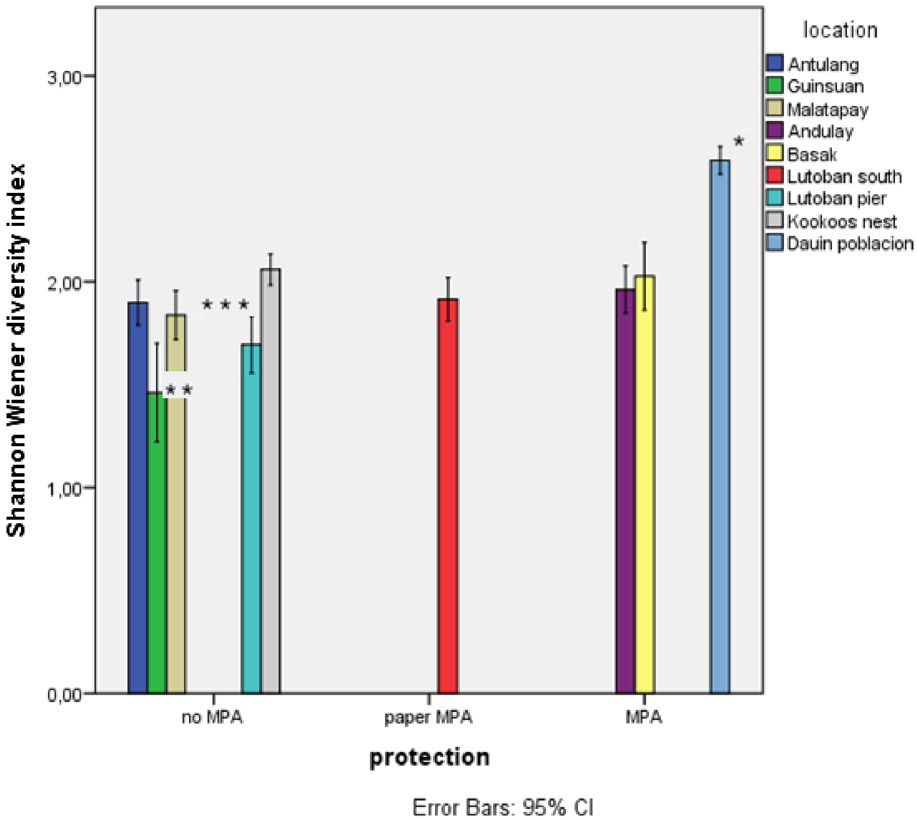

*Figure 3.3: The Shannon wiener diversity index per site divided in different protection status. * Dauin poblacion shows significant higher diversity then every other site(p<0.05), ** Guinsuan shows significant lower diversity then every other site (p<0.05), *** Lutoban pier shows significant lower diversity then Basak and Andulay (p<0.05).*

The percentage life coral cover and reef rugosity are showing a significant positive influence on the Shannon Wiener diversity index (p<0.05) (figure 3.4 and figure 3.5). The percentage life coral cover and rugosity show a significant relation per site (p<0.05).

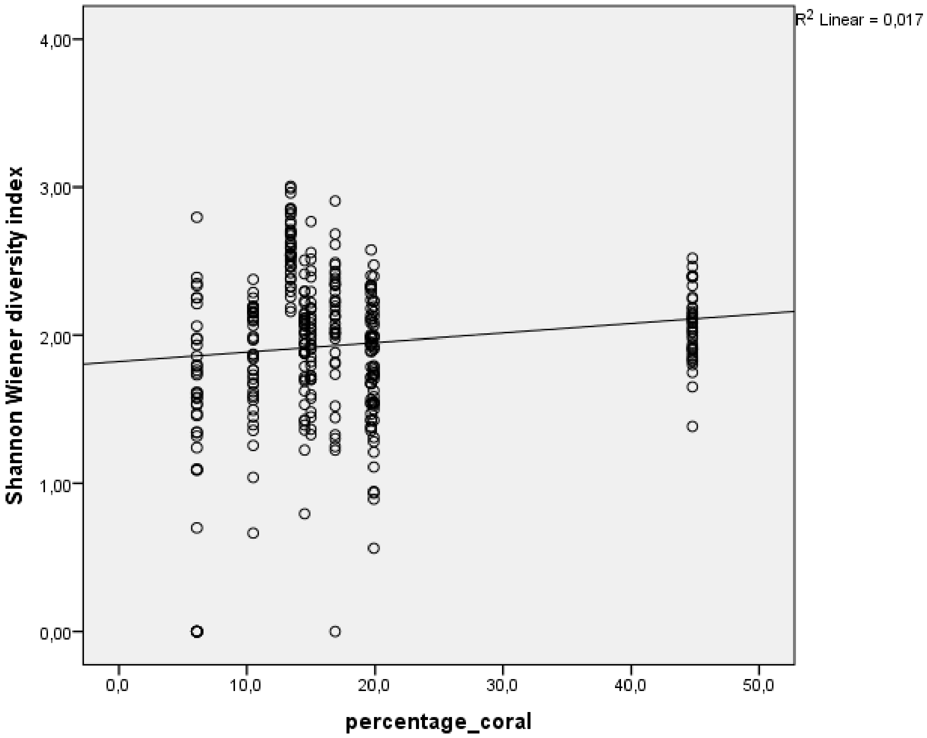

Figure 3.4: The linear regression of percentage life coral cover and the Shannon Wiener diversity index. Percentage life coral cover shows a significant positive influence (R^2=0.017) on the Shannon Wiener diversity index (p<0.05).

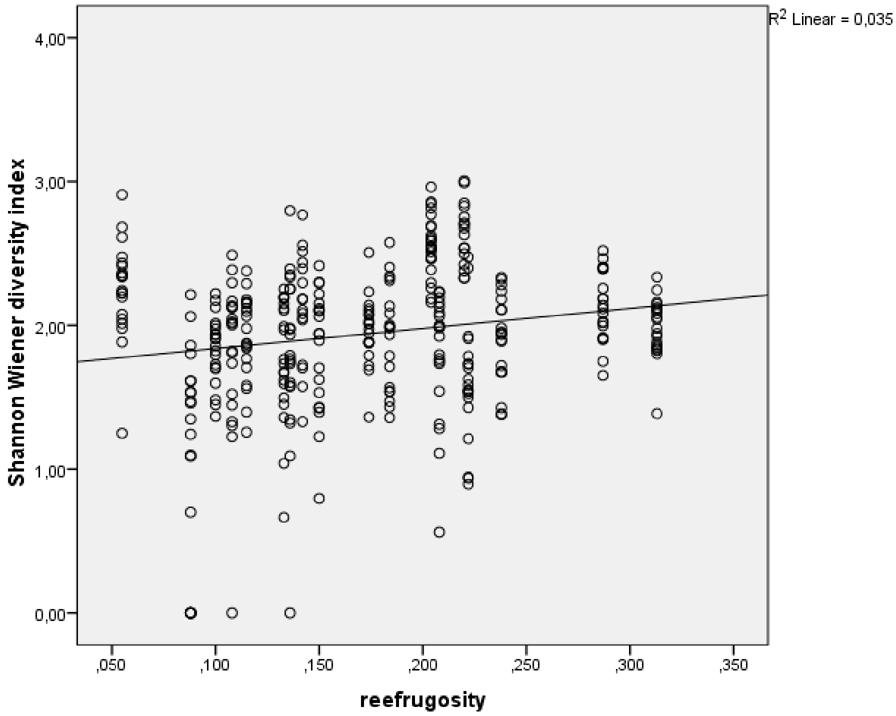

Figure 3.5: The linear regression of reef rugosity and the Shannon Wiener diversity index. Reef rugosity shows a significant positive influence (R^2=0.035) on the Shannon Wiener diversity index (p<0.05).

Distance to mangrove forests and seagrass beds have significant positive influence on the diversity ($p<0.05$), showing that the diversity decreases with mangroves and seagrass beds at a shorter distance (figure 3.6 and figure 3.7). Water temperature, water clarity and size of mangrove forests and seagrass beds did not have a significant relationship with the Shannon Wiener diversity index.

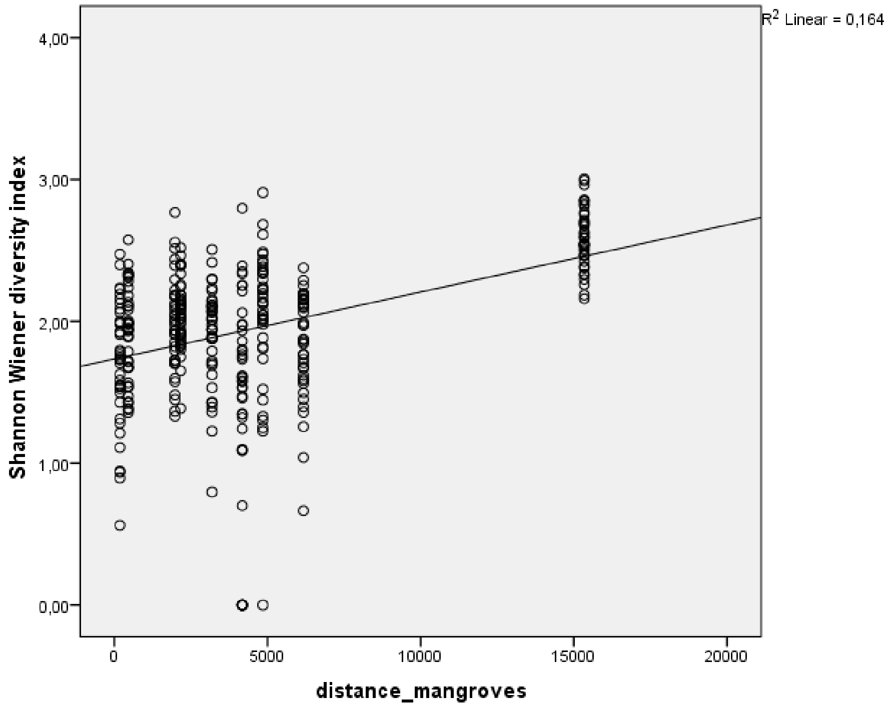

Figure 3.6: The linear regression of the distance to mangrove forests and the Shannon Wiener diversity index. The distance to mangrove forests shows a significant positive influence (R^2=0.164) on the Shannon Wiener diversity index ($p<0.05$).

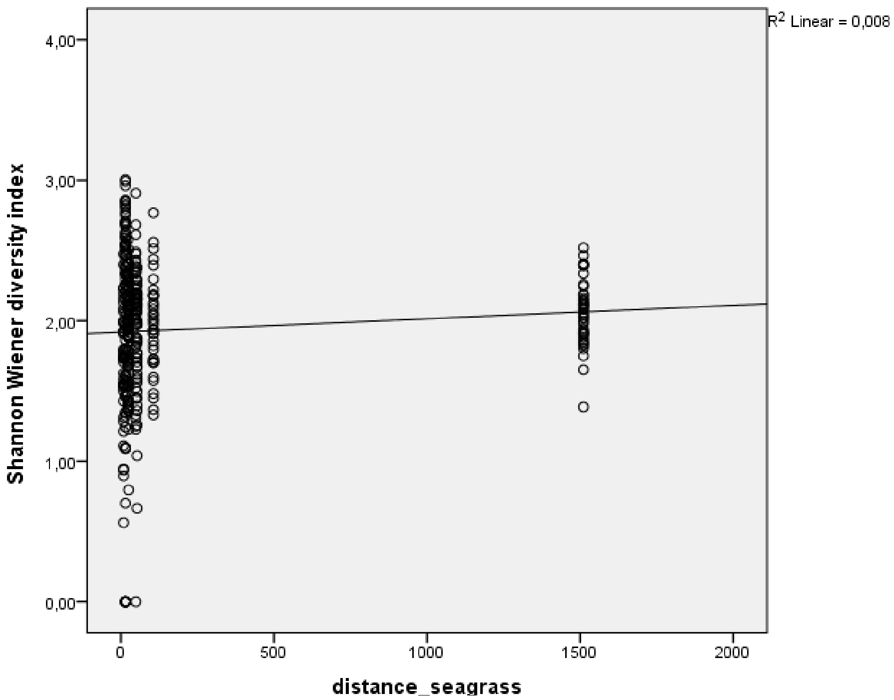

Figure 3.7: the linear regression of the distance to seagrass beds and the Shannon Wiener diversity index. The distance to seagrass beds shows a significant positive influence (R^2=0.008) on the Shannon Wiener diversity index ($p<0.05$).

30% of all indicator fish species (appendix 2) shows a significant higher abundance in MPA's compared to paper MPA's and non MPA's ($p<0.05$). The same 30% also shows significantly more presence in MPA's compared to paper MPA's and non MPA's ($p<0.05$). Dauin poblacion shows significantly more higher abundances compared to other sites ($p<0.05$). Especially species from the families Acanthuridae, Scaridae and Siganidae (figure 3.8).

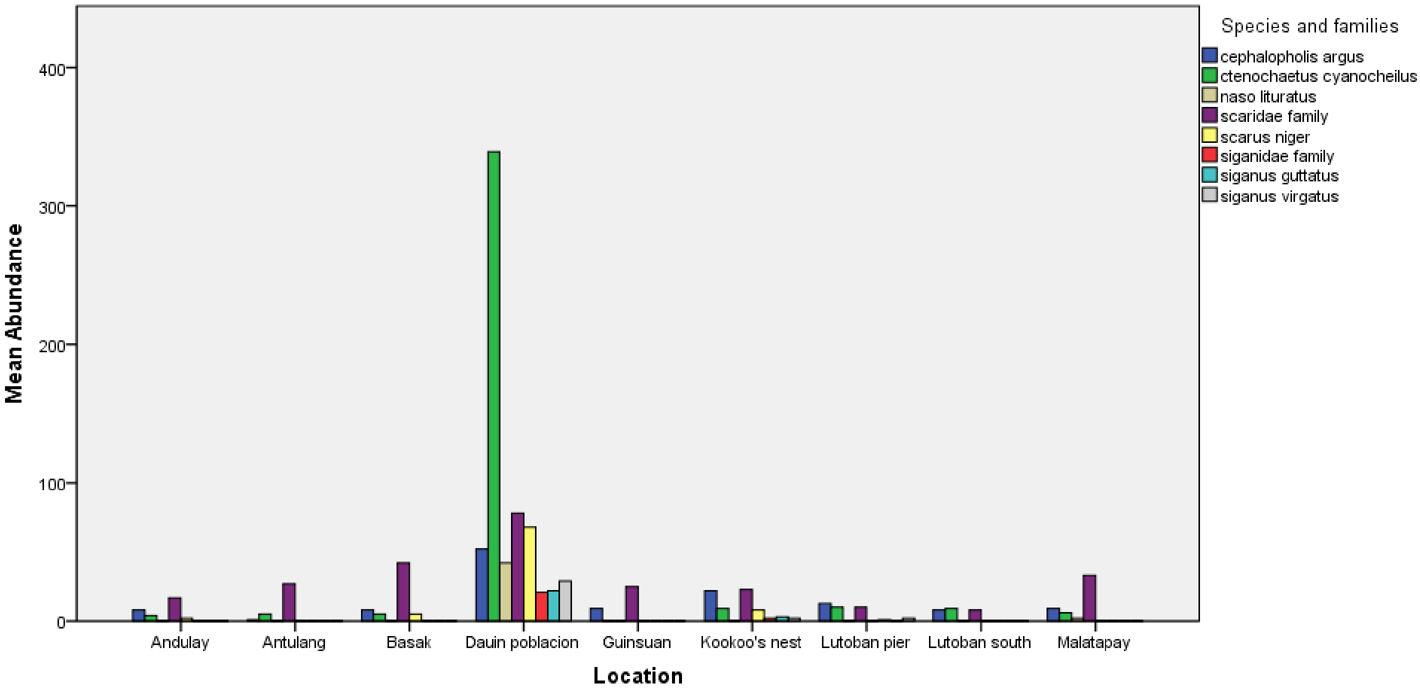

Figure 3.8: Abundance per site for the species cephalopholis argus, stenochaetus cyanocheilus (acanthuridae), naso lituratus (Acanthuridae), scarus niger, siganus guttatus and siganus virgatus and for the families scaridae and siganidae

The families Acanthuridae, Chaetodontidae, Scaridae, Serranidae, Siganidae and Pomacanthidae showed significant higher abundance and/or presence in MPA's and/or with a higher reef rugosity ($p=0.05$) (table 3.2).

Table 3.2: A schedule of significant higher abundance and/or presence in MPA's compared to paper MPA's and non MPA's and/or with a higher reef rugosity for the families acanthuridae, chaetodontidae, scaridae, serranidae, siganidae and pomacanthidae ($p<0.05$).

Family	Higher *value* in MPA		Higher *value* with higher reef rugosity	
	Abundance	Presence	Abundance	Presence
Acanthuridae	**X**		**X**	
Chaetodontidae	**X**		**X**	
Scaridae	**X**	**X**		
Serranidae	**X**	**X**	**X**	
Siganidae	**X**	**X**	**X**	
Pomacanthidae	**X**	**X**	**X**	**X**

The families Haemulidae, Scaridae, Serranidae and 45% of the species of the Labridae family shows a significant higher presence with a higher percentage of life coral cover ($p<0.05$). The same 45% of the Labridae family has significantly more presence at the 5 meter transect than at the 10 meter transect ($p<0.05$).

The species Abudefduf sexfaciatus, Abudefduf vaigiensis, Cheilinus chlorourus, Cheilio inermis, Halichoeres argus, Halichoeres hortulanus, Halichoeres scapularis and Stethojulis trilineata show a significant reduce in presence with further distances from seagrass beds ($p<0.05$).

4. Discussion

Protection of marine area's provided by MPA's in the south-eastern part of Negros Oriental in the Philippines, has resulted in a higher diversity of reef fish. Higher rugosity and higher percentage life coral cover also showed positive influence on the diversity of reef fish, due to a strong correlation between those two environmental features per site. Nevertheless, sites with a higher status of protection, e.g. Basak and Andulay, showed a higher number of diversity compared to sites with a low protection status and a higher number of rugosity and percentage life coral cover like Lutoban pier. The outcomes of this research confirm earlier research of Stockwell et al. (2009) who did research in roughly the same area and shows that protection is more important than habitat for reef fish. Also rugosity and percentage life coral cover are very close related but are not always higher at the protected area's (Abesamis et al., 2006; Stockwell et al., 2009). This shows that the highest amount of ecosystem services is not always provided by the healthiest reefs as well as that a higher species diversity isn't always referring to a healthier reef. It is conceivably more likely that higher functional diversity refers to a healthier reef (Nyström, 2006).

Dauin poblacion shows by far the highest diversity and significantly high abundances. This is especially the case for herbivorous families like Scaridae, Acanthuridae and Siganidae. Those families are subject to a high pressure of overfishing (Alcala et al., 2008; Alcala, 1999). Dauin poblacion has been a MPA already for 16 years and has a strict enforcement (Alcala & Russ, 2006). The possibility that duration and the different methods of enforcement has influence on the diversity and abundance of reef fish is high (Stockwell et al., 2009; Maypaab et al., 2012; Alcala, 1999). Most of the fish species that show a significantly higher abundance are herbivorous fish, indicating that their food source is in good condition. Herbivorous fish eat, among other things, algae. They strengthen reef resilience by preventing algae dominated reefs (Green & Bellwood, 2009; Guillemot et al., 2013; Hughes et al., 2007). For that reason the algal communities are also of great importance for herbivorous fish and should therefore be taken into account in further research. With a high diversity and abundance of herbivorous fish, Dauin should have a healthy algal population with the algae growth kept in cache by the herbivorous fish.

30% of the fish species that show significant positive influence on abundance and presence by protection are the big herbivorous fish like the family of the Scaridae, Acanthuridae and Siganidae, bigger predator species like Cephalopholis argus and Lutjanidae decussatus, but also include the corallivores Chaetodontidae and the family Labridae. The fish species from the families Acanthuridae, Chaetonidae, Labridae, Scaridae and Siganidae have a high reliance on the reef because of their diet and the fish species Cephalopholis argus, Lutjanidae decussatus and species of the families Labridae, Scaridae and Siganidae are under high pressure by fishing (Kulbicki et al., 2005; Nagelkerken et al., 2000; Alcala et al., 2008; Alcala, 1999). The bigger predators that are under pressure by fishing and show more presence in a protected area are represented in small numbers of species. The species which occur more often and in higher numbers and are tallied more often show a significant interaction with protection. It is possible that if more data would have been collected for the other species more significant effects would have occurred.

A lot of comparable research take biomass into account. Biomass can differ between protected and not protected areas because non-take area's allows fish to grow to adult size (Nagelkerken et al., 2012; Graham et al., 2008; Stockwell et al., 2009; Russ et al., 2004). During this research we've observed bigger fish, e.g. fish species of the family Scaridae, Labridae, Lutjanidae, Serranidae and Lethrinidae, at protected areas like Dauin poblacion compared to a non-protected area like Kookoo's nest, even when diversity and abundance is high at both sites.

The distances from the reef to mangrove forests and seagrass beds have shown a positive effect on diversity at longer distances, i.e. the fish diversity decreased with a shorter distance to mangroves and seagrass beds, while the opposite would have been expected (Honda et al., 2013; Nagelkerken et al., 2012). The species of the family Labridae and the genus Abudefduf show a negative effect on the presence/absence at longer distances are known for their reliance on seagrass as a nursery habitat (Honda et al., 2013). Half of those species also show a higher abundance with higher protection. The distance to seagrass beds should be taken into account for those species with establishment of a MPA.

The water clarity measurements with a Secchie disk has shown no differences between all nine sites. All sites have a high water clarity (> 10 meters), resulting in an environmental factor of little influence (De'ath & Fabricius, 2008). For further research other methods can be used. The amount of silt can be measured with traps, grab samplers and pump samplers. Particle size and the distribution of the silt can be taken into account in these methods (Edwards, T.E., 1999). Using a more comprehensive method will possibly show differences between the nine sites.

The Reef check method of the Fish belt transect that was used during the fish surveys is a widely used method for projects and studies that are working with volunteers and/or a big group of people. It is designed for anybody to use with little training (Hill, 2006; Hill & Wilkinson, 2004; PERSGA., 2010; Longhurst & Clay, 2013). The influence of the observer and particularly the amount of experience of the observer is likely to still have an effect on the data of the surveys. Therefore it is preferable to work with as much experienced people as possible. With the amount of coming and going of volunteers this will not always be possible.

In conclusion, the results of the present study show that protection is more important for reef fish diversity than their habitat. This is considered very effective for the Philippines because the Philippines contains 1785 MPA's (Philippine MPA Database, 2014). Protection also shows a positive effect on the abundance of herbivorous fish and a small number of predators. For the families Labridae and genus Abudefduf the distance to seagrass beds should be taken into account for establishment of MPA's. For further research about the importance of environmental factors and of the habitat and protection of the reef fish, algal communities, sediment measurements and measuring biomass is highly recommended. Other recommendations are collection of a higher number of data by performing more surveys and taking the influence and especially the experience of the observers into account.

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Appendix 1

Table 1.1: The indicator species presented with common name, scientific name, genus and family

Common Name	Scientific Name	Genus	Family	Family common name
Yellowmask Surgeonfish	Acanthurus mata	Acanthurus	Acanthuridae	Surgeonfish
Mimic Surgeonfish	Acanthurus pyroferus	Acanthurus	Acanthuridae	Surgeonfish
Whitetail Surgeonfish	Acanthurus thompsoni	Acanthurus	Acanthuridae	Surgeonfish
Bluelipped Bristletooth	Ctenochaetus cyanocheilus	Ctenochaetus	Acanthuridae	Surgeonfish
Orangespine Unicornfish	Naso lituratus	Naso	Acanthuridae	Surgeonfish
Bluespine Unicornfish	Naso unicornis	Naso	Acanthuridae	Surgeonfish
Five lined Cardinalfish	Cheilodipterus quinquelineatus	Cheilodipterus	Apogonidae	Cardinalfish
Titan Triggerfish	Balistoides viridescens	Balistoides	Ballistidae	Triggerfish
Pinktail Triggerfish	Melichthys vidua	Melichthys	Ballistidae	Triggerfish
Redtooth Triggerfish	Odonus niger	Odonus	Ballistidae	Triggerfish
Scissortail Fusilier	Caesio caerularea	Caesio	Caesionidae	Fusilier
Bluestreak Fusilier	Pterocaesio tile	Pterocaesio	Caesionidae	Fusilier
Ornate Butterflyfish	Chaetodon ornatissimus	Chaetodon	Chaetodontidae	Butterflyfish
Spot-Banded Butterflyfish	Chaetodon punctatofasciatus	Chaetodon	Chaetodontidae	Butterflyfish
Latticed Butterflyfish	Chaetodon rafflesi	Chaetodon	Chaetodontidae	Butterflyfish
Oval-Spot Butterflyfish	Chaetodon speculum	Chaetodon	Chaetodontidae	Butterflyfish
Triangular Butterflyfish	Chaetodon triangulum	Chaetodon	Chaetodontidae	Butterflyfish
Vagabond Butterflyfish	Chaetodon vagabundus	Chaetodon	Chaetodontidae	Butterflyfish
Longnose Butterflyfish	Forcipiger flavissimus	Forcipiger	Chaetodontidae	Butterflyfish
Singular Bannerfish	Heniochus singularius	Heniochus	Chaetodontidae	Butterflyfish
Pale Monocle Bream	Scolopsis affinis	Scolopsis	Nemipteridae	Coral Breams
Yellow-Striped Whiptail	Pentapodus	?	Nemipteridae	Coral Breams
Pinnate Batfish	Platax pinnatus	Platax	Ephippidae	Batfish
Cornetfish	Fistularia commersonii	Fistularia	Fistulariidae	Cornetfish
Goldspotted Sweetlips	Plectorhinchus flavomaculatus	Plectorhinchus	Haemulidae	Sweetlips
Diagonal-banded sweetlips	Plectorhinchus lineatus	Plectorhinchus	Haemulidae	Sweetlips
Ribbon Sweetlips	Plectorhinchus polytaenia	Plectorhinchus	Haemulidae	Sweetlips
Splendid Soldierfish	Myripristis botche	Myripristis	Holocentridae	Soldierfish
Redfin Hogfish	bodianus dictynna	Bodianus	Labridae	Wrasse
Floral Wrasse	cheilinus chlorourus	Cheilinus	Labridae	Wrasse
Humphead Wrasse	cheilinus undulatus	Cheilinus	Labridae	Wrasse
Cigar Wrasse	cheilio inermis	Cheilio	Labridae	Wrasse
Yellowback Wrasse	cirrhilabrus lubbocki	Cirrhilabrus	Labridae	Wrasse
Yellowtail Coris	coris gaimard	Coris	Labridae	Wrasse
Argus Wrasse	halichoeres argus	Halichoeres	Labridae	Wrasse
Checkerboard Wrasse	halichoeres hortulanus	Halichoeres	Labridae	Wrasse
Pinstriped Wrasse	halichoeres melanurus	Halichoeres	Labridae	Wrasse
Zigzag Wrasse	halichoeres scapularis	Halichoeres	Labridae	Wrasse
Tubelip Wrasse	labrichthys unileatus	Labrichthys	Labridae	Wrasse
Bluestreak Cleaner Wrasse	labrioides dimidiatus	Labrioides	Labridae	Wrasse
Leopard Wrasse	macropharyngodon meleagris	Macropharyngodon	Labridae	Wrasse
Linedcheeked Wrasse	oxycheilinus digrammus	Oxycheilinus	Labridae	Wrasse

Common Name	Scientific Name	Genus	Family	Family common name
Sixstripe Wrasse	pseudocheilinus hexataenia	Pseudocheilinus	Labridae	Wrasse
Cutribbon Wrasse	stethojulis interrupta	Stethojulis	Labridae	Wrasse
Fourline Wrasse	stethojulis trilineata	Stethojulis	Labridae	Wrasse
Crescent Wrasse	thalassoma lunare	Thalassoma	Labridae	Wrasse
Thumbprint Emperor	Lethrinus harak	Lethrinus	Lethrinidae	Emperor
Ornate Emperor	Lethrinus ornatus	Lethrinus	Lethrinidae	Emperor
Twospot Snapper	Lutjanus biguttatus	Lutjanus	Lutjanidae	Snappers
Red Snapper	Lutjanus bohar	Lutjanus	Lutjanidae	Snappers
Chequered Snapper	Lutjanus decussatus	Lutjanus	Lutjanidae	Snappers
Humpback red Snapper	Lutjanus gibbus	Lutjanus	Lutjanidae	Snappers
Onespot Snapper	Lutjanus monostigma	Lutjanus	Lutjanidae	Snappers
Midnight Snapper	Macolor macularis	Macolor	Lutjanidae	Snappers
Broom Filefish	Amanses scopas	Amanses	Monacanthidae	Filefish
Yellowstriped Goatfish	mulloidichthys flavolineatus	Mulloidichthys	Mullidae	Goatfish
Dash-Dot Goatfish	parupeneus barberinus	Parupeneus	Mullidae	Goatfish
Solor Boxfish	Ostracion solorensis	Ostracion	Ostraciidae	Boxfish
Blackspotted Puffer	Arothron nigropuncatus	Arothron	Tetraodontidae	Puffer
Black-Saddled Toby	Canthigaster valentini	Canthigaster	Tetraodontidae	Puffer
Keyhole Angelfish	Centropyge tibicen	Centropyge	Pomacanthidae	Angelfish
Vermiculated Angelfish	Chaetodontoplus mesoleucus	Chaetodontoplus	Pomacanthidae	Angelfish
Emperor Angelfish	Pomacanthus imperator	Pomacanthus	Pomacanthidae	Angelfish
Regal Angelfish	Pygoplites diacanthus	Pygoplites	Pomacanthidae	Angelfish
Black-tail Sergeant	Abudefduf lorenzi	Abudefduf	Pomacentridae	Damselfish
Scissortail sergeant	Abudefduf sexfasciatus	Abudefduf	Pomacentridae	Damselfish
Indo-Pacific Sergeant	Abudefduf vaigiensis	Abudefduf	Pomacentridae	Damselfish
Bleeker's Parrotfish	Chlorurus bleekeri	Chlorurus	Scaridae	Parrotfish
Bullethead Parrotfish	Chlorurus sordidus	Chlorurus	Scaridae	Parrotfish
Swarthy Parrotfish	Scarus niger	Scarus	Scaridae	Parrotfish
Tricolor Parrotfish	Scarus tricolor	Scarus	Scaridae	Parrotfish
Peacock Grouper	Cephalopholis argus	Cephalopholis	Serranidae	Grouper
Chocolate Grouper	Cephalopholis boenak	Cephalopholis	Serranidae	Grouper
Blacktip Grouper	Epinephelus fasciatus	Epinephelus	Serranidae	Grouper
Brown-marbled grouper	Epinephelus fuscoguttatus	Epinephelus	Serranidae	Grouper
Squaretail Coral Grouper	Plectropomus areolatus	Plectropomus	Serranidae	Grouper
Yellow-edged Lyretail	Variola louti	Variola	Serranidae	Grouper
Coral Rabbitfish	Siganus corallinus	Siganus	Siganidae	Rabbitfish
Golden Rabbitfish	Siganus guttatus	Siganus	Siganidae	Rabbitfish
Virgate Rabbitfish	Siganus virgatus	Siganus	Siganidae	Rabbitfish
Great Barracuda	Sphyraena barracuda	Sphyraena	Sphyraenidae	Barracudas

Table 2.2: List of the indicator fish species and their criteria.

	Functional group													Habitat (water column)				Adult Habitat	Juvenile habitat			Human impact		Water quality		Home range					
Scientific Name	Scrapers	Browser	Grazer	Generalist	Invert specialists	Corallivores	Piscivore	Filter feeding planktivores (zoo/phyto)	Selective planktivore	Detrivores	Cleaners	Crown-of-thorns eaters	Diadema eater	Benthic	Semi-pelagic	Benthopelagic	Pelagic	Coral rich	mangroves	seagrass	coral reef	Commercially interesting	Aquarium species	Murky	Clear	Small	Big	Easily recognizable	Spawning aggregation yes/no	Control species for another species?	Used in another research methodology
Abudefduf lorenzi																			x	x											
Abudefduf sexfasciatus																			x	x											
Abudefduf vaigiensis																			x	x											
Acanthurus mata								x													x	x	x	x				x	x		
Acanthurus pyroferus			x																		x	x	x					x	x		
Acanthurus thompsoni								x								x					x		x						x		
Amanses scopas						x								x								x			x			x			
Arothron nigropuncatus						x								x									x					x			
Balistoides viridescens					x									x							x	x						x			
Bodianus dictynna														x				x										x			
Caesio caerularea									x						x							x									
Canthigaster valentini				x										x									x					x			
Centropyge tibicen			x											x									x			x		x			
Cephalopholis argus					x		x														x	x	x			x		x			x
Cephalopholis boenak					x		x																					x			x
Chaetodon ornatissimus						x								x				x			x	x	x		x	x		x			x
Chaetodon punctatofasciatus						x								x				x				x	x			x		x			x
Chaetodon rafflesi				x										x				x				x	x			x		x			
Chaetodon speculum					x									x								x	x			x		x			x
Chaetodon triangulum						x																	x			x		x			x
Chaetodon vagabundus				x																	x	x	x			x		x			x
Chaetodontoplus mesoleucus				x										x								x	x					x			
Cheilinus chlorourus					x									x						x		x						x			
Cheilinus undulatus																x		x				x	x					x			x
Cheilio inermis					x									x						x		x	x								
Cheilodipterus quinquelineatus																		x	x	x											
Chlorurus bleekeri	x															x						x	x		x		x	x			x
Chlorurus sordidus	x									x											x	x	x			x		x			x

	Functional group													Habitat (water column)				Adult Habitat	Juvenile habitat			Human impact		Water quality		Home range					
Scientific Name	Scrapers	Browser	Grazer	Generalist	Invert specialists	Corallivores	Piscivore	Filter feeding planktivores (zoo/phyto)	Selective planktivore	Detrivores	Cleaners	Crown-of-thorns eaters	Diadema eater	Benthic	Semi-pelagic	Benthopelagic	Pelagic	Coral rich	mangroves	seagrass	coral reef	Commercially interesting	Aquarium species	Murky	Clear	Small	Big	Easily recognizable	Spawning aggregation yes/no	Control species for another species?	Used in another research methodology
Cirrhilabrus lubbocki								x						x				x				x	x					x			
Coris gaimard					x									x				x				x	x					x			
Ctenochaetus cyanocheilus			x																		x							x			
Epinephelus fasciatus					x		x									x						x	x					x			x
Epinephelus fuscoguttatus					x		x													x		x	x		x	x		x			x
Fistularia commersonii																			x												
Forcipiger flavissimus					x											x							x					x			x
Halichoeres argus																			x	x		x	x					x			
Halichoeres hortulanus					x									x						x		x	x					x			
Halichoeres melanurus					x																	x	x					x			
Halichoeres scapularis					x									x					x	x		x	x					x			
Heniochus singularius						x								x				x			x	x	x								
Labrichthys unileatus																		x										x			
Labrioides dimidiatus											x							x										x			
Lethrinus harak					x		x							x					x	x		x						x	x		
Lethrinus ornatus					x		x							x								x						x	x		
Lutjanus biguttatus					x		x															x									x
Lutjanus bohar					x		x																					x			x
Lutjanus decussatus					x		x												x			x						x			x
Lutjanus gibbus																						x						x			
Lutjanus monostigma					x		x												x	x		x									x
Macolor macularis									x												x	x						x			x
Macropharyngodon meleagris					x													x				x	x					x			
Melichthys vidua				x												x						x						x			
Mulloidichthys flavolineatus					x															x		x						x			
Myripristis botche																						x									
Naso lituratus		x																			x	x						x			
Naso unicornis		x														x					x	x	x				x	x			
Odonus niger				x										x							x	x						x			
Ostracion solorensis					x									x							x		x					x			

Scientific Name	Functional group													Habitat (water column)				Adult Habitat	Juvenile habitat			Human impact		Water quality		Home range					
	Scrapers	Browser	Grazer	Generalist	Invert specialists	Corallivores	Piscivore	Filter feeding planktivores (zoo/phyto)	Selective planktivore	Detrivores	Cleaners	Crown-of-thorns eaters	Diadema eater	Benthic	Semi-pelagic	Benthopelagic	Pelagic	Coral rich	mangroves	seagrass	coral reef	Commercially interesting	Aquarium species	Murky	Clear	Small	Big	Easily recognizable	Spawning aggregation yes/no	Control species for another species?	Used in another research methodology
Oxycheilinus digrammus					x													x				x	x					x			
Parupeneus barberinus					x														x	x		x	x					x			
Pentapodus aureofasciatus																												x			
Platax pinnatus																						x						x			
Plectorhinchus polytaenia					x		x							x							x	x						x			
Plectropomus areolatus							x															x						x			x
Pomacanthus imperator					x																x	x	x			x		x			
Pseudocheilinus hexataenia					x													x				x	x		x			x			
Pterocaesio tile									x						x							x						x			
Pterois volitans																				x											
Pygoplites diacanthus					x													x					x					x			
Scarus niger	x															x					x	x	x		x			x			x
Scarus tricolor	x															x						x	x					x			x
Scolopsis affinis																			x	x		x						x			
Siganus corallinus		x																		x		x						x	x		
Siganus guttatus			x																x	x		x						x	x		
Siganus virgatus			x																x			x		x	x			x	x		
Sphyraena barracuda							x										x														x
Stethojulis interrupta					x																	x	x					x			
Stethojulis trilineata					x													x	x	x		x									
Thalassoma lunare					x																	x	x					x			x
Variola louti					x		x															x	x		x			x			x

Appendix 2

Table 2.1: The scientific names of the species that showed a significant higher abundance and presence with a higher protection status.

Scientific name
Acanthurus pyroferus
Bodianus dictynna
Cephalopholis argus
Chaetodon ornatissimus
Chaetodon rafflesi
Chaetodon triangulum
Chaetodon vagabundus
Cheilio inermis
Chlorurus bleekeri
Coris gaimard
Ctenochaetus cyanocheilus
Halichoeres hortulanus
Labrichthys unileatus
Lutjanus decussatus
Macropharyngodon meleagris
Melichthys vidua
Naso lituratus
Odonus niger
Pseudocheilinus hexataenia
Scarus niger
Scolopsis affinis
Siganus guttatus
Siganus virgatus
Stethojulis trilineata
Thalassoma lunare