

The Efficacy of Marine Protected Areas in Southern Leyte, Philippines: Implications on Fish Density and Diversity

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Abstract

Biological diversity within the oceans is endangered worldwide and so management practices need to be undertaken to prevent further degradation of marine systems. The aim of this research was to quantify the success of a small-scale, community based marine protected area (MPA) in Southern Leyte, Philippines. Data collected through underwater marine transect surveys was statistically analysed and related to further literature, to demonstrate and justify the impact of this MPA. The main focus points were on fish abundance, diversity and size, with in-depth assessment of three fish families: grouper, parrotfish and surgeonfish. The results showed a diversity increase, no change in overall fish abundance and a decrease in fish size. These apparently negative impacts can be linked largely to specific family characteristics and conclusions demonstrated that overall, conservational success was seen as a result of this MPA implementation.

Key words: Marine Protected Area, small-scale, Philippines, conservation

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1 Introduction

1.1 Marine Protected Areas

The need for marine conservation was acknowledged in the 1990s, when scientists combined data showing that worldwide biological diversity within the ocean was endangered (Soule, Norse and Crowder 2005). As more is understood about these systems, conclusions show that the status of the world's coastal and marine ecosystems is in global decline, magnified by both direct and indirect human effects (Hughes et al. 2003). Direct human effects include activities such as fishing and indirect effects involve factors such as an increase in anthropogenic carbon dioxide, resulting in global climate change (Hughes et al. 2003). Over-exploitation of marine systems and destructive fishing methods has meant these marine system's value to both society and the environment is threatened (White and Vogt 2000).

Marine protected areas (MPAs) are a vital management tool and their global coverage has increased rapidly since the 1970s, but there is a high variability in the success of these areas (Green et al. 2011). MPAs are designed to protect natural resources in both coastal and offshore regions by implementing restrictions on the damaging activity, for example fishing, that is permitted there (Agardy and Staub 2006).

"MPAs have been identified as one of the key methods for mitigating...human impacts"
(Pollnac and Seara 2011 p. 584).

Protecting the habitat, through management such as MPAs, can increase the number of fish that reach maturity, resulting in a greater proportion of fish that are able to reproduce (Russ et al. 2004; Lowry, White and Christie 2009). This effect is enhanced by MPAs increasing larvae and fish spill over to the surrounding areas (Russ et al. 2004; Lowry, White and Christie 2009).

In the Philippines, finding an effective way to protect the sensitive marine habitats is essential due to the need to protect the high biodiversity in the area (Carpenter and Springer 2005; Nanola, Alino and Carpenter 2011). This issue is further amplified due to the high dependence on fishing to sustain the local's livelihoods (Nanola, Alino and Carpenter 2011; Horigue et al. 2012). From work by Lowry, White and Christie (2009) it is suggested that only 20% of MPAs that are currently in place in the Philippines are reaching their management objectives and so assessing the success of this management tool is extremely important.

Through the aims and objectives stated below, this study will use a small, community based MPA in the Southern Leyte region of the Philippines to demonstrate the longer term impact of marine

protection. It is imperative to understand the long term impacts that closing a reef can have on marine ecosystems due to a huge proportion of the Philippine population being so dependent upon them. To demonstrate the affect that protecting marine ecosystems has on the abundance, diversity and size of fish after reef closure, the following study uses statistical tests between 2008 and 2012 along with comparisons to wider literature to determine the overall impact of MPAs in the Philippines as well as in the global context.

1.2 Study Site

The MPA that this study focuses on is situated in the Visayas region of the Philippines. The MPA itself is in the Napantao area of Sogod Bay and this is situated on Panaon Island at the bottom of Southern Leyte. Calumpong et al. (1994) described the bay as having narrow coral reefs, intertidal zones and beaches, along with limited sea grass beds and mangrove areas.

Between 1990 and 1993, the first comprehensive study of the area was carried out to determine the state of the fisheries and of the local environment (Koch 1993). From surveys and interviews with the local people, Koch (1993) discovered that there had been a decrease in fish catches from the coastal areas. Marine surveys from this study also validated concerns over extreme damage to critical habitats such as coral reefs, many of which could be linked to anthropogenic activity.



Figure 1. Map of Panaon Island showing the Napantao study site circled in red (Coral Cay Conservation 2012)

The Napantao MPA was set up in 1996, as a completely no take area and covers 5 hectares. It is run by a committee of local representatives from both the barangay, the native term for village, and the Municipal Government. The organisation, Coral Cay Conservation (CCC), which uses the scientific data from the reef, assists with the MPA management by providing technical advice and carries out data collection on the reef. Currently, the Napantao MPA is not part of an MPA network and the closest MPAs are approximately 2km north and south of the protected reef. These are all independently managed and there has been no effort to join these up into a network of MPAs.

Calumpang et al. (1994) presented their concern over the low ecosystem diversity in the Sogod Bay area, where Southern Leyte is situated, and the detrimental impacts that environmental degradation has on this. From this, the employment of MPAs in the area is projected to allow ecosystem recovery and this study aims to assess the development and success of this.

1.3 Aims and Objectives

1.3.1 Aim

- To determine the impact of the Napantao, Southern Leyte MPA on the population dynamics of the fish communities from 2008 to 2012.

1.3.2 Objectives

- 1) Investigate the impact that the Napantao MPA on fish abundance from 2008-2012
- 2) To assess whether there is a change in species diversity from 2008-2012
- 3) To determine whether there is a significant change in fish size over the study period

2 Literature Review

Sumaila (2010) commented that increased use of marine resources has driven the need to protect them. To optimise the potential benefits resulting from reef closure, studies such as this one need to be carried out in order to determine whether MPAs are in fact the correct management pathway to take and what effects they have on marine ecosystems on a longer timescale.

2.1 MPAs Worldwide

Marine protected areas were first introduced in the nineteenth century and since then they have become a popular tool in marine resource management (Sumaila 2010). They are implemented in order to increase fish stock and fish size as well as maintaining and improving the biodiversity of the reef (Sumaila 2010).

MPAs are thought to increase fish stocks through processes such as spill-over and recruitment subsidy (Abesamis and Russ 2005). Spill-over is the net export of adult and juvenile fish whilst recruitment subsidy involves egg and larvae net export (Abesamis and Russ 2005). This movement of fish is classified as either density-dependent (movement induced as a result of territorial interactions or space limitation) or density-independent (movement as a result of migration and home ranges) (Abesamis and Russ 2005; Maypa et al. 2012a). If these processes

occur, it will enable fish stock recovery and so reducing the over-exploitation risk faced by many species (Russ and Alcala 1996).

2.1.1 *MPAs in the Philippines*

Marine conservation in the Philippines is vital for global biodiversity protection as the Philippines is situated within an area where biodiversity is extremely high (Bundy 2004; Lowry, White and Christie 2009; Weeks et al. 2009). There are over 1700 reef fish species in the Philippine archipelago (Carpenter and Springer 2005). The high biodiversity combined with many Filipino's being very dependent on fisheries for their livelihoods (Nanola, Alino and Carpenter 2011; Horigue et al. 2012) means protecting these fragile resources is imperative.

2.2 **Development of MPAs**

The Hundred Islands National Park was established in 1940 and was the first MPA to be set up in the Philippines (Horigue et al. 2012). Now, there are over 1000 MPAs in place (Maypa et al. 2012b) and the main aim of their establishment was to increase the success of coral reef fisheries (Lowry, White and Christie 2009).

Fishery biologists noticed that small-scale fishers were seeing smaller catches and lower incomes in the 1980s and 1990s as the exploitation of fisheries increased (Pauly 2004, cited in Horigue et al. 2012 p. 17). This emphasised the need to do something to protect marine resources. As a result of these concerns, in the 1998 Fisheries Code legislation, 15% MPA coverage of municipal waters was proposed and by 2020 the aim was to have 10% of coral reef in no-take areas (Weeks et al. 2009; Pollnac and Seara 2011).

2.3 **Conflict Surrounding MPAs**

Problems arose when MPAs were first encouraged as it was around the same time that the fishing industry took off as a result of the government pushing fishing as a source of income (White and Courtney 2006). This increase in fishing activity played a huge role in degrading coastal habitats and resources (Horigue et al. 2012). As MPA implementation put restrictions on fishing to protect marine resources it did not correspond well with using these resources as a source of income (Horigue et al. 2012).

In fishing communities, there is a huge problem revolving around the need to fish to feed the community and the need to protect the marine ecosystems so that fishing stocks will be sustained in order to keep feeding the people (Muallil et al. 2012).

“Many coastal communities rely on the sea for income and food...therefore, declining resources combined with population growth lead[s] to increased poverty” (Beger et al. 2004 p.787).

In the Philippines, this issue is further enhanced due to opportunities outside of fishing being much harder to come by and so a combination of increasing poverty in fishing communities and a lack of alternative livelihood opportunities heightens fishing pressure, making many fisheries unsustainable (Muallil et al. 2012). If outsiders to the community come in and establish MPAs, without gaining the support of the locals first, or educating them about the long term benefits of MPAs, there is the likelihood that there will be outright opposition to the ban or restriction of fishing, or initial support will be gained but then lost as time goes on (Christie 2004).

A study was carried out on a number of fishing towns across the Philippines and it was noted that the average fish yield was approximately 14 (± 30) MT/km²/yr which is nearly three times higher than the maximum sustainable yield (MSY) in the area (Newton et al. 2007, cited in Muallil et al. 2012 p. 3). As a result of this, these fishing grounds are at risk of collapse due to the high rate of overfishing (Muallil et al. 2012). For coastal resource management (CRM) to be successful in these areas and for the fisheries to become sustainable, MPAs must account for 56% of municipal waters (Muallil et al. 2012). This is an extremely large proportion of coastal waters especially as the Filipino population is generally very dependent on them for fishing (Muallil et al. 2012).

As such a huge proportion of the Filipino community rely on fisheries for their livelihood, other livelihood opportunities need to be increased in order to sustain the local communities if MPAs are put into place that either restrict or ban fishing (Muallil et al. 2012). It is therefore vital that more studies are carried out in different locations and in different situations to quantify whether or not MPAs are having an overall, positive long term effect or whether they are simply displacing environmental degradation, making the lives of the locals more challenging. For MPAs to gain wide-spread support from those who will be most affected, generally the local communities, MPAs' long-term affects need to be quantified in order to prove that they are the correct management pathway to take. This highlights the need for MPA in Napantao to be assessed in respect to longer term changes in population dynamics to assess whether this management technique is successful in the long run.

2.4 Are MPAs the correct management path to take?

McClanahan et al. (2006) carried out a study that compared the effectiveness of MPAs with traditional management techniques. In this investigation, it was discovered that three out of the four study sites that showed an increase in the average size and biomass of fish were as a result of

traditional, self-governing management schemes. It can therefore be argued that permanent closure is not always the most successful management technique. Successful, traditionally conserved areas saw no permanent closures but just periodic closures in which no fishing was allowed for certain periods of the year. The forth site that showed a significant increase in fish density was an area of permanent reef closure.

On the contrary, Taylor, McIlwain and Kerr (2012) noted that limiting the minimum size of extracted fish and closing areas on a rotational basis has been successful in temperate regions but for coral reefs, marine protected areas using permanent closures are widely recommended. This demonstrates that there are many different views and perceptions concerning the success of MPAs and so more research needs to be undertaken to clarify their success.

2.5 What impacts are current MPAs shown to have?

There are many differing opinions concerning the success of MPAs. Whether the management undertaken is seen as a success or failure depends on the viewpoint from which it is seen.

“Much of the confusion surrounding the use of MPAs has stemmed from their intended objectives” (Kaiser 2005 p. 1194).

Kaiser (2005) then continued to argue that whilst in some areas, and for some species, MPAs can provide successful biodiversity outcomes, they are not the solution to every marine conservation situation. Kaiser (2005) also commented that for certain species in certain locations, conservation techniques such as MPAs can show great success yet for others, MPAs are an unsuitable management method and can result in economic problems and environmental issues further afield. Alongside the viewpoints of the local communities and conservationists, overall global biodiversity aims also need to be taken into account when quantifying the success of MPAs.

Many smaller, municipal-based MPAs range from 10-100 hectares in size and although they may locally protect the habitat and result in an increase of marine life biomass, these smaller sized MPAs are not considered sufficient for overall species protection (Lowry, White and Christie 2009). For larger pelagic species, these small MPAs are thought to offer little protection as fish frequently move beyond the boundaries (Lowry, White and Christie 2009). Horigue et al. (2012) also combined evidence that although smaller, community-based MPAs have achieved fishery and conservation targets on the local scale, ecological connectivity is not usually considered. This means that although on the local scale MPAs can produce great outcomes, on a larger scale they do not generally provide resilience to climate change and wide-scale biodiversity conservation. If small-scale MPAs are put into practice, their outcomes on the local scale need to be quantified to ensure the implementation is worthwhile.

Since the early 1980s small community-based MPAs have been at the forefront of MPA establishment in the Philippines and there have been many success stories surrounding these (Christie, White and Deguit 2002). Community-based MPAs are common across the country and have been shown to be effective in reaching fisheries conservation targets at the local scale (Alcala and Russ 2006; Govan 2009). On the other hand however, Christie, White and Deguit (2002) also presented evidence that up to 80% of these MPAs did not show the projected success and resulted in socio-political and environmental challenges.

The failure of MPAs can often be linked to a lack of community support (White and Vogt 2000) and this is an issue that needs to be addressed in order to increase the effectiveness of MPAs in the Philippines. Emphasizing the positive outcomes of marine protection and highlighting the benefits that the local communities will see is crucial to increase community support. As a result of this, more studies need to be carried out to quantify the outcomes of closing marine areas.

2.5.1 *The Impact of MPA Age*

Claudet et al. (2008) carried out a meta-analysis to determine whether or not MPA size and age matter in terms of MPA effectiveness. The data collection method for 39 of the 58 reserves studied by Claudet et al. (2008) was in accordance with the data collection method used in this study of the Napantao MPA; underwater visual census along transects. This paper however critiques the use of visual transect surveys to measure pelagic species density and so discounted them from the analysis which is the opposite to the methodology that this study follows. The authors also assumed that MPAs did not protect these pelagic, highly mobile species and so this provided them with another reason to exclude them from the analysis.

However aside from this, in terms of MPA effectiveness, there was an increase in the density of commercial fish as a result of the marine reserves (Claudet et al. 2008). Compared to the fished areas either side of the reserves, the mean density was 2.46 times greater inside the MPA although this was not consistent across all of the assessed reserves. The impact that time had on the efficiency of this reserve is substantial as this study showed there was an 8.3% increase in commercial fish density for each consecutive year of protection. As the study did not take account of all the species in the area, the overall effect of the MPA on all species was therefore not determined but a combination of data expressed by Gell and Roberts (2003) complimented the work by Claudet et al. (2008) showing MPA success. The work by Gell and Roberts (2003) also showed for long-term studies of MPAs, the increases in abundance, diversity and biomass generally occurred in orders of magnitude.

A study by Anticamara, Zeller and Vincent (2010) was carried out in the Philippines to determine the effect of the duration of closure to fishing in terms of reef fish diversity. Their work used a similar method to this Napantao study and abundance-biomass comparison (ABC) curves were used across the sites to evaluate the influence of the duration of protection. The results from Anticamara, Zeller and Vincent (2010) showed that with a longer duration of reef protection, the curves shifted to having a higher biomass than abundance. This indicates that there was an increase in large-bodied species with time, therefore resulting in a higher overall biomass. There was also a significant increase in species richness within the protected sites with time showing that the reserves were having a positive effect on both the size of the fish, and on the diversity present.

In many cases, for spill-over and recruitment to fully occur, a long time period is required and it is dependent upon many different factors, such as life-history characteristics (Russ, Alcala and Maypa 2003). Russ, Alcala and Maypa (2003) suggest that it may be decades before the population inside MPAs recovers.

2.5.2 *Studies presenting results on fish biomass, abundance and diversity*

Alcala et al. (2005) carried out a study on two MPAs over two decades, on two different islands in the Philippines, Sumilon Island and Apo Island. Their study concluded that overall, the biomass of fish in these two no-take reserves increased over the 18 year study period.

The MPA on Sumilon Island was set up in 1974 and for the first 9.5 years was a strictly no-take area. A 0.75km section was dedicated to the reserve which encompassed roughly 25% of the coral reef in the area. The decision to dedicate this area of reef as a protected area, and similarly with the Apo Island reserve, came from the local municipality and so is a similar situation to in Napantao. From 1974-2001, Sumilon underwent many different stages of management from periods of complete no-take protection, to periods where all fishing activity was allowed. From assessments carried out during all these stages, it was found that during the periods of complete protection, there was a significant positive correlation between biomass inside the protected area and years of protection. When protection ceased, biomass dropped by 42.7% as a result of intense fishing activity. From 1995-2001, the only fishing allowed was hook and line, and during this time, fish biomass increased by 132%. This can provide evidence for arguments against MPAs as biomass still increased even though some fishing was allowed. However the overall conclusion that Alcala et al. (2005) came to on Sumilon island however was that there was always a higher biomass increase associated with full protection compared to partial protection.

On Apo Island, the MPA showed a much more consistent state from when it was set up in 1982, with full, no-take protection for the duration of the period to 2001. This MPA was smaller compared to that of Sumilon Island with 10% of the coral reef protected and an area of 0.45km (Alcala et al. 2005). The overall outcome of this MPA was an increase in fish biomass over 19 years but this increase was not consistent over the time period (Alcala et al. 2005). For the first 9 years, there was a significant positive correlation between fish biomass and years of protection, but for the following years, this correlation was not positively significant. Although this does not defer from the MPA showing an overall increase of fish biomass over the protected period, the cease in biomass after a period of protection increase is interesting. This Napantao study will consider this affect through analysis and reasoning of the twelfth to sixteenth years of protection.

2.5.3 MPA Failure

The opposition to the use of MPAs suggests that protecting one area will simply displace the fishing and damaging activity to other, nearby areas further degrading the reef (Dinmore et al. 2003). Christie (2004) also acknowledged the potential for MPAs to have less than the desired affect in that even though they may result in biological success, social harm may be an unprecedented consequence of this. Expanding this, Christie (2004) demonstrated that although the MPA may see an improvement in the biodiversity of the area, the future of the MPA may be subject to huge opposition from the local community. This is likely to result if the implementation of the MPA has cost them their livelihood, such as fishing restrictions, without appropriate compensation and therefore resulting in economic problems (Christie 2004). The debate over whether or not MPAs are able to meet their management objectives continues with evidence that only 20% of MPAs in the Philippines are actually reaching the targets set for them (Lowry, White and Christie 2009; Launio et al. 2010).

2.6 Target Fish

All the target fish families surveyed were chosen by CCC because they are either: commercially important, a good ecological indicator, generally common in the area, easy to identify or due to a combination of these factors. A study by Hodgson (1999) also chose target fish based on a similar criteria. In addition to the fish listed by Sadovy de Mitcheson et al. (2012) below, Hodgson (1999) and Samoilys et al. (2007) also looked at butterfly fish (Chaetodontidae), barracuda (Sphyraenidae) and sweetlips (Haemulidae) as indicators of reef and ecosystem health. The other fish considered were groupers (Serranidae), snappers (Lutjanidae), parrotfish (Scaridae), surgeonfish (Acanthuridae) and unicornfish (Acanthuridae) and it is these fish that dominate

fishers catches in the Philippines (Sadovy de Mitcheson et al. 2012). Small-scale fisheries, like many fisheries in the Philippines, are vital for millions of people for both their livelihoods and food security (Sadovy de Mitcheson et al. 2012). Groupers, snappers and wrasses are becoming increasingly rare on coral reefs as a result of over-fishing and so there is now a shift to fish further down the food web, meaning that fish at all trophic levels are now at major risk (Comeros-Raynal et al. 2012).

Three target families were looked at in detail for the purpose of this study and the justification for this is detailed below.

2.6.1 *Groupers*

Groupers are a particularly important predatory fish, both commercially and ecologically (Morris, Roberts and Hawkins 2000; Sadovy de Mitcheson et al. 2012). As one of the top predators on coral reefs (Morris, Roberts and Hawkins 2000), they play a huge part in regulating the abundance of smaller fish (Sadovy de Mitcheson et al. 2012) and so regulate the reef ecosystem.

Groupers are vulnerable to fishing pressure and over-exploitation due to their life strategies; late sexual maturation (5-10 years), long-life span (1-4 decades), slow growth rate and ability to reach large sizes (Morris, Roberts and Hawkins 2000; Sadovy de Mitcheson et al. 2012). They also often exhibit territorialism and form large spawning aggregations which makes it easy for fishermen to target them (Morris, Roberts and Hawkins 2000; Sadovy de Mitcheson et al. 2012).

Out of 163 Grouper species, if current over-exploitation trends continue, 20 species are at risk of extinction and a further 22 species are considered 'Near Threatened' (Sadovy de Mitcheson et al. 2012). This demonstrates the need to address the problem of over-exploitation and assess whether management practices such as MPAs do achieve their goals of increasing species abundance and biomass (Sadovy de Mitcheson et al. 2012). Initially, only large groupers were considered economically important but as such a huge proportion of these have been fished out, smaller species are now being targeted and so the threat to the family is ever increasing (Sadovy de Mitcheson et al. 2012).

With the Philippine population having such a high dependence on fish (Nanola, Alino and Carpenter 2011; Horigue et al. 2012), the overexploitation of this family could end in huge detrimental impacts for an extremely large proportion of the Philippine population. Providing a successful management technique and determining its implications in the long run are therefore extremely necessary.

2.6.2 *Parrotfish and surgeonfish*

Parrotfish are important prey for fish such as groupers, barracuda and large snappers (Hughes et al. 2007). They also regulate the dynamics of tropical reefs in terms of grazing seaweed and eroding dead corals so that the reef does not get overridden by a dominant species, such as macroalgae (Hughes et al. 2007). A reduction of herbivores such as parrotfish and surgeonfish can result in a shift from coral dominance to macroalgae-dominance, providing many problems for the coral reef inhabitants (Moberg and Folke 1999).

Like parrotfish, surgeonfish also play a major role in regulating the growth of primary producers and detrital matter (Comeros-Raynal et al. 2012). When grazing by fish is reduced, corals can become smothered in algae blooms and so the balance of the whole habitat is thrown (Hughes et al. 2007). These two fish families are one of the most dominant groups on coral reefs and so reduced numbers can have huge and often extremely detrimental impacts (Comeros-Raynal et al. 2012).

Along with playing such a huge ecological role, parrotfish and surgeonfish are also heavily fished as a result of human dependence on them for food, especially in the Coral Triangle, which includes the Philippines (Comeros-Raynal et al. 2012). As a result of increased removal of top predators, such as grouper, there has been an increase in the removal of parrotfish for food, highlighting the need to monitor and manage the recovery of these species (Comeros-Raynal et al. 2012). This again links to the high dependence of the Filipino's on fish and so managing these resources effectively is essential.

2.7 **Overall MPA Contribution to Marine Biodiversity**

For habitat specific fish, generally those associated with coral and temperate reefs, MPAs have been shown to be effective in protecting sensitive habitats (Willis, Millar and Babcock 2003). Lowry, White and Christie (2009) combined evidence that showed for some MPAs in the Philippines, there are also additional benefits to the locals as a result of protecting their marine ecosystems. Alongside fishery enhancement, this includes development in tourism which increases livelihood opportunities.

Results show that MPAs that are well established and have been present for long periods of time have higher success rates in increasing biodiversity and abundance as a result of the long life span, in some cases 40 years, of some commercially targeted species (Halpern 2003). These species usually also have slow reproductive rates and therefore it takes a long time for their numbers to

increase once the MPA has been established (Morris, Roberts and Hawkins 2000; Sadovy de Mitcheson et al. 2012).

Whether or not a species is benefited by a reserve can depend upon whether or not it spends a large proportion of its life within that reserve, and the species that generally benefit most spend a significant section of their life there (Gell and Roberts 2003). This has led to beliefs that only sedentary fish will benefit from MPA employment but a study from Willis, Parsons and Babcock (2001) provided evidence on the contrary. They presented evidence showing that there was an increase in the proportion of these mobile fish within the reserve. As many reef fish are not sedentary, MPAs having a positive impact even on these species shows very beneficial outcomes as a result of MPA implementation. It is the success of these areas in the long term that needs to be determined and this is what this study will conclude.

3 Methodology

3.1 Data Collection

The data used was secondary data collected by the organisation Coral Cay Conservation (CCC). The data collection method was as follows:

A series of plot-less transects were set perpendicular to the coral reef, starting at a depth of 24m and extending to the reef crest, or where the reef became very shallow, below 0.5m. Fifteen target reef families were identified but for the purpose of this study, only three families were looked at in detail. These fish were recorded if seen 2.5m either side of the transect line.

3.1.1 Justification

Mumby et al. (1995) carried out a study measuring the efficacy of organisations, such as CCC, using data collected by volunteers to assess the effectiveness of MPAs. Within this study, many parameters were tested to assess to what extent the volunteer collected data provided accurate results. Variables such as identification accuracy, consistency and identification percentage were used and it was concluded that there was sufficient correlation between volunteer and staff collected data to confirm that the data sets were of sufficient standard. This however did assume that the data collected by the staff was of the appropriate quality but for the purpose of this study, the assessment of the data collection by (Mumby et al. 1995) proved it to be of satisfactory standard.

Harding, Lowery and Oakley (2003) also carried out a study to assess the use of volunteers in coral reef surveys. Their assessment also came to the same conclusions as Mumby et al. (1995) and they commented that with the correct training and assessment, volunteer data collection could result in large and suitably accurate data sets at little cost.

In terms of the data collection, Hill and Wilkinson (2004) provided advice for managers of coral reefs on the best monitoring method to take. For the data collection used for this study, looking at their suggestions of various different methods for various situations, the method chosen is the most suitable. Line transects are suitable for medium scale studies and visual census methods are good for fishery-independent studies, which the Napantao MPA study is. The transect line is permanent which is beneficial for long-term monitoring as it provides consistent, repeatable and generally reliable data. For highly mobile fish, Hill and Wilkinson (2004) suggest undertaking quarterly surveys. The majority of this study's data was collected between September and October, and so as the data for this study was not collected throughout the year, behavioural differences within the fish families could present some bias as to the overall effect that MPAs have.

Transects with a 50m length and 5m width, which were used, are preferential to monitor more mobile fish, such as groupers, parrotfish and surgeonfish (Hill and Wilkinson 2004). They have also been proved to be a successful method to quantify the community composition and abundance of fish within the area (Hill and Wilkinson 2004).

The main limitations associated with this study include observer error and inadequate training in identification combined with presence of the divers possibly attracting or scaring the fish.

3.2 Statistical Analysis

The data presented was count data for 15 fish families across 2008 and 2012 from a number of transect replicas, 27 and 33 respectively. The analysis looked at any changes between 2008 and 2012 in terms of abundance, diversity and size, concentrating on three main fish families: grouper, parrotfish and surgeonfish.

3.2.1 Paired t-test

To answer objective 1, a paired t-test was used to determine whether or not there was a significant difference in the abundance of fish in 2008 compared to in 2012. The data collected was from the same site over different years comparing the same fish families. A t-test was therefore used as

each measurement from 2008 could be paired to a measurement in 2012 testing whether or not the two samples have the same mean (Townend 2002). For the statistical test to show a significant difference, the P value should be equal to or less than 0.05. Anything above this will show that there is not a significant difference between the data sets that are being tested (Townend 2012).

3.2.2 *Shannon-Weiner*

A Shannon-Weiner diversity index was carried out to test if there was a significant difference in the diversity of fish as the MPA aged, objective 2.

$$H' = \sum p_i \ln(p_i)$$

An overall diversity index was calculated for each of the four years and then a series of indices were calculated for each transect in 2008 and 2012. This was so a t-test could be carried out in order to determine whether or not any changes in diversity between 2008 and 2012 were significant or not.

3.2.3 *Chi-Square*

To show if there were any changes in the size of fish in certain families, objective 3, a Chi-Square test was undertaken. This test was chosen to assess whether or not the proportion of fish in certain size categories changed from 2008 to 2012 (Townend 2012). By using the observed values for each year, the values that were expected to be seen could be calculated, and from this it could be determined as to whether or not there was a significant difference between the two data sets.

$$\chi^2 = \sum \frac{(o - e)^2}{e}$$

4 **Results**

The following section presents the results found when the statistical tests, outlined in section 3, were performed. It is broken down into the objectives that were stated at the beginning of this work. Abundance will be displayed first, followed by diversity and finally size.

4.1 Abundance

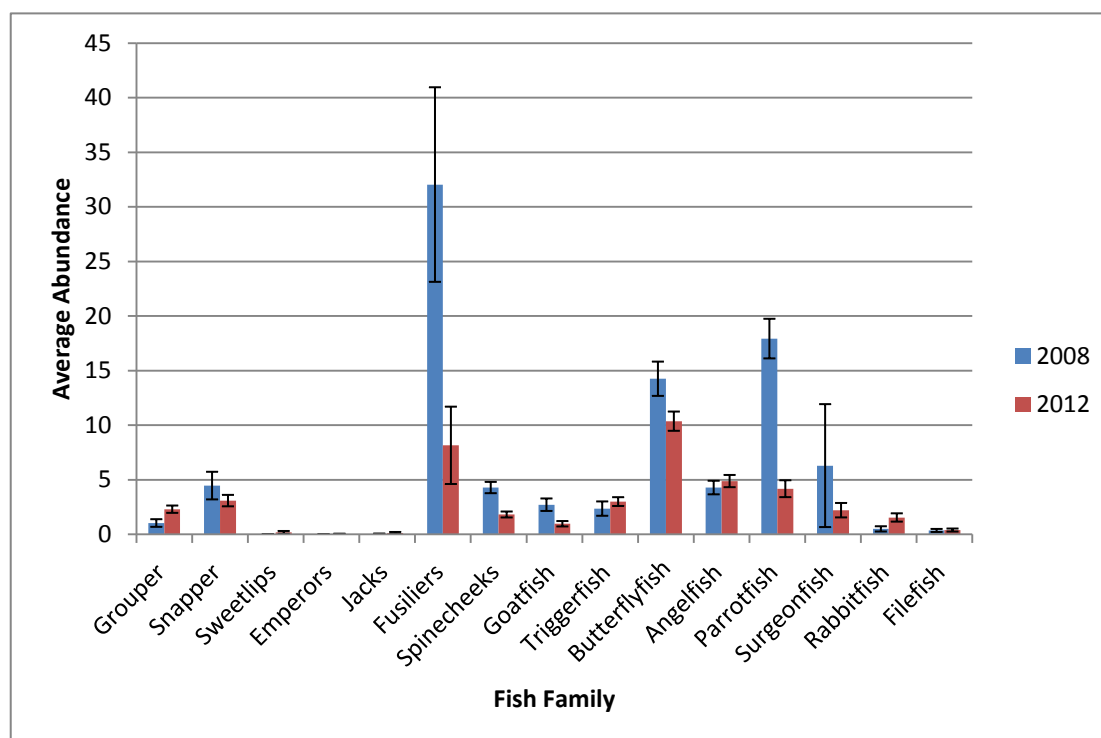


Figure 2. Difference in abundance between 2008 and 2012 across all the 15 fish families

There was no significant difference between the average abundance of all fish in 2008 compared to 2012 ($p=0.172$), although figure 2 does suggest that there is generally higher abundance across the fish families in 2008.

4.1.1 Grouper

Figure 2 shows that in 2012 there is a slightly higher average abundance of grouper in comparison to 2008, 2.303 and 1.036 respectively. There is a significant difference between these two data sets showing that the increase in grouper abundance is not due to chance ($p=0.011$). This indicates that the MPA is still having an impact on increasing the abundance of grouper even after it has been established for a long period of time.

4.1.2 Parrotfish

There is a large difference in parrotfish abundance between the two years with 2008 having higher numbers, as seen on figure 2. This difference is significant showing that there is a higher abundance of parrotfish in 2008 compared to 2012 ($p<0.001$). This demonstrates that when the MPA has been established for a longer period of time, a decrease in parrotfish abundance is seen.

4.1.3 Surgeonfish

Figure 2 shows there are more surgeonfish in 2008 compared to 2012 but this difference is not significant and therefore could be due to chance ($p=0.066$). The MPA is therefore not having an affect on surgeonfish abundance as it ages.

4.2 Diversity

When a Shannon-Weiner diversity index was carried out across all families and years, the general trend showed an increase in diversity from 2008 to 2012. Figure 3 shows that although there is an overall increase in diversity from 2008-2012 there is a large decrease in diversity between 2008 and 2010. Aside from this however, a paired t-test gave a significant result ($p=0.013$) for the diversity between 2008 and 2012, demonstrating that there is an increase in diversity from 2008-2012. From figure 4 it can be seen that the diversity across the majority of transects was higher in 2012 in comparison to 2008. The overall Shannon-Weiner diversity index value from across all the transects reflects 2012 being higher in diversity, with 2012 showing a diversity result of $H'=2.236$ and in 2008 $H'=1.932$.

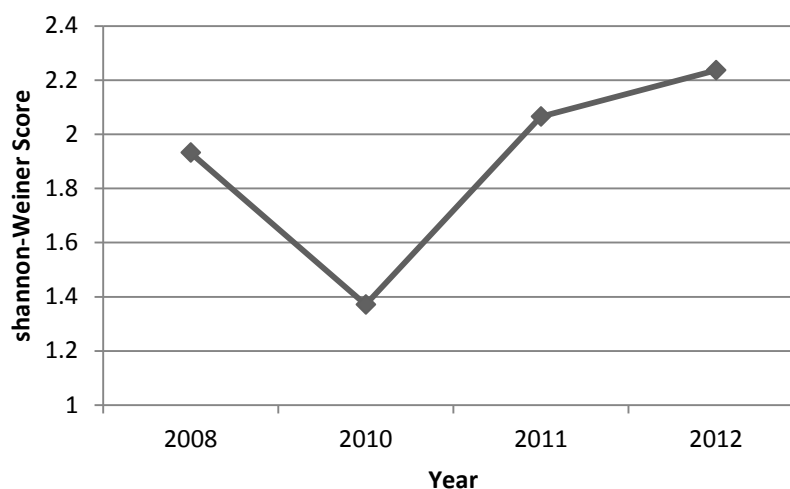


Figure 3. Trend in Shannon-Weiner diversity score for the years 2008, 2010, 2011 and 2012

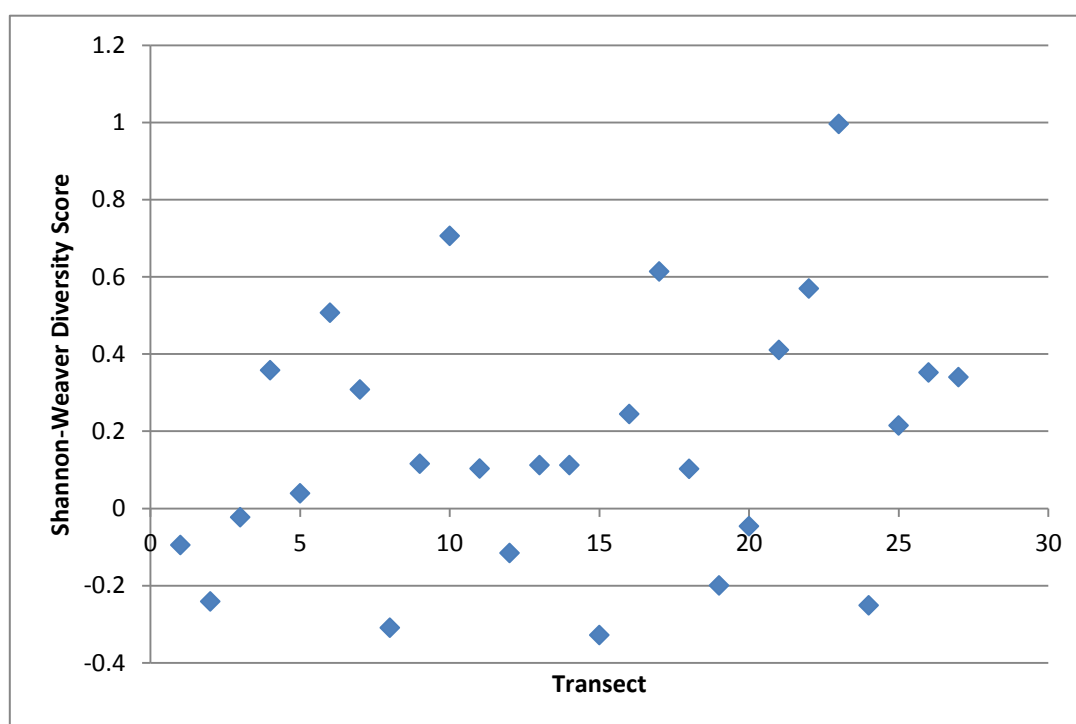


Figure 4. Difference between the Shannon-Weiner biodiversity index value from 2008 to 2012

The diversity within the MPA increases from 2008 to 2012 and there is a significant difference in the higher biodiversity value for 2012. As the MPA increases with age, so does the diversity within it.

4.3 Fish Size

The difference in abundance of fish in each size category for the selected families was not uniform across these three families and across the years. For grouper, the MPA favoured the middle categories, for parrotfish it favoured smaller fish and finally for surgeonfish it resulted in a larger range of size.

4.3.1 Grouper

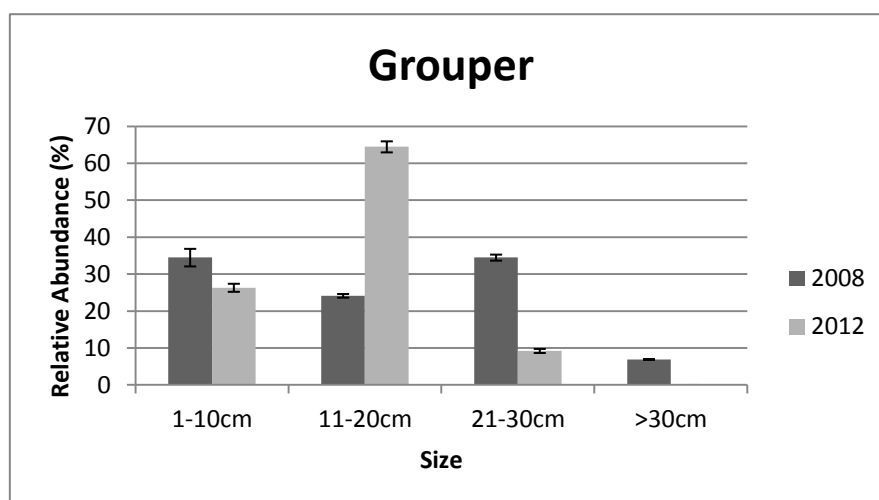


Figure 5. Relative abundance of groupers in each size category for 2008 and 2012

The Chi-Square test shows a significant difference between the categories of fish size between 2008 and 2012 ($p < 0.001$). This result must be treated with caution however as there were more than 20% of the values below 5. From figure 5 it can be seen that in all the categories, apart from 11-20cm, there is a greater relative abundance of groupers in 2008 compared to 2012 and there are no groupers in 2012 above 30cm. The graph demonstrates that in 2008 there was a more even size distribution of grouper in comparison to 2012, which is dominated by fish size 11-20cm (fig. 5). This shows that for the grouper family, the MPA has heavily favoured fish in the middle size category.

4.3.2 Parrotfish

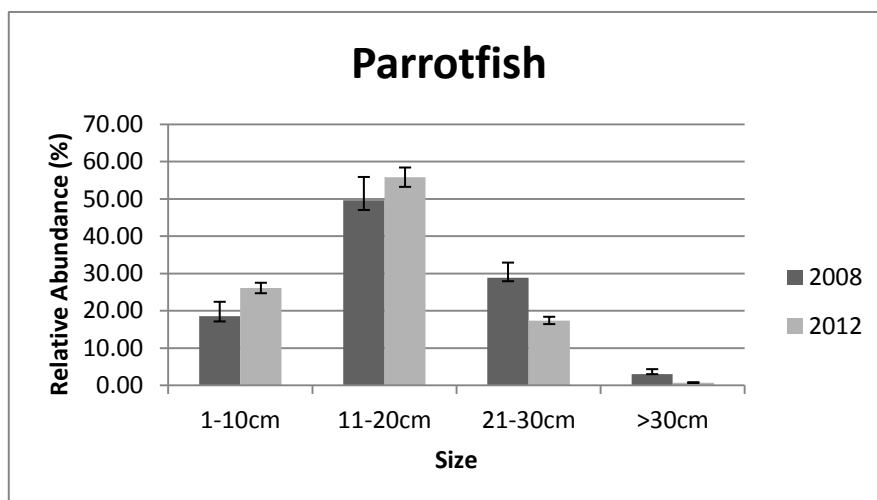


Figure 6. Relative abundance of parrotfish in each size category for 2008 and 2012

When the Chi-Square test was carried out on the parrotfish family, there were less than 20% of the values below 5 and therefore the test results are much more likely to be reliable compared to the grouper family. As the p value it is less than 0.05 and therefore the two data sets, 2008 and 2012, are significantly different ($p = 0.009$). Figure 6 shows that as the MPA gets older, in 2012, there are more parrotfish in the smaller size categories. There are more groupers over 21cm in 2008 compared to 2012 showing that as the MPA ages, the proportion of parrotfish in the larger size categories decreases.

4.3.3 Surgeonfish

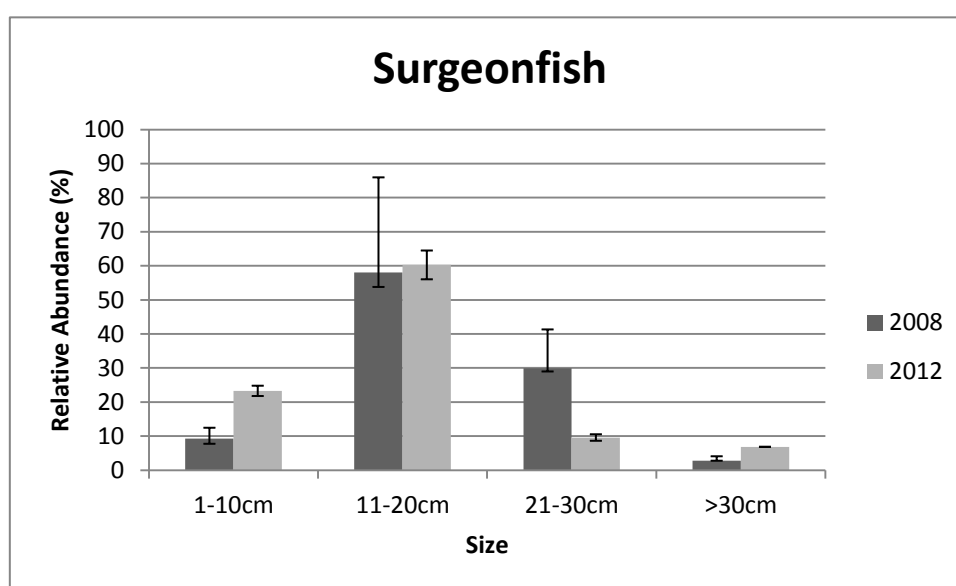


Figure 7. Relative abundance of surgeonfish in each size category for 2008 and 2012

Figure 7 shows that in the 11-20cm category, there is very little difference between 2008 and 2012 in the abundance of surgeonfish but there is a large standard error in the 2008 data set. For this family, there is a higher abundance at both ends of the scale in 2012 compared to 2008. There is a significant difference in the proportion of individuals within the size categories ($p < 0.001$). This shows that as the MPA gets older, there are more juveniles and older, larger fish.

4.4 Summary of Results

The results from the Napantao MPA between 2008 and 2012 show that there was no significant difference in abundance between the two years, that there was a significant increase in species diversity to 2012 and that the impact that the MPA had on individual fish size was varied across the three analysed families.

5 Discussion

MPAs are set up with the aim of increasing fish abundance, diversity and size (Sumaila 2010). The overall abundance and diversity from this study takes into account all fish families. As each family takes a different period of time to recover from population decrease, different responses will be seen in response to MPA implementation across families and over time.

Once the MPA has reached its carrying capacity, it cannot sustain any further increase in fish numbers. As there is no significant difference between 2008 and 2012 in terms of fish abundance, this is a possible explanation. Other factors such as sampling error and a small distribution of years to assess could also provide explanations to this. There is however a significant difference in diversity between the two years, showing there are changes to the population dynamics within the protected area. There are also changes in the size of fish in certain families from 2008-2012 showing that not all families respond in the same way to MPA employment.

As the debate over whether or not MPAs are the correct management path to take is very important, especially to the local communities, it is vital to understand the impact that smaller MPAs have over a long period of time. Regarding this, the literature states that there are mixed results for the success of MPAs (Kaiser 2005; Lowry, White and Christie 2009; Horigue et al. 2012). This means studies such as this one are needed to gain a wider understanding of the longer term impacts on factors such as fish diversity, fish abundance and fish size.

5.1 Abundance

Objective: Investigate the impact that the Napantao MPA on fish abundance from 2008-2012

The Napantao MPA was put into practice in 1996 and studies by (Halpern and Warner 2002) suggest that there is generally rapid recovery after reef closure. Rapid recovery could explain why there is no increase in fish abundance from 2008-2012; the ecosystem could have reached its carrying capacity.

An ecosystem can only carry a certain number of individuals before there are too many for the resources available to sustain them all (Oxford Dictionaries 2013). Since the protection of marine resources has been shown to increase the number of fish individuals (Lowry, White and Christie 2009), and although population recovery may take decades (Russ, Alcala and Maypa 2003), as there is no significant difference in abundance between 2008 and 2012, the carrying capacity having been reached is likely to be the case.

When fishing activity is high, smaller bodied fish that are unattractive to fishers are likely to dominate. Once an MPA is put into practice, fish such as grouper are able to increase in number (Mosquera et al. 2000). As a result of this the number of predators in the area will increase, decreasing the numbers of the low trophic level fish. This means that there will not be a change in the overall abundance of the fish within the reserve, but a change in the population dynamics.

Another explanation could stem from natural variation of numbers within the fish community. As abundance was only looked at for two years, a trend cannot be seen from the date of implementation and so natural variation cannot be discounted.

5.2 Diversity Changes

Objective: To assess whether species diversity changes from 2008-2012

When fishing occurs particular families are targeted and so there is a loss of diversity (Christie, White and Deguit 2002; Bundy 2004). Once fishing ceases, the fish are able to recover but not all fish families have the same recovery times and so it will take a substantial period of time before the population reaches equilibrium. As some families take long periods of time to recover from high exploitation, generally top predators (McClanahan 2000; Russ et al. 2004), these increase in number after longer protection times. Fish that have fast recovery rates will initially dominate and will then later be replaced by the fish families that recover and increase in abundance more slowly, altering the diversity.

The general trend showing an increase in species diversity from 2008 to 2012 is in accordance with the change in population dynamics but it does not explain why there is a dramatic drop in diversity in 2010. This decreased diversity is likely to be as a result of natural variation. As there are only a few years that have been sampled, it cannot be seen whether or not this drop is part of a natural cycle of diversity or natural diversity fluctuations, but natural variation is the most likely cause for the steep drop and then the increase back up to 2011 and 2012.

Maintaining a high level of marine biodiversity is vital. This is because with a decrease in biodiversity comes many environmental issues including a reduced food production, reduced water quality and a reduction in the ocean's ability to cope with changes (Worm et al. 2006). In terms of the wider issue of maintaining global biodiversity and marine stability, if the biodiversity of these marine systems are allowed to drop significantly then there could be widespread ecosystem effects that are felt far away from the original source. Worm et al. (2006) links

biodiversity loss with ecosystem services loss, which would in turn can have huge detrimental impacts on the vast population that relies on marine systems for their livelihoods.

The MPA in Napantao showing an increase in biodiversity is a very positive outcome in respect to maintaining and increasing marine biodiversity. The work by Anticamara, Zeller and Vincent (2010) noting that diversity increases with MPA age is in accordance with the Napantao study. This therefore provides more evidence for the longer term positive outcomes that result due to protecting marine resources.

5.3 Size Distribution Changes

Objective: To determine whether there is a significant change in fish size over the study period

Studies by Roberts and Polunin (1993) and Anticamara, Zeller and Vincent (2010) suggested that with longer protection of the reef, there would be a higher proportion of larger fish. These propositions are in accordance with the study carried out by Stockwell et al. (2009), who observed that only the oldest MPAs contained parrotfish and surgeonfish above 35cm, and after 12 years of protection, the biomass of these herbivorous fish was still increasing exponentially. In contrast, the work undertaken by (Alcala et al. 2005) showed that over the 19 year protection period, the overall biomass increase was not consistent. In their study, for the second half of protection there was no significant increase in biomass. Although in Napantao smaller fish sizes are being seen, the study by Alcala et al. (2005) related much more to the Napantao findings.

The idea presented by Abesamis and Russ (2005) and Maypa et al. (2012a) concerning density dependent movement is a possible explanation regarding there being a higher abundance of fish in the smaller size categories. If there is space limitation as a result of there being more large bodied fish, then these larger fish are likely to move out of the MPA to the surrounding waters through spill-over. This will then leave a higher proportion of smaller bodied fish within the MPA boundaries.

Aside from specific family characteristics that could result in these changes, there are two other possibilities that could explain these results. The work by Hixon and Carr (1997) proposing strong, natural variation in the year to year recruitment of fish juveniles could be an explanation for the decrease in larger bodied individuals from 2008 to 2012. Sampling error is another possible reason for the decrease in fish size. Although there is evidence suggesting that volunteer collected data is of sufficient standard to provide reliable results for this kind of study (Mumby et al. 1995; Harding, Lowery and Oakley 2003), there could still be data collection errors surrounding the

estimates of fish size. This could have resulted in errors in overestimating or underestimating the size of the fish across the years and so providing results that may not be representative of the fish population with the Napantao MPA.

As a result of not having a long data set and only comparing 2008-2012, it cannot be seen whether changes in size are a trend or an anomaly and therefore this cannot be discounted as an explanation as to why fish seem to be decreasing in size.

If the results presented in this study concerning fish size are representative of the reef then this provides some interesting consequences for the success of MPAs. MPAs are implemented with the aim to increase fish biomass (Lowry, White and Christie 2009) and so if this is a indicator for MPA success, then in this case the Napantao MPA is failing to reach it's targets. This being said however, this may be as a result of natural variation within the ecosystem or due to human error.

5.4 Specific Family Changes

Each of the target families chosen for this study responds differently to MPA implementation due to their different life history characteristics. These characteristics can help explain a number of different factors such as why numbers of groupers are increasing even though the overall abundance has remained constant and why the MPA is favouring parrotfish in the smaller size categories. In terms of worldwide marine protection, this emphasises the argument made by Kaiser (2005) who said that although MPAs may show successes in some areas, they are not the solution to every conservation issue.

An argument presented by Christie, White and Deguit (2002) suggested that having an MPA that was too small could result in a decrease in target fish. This point again highlights the need for a more detailed assessment of the impact that small small-scale MPAs have in the long run to determine whether they are in fact having the positive outcomes that is expected of them.

5.4.1 Grouper

The results concerning the abundance of grouper showing a significant increase in numbers, even after the MPA had been in effect for 16 years, can be attributed to the life characteristics of the grouper family. Their late sexual maturation (Morris, Roberts and Hawkins 2000; Sadovy de Mitcheson et al. 2012) means that it takes a long time for each fish to reach an age where they are able to reproduce and so increasing their abundance is a slow process. This slow re-establishment is heightened due to them being so attractive to fishers as a result of their high economic value

(Samoilys et al. 2007), resulting in over exploitation and so extremely low initial numbers. As they have been so overfished, low numbers result in it taking a long time for the population to increase and so as a result of a combination of heavily reduced numbers and late sexual maturity, the grouper population is still re-establishing a long time after the initial reef closure.

Due to their predatory nature, an environment where their prey is highly available, assuming other conditions are also in their favour, is likely to aid grouper reestablishment. As parrotfish, one of the grouper's prey, is in high abundance in 2008, there is a plentiful food supply for the groupers. This is therefore likely to assist in increasing the abundance of grouper in 2012.

The change in grouper size however is not in accordance with what is expected. As a result of their long life span and slow growth rate (Morris, Roberts and Hawkins 2000; Sadovy de Mitcheson et al. 2012), it can be expected that as the MPA ages, grouper size increases. Groupers have the ability to grow to over 1 meter in length (Sadovy de Mitcheson et al. 2012) and so as there is not an increase in the proportion of fish in the higher abundance categories as the MPA ages, there must be other factors that cause these results to be seen.

Natural variability or human observer error are again likely reasons to explain these results as there is little evidence in the literature that justifies why there is an apparent decrease in the amount of grouper that are reaching the larger size categories.

In terms of marine management, an increase in grouper abundance is a very promising outcome for MPA success as there is major concern over the increasing rarity of these fish due to human consumption (Comeros-Raynal et al. 2012). In 2012 there is not a greater proportion of fish over 30cm in length but there is also only a limited selection of years to base this on. It therefore cannot be known whether or not this is a fluctuation in the data and so whether or not it is a correct indication of MPA function worldwide cannot be determined.

5.4.2 *Parrotfish*

The decrease in parrotfish from 2008 and 2012 can in part be explained as a result of the increase in predators, such as grouper. As parrotfish are prey to these families, groupers are in the top trophic level (Samoilys et al. 2007), as the abundance of these predatory fish increases, so it can be expected that the abundance of fish within prey families will decrease.

Fishing pressure outside of the reserve could also be a reason for the decrease in parrotfish abundance. As a result of there being less top predators and so more families such as parrotfish

being targeted (Comeros-Raynal et al. 2012), as fishing is not restricted in the areas adjacent to the MPA, parrotfish are at risk from this change in target preference.

A study undertaken in the Philippines by Stockwell et al. (2009) gave evidence for parrotfish populations showing a high proportion of recovery within 5 years of MPA implementation. When a Ricker model was used for the abundance of parrotfish, the results showed that up until roughly the 7th or 8th year there was an increase in abundance but this was then followed by a gradual decline. This is in accordance with this Napantao MPA study because although there is no data presented showing what has happened before 2008, 12 years after the MPA was first established there was a significant decline in parrotfish abundance to 2012. This is further enhanced through work by McClanahan et al. (2007) and Stockwell et al. (2009) that presented evidence for parrotfish reaching their carrying capacity 7-12 years after protection of the area. This shows that although parrotfish abundance has decreased with time, this is what has been seen in other studies and is what was expected.

The Napantao MPA showing a decrease in average size from 2008 to 2012, like for grouper, again is not in accordance with the literature. Parrotfish generally live for under 20 years, have reasonably fast population turnover rates (Choat and Robertson 2002; Stockwell et al. 2009) and initially have a rapid growth rate (Choat and Axe 1996). Once the area had stopped being fished, the parrotfish population would have been able to re-establish and therefore increase in numbers (Stockwell et al. 2009). As the MPA has now been in action for 16 years, the parrotfish population is likely to have reached equilibrium and therefore it would be expected to see a constant distribution of parrotfish across the size categories from 2008 to 2012.

In respect to using MPAs as a management resource, the decrease in parrotfish abundance represents that there is an increase in top predators on the reef, showing management success, but the decrease in parrotfish size was not expected and so more research needs to be undertaken to determine the cause of this.

5.4.3 Surgeonfish

Like parrotfish, surgeonfish are prey to fish at higher trophic levels such as grouper (Samoilys et al. 2007) and a decrease in surgeonfish numbers can be expected as the numbers of these predators increases. The difference between 2008 and 2012 in surgeonfish abundance was not significant but from figure 2 it can be seen that there is a smaller abundance in 2012 in comparison to 2008.

In studies undertaken in the Philippines by Russ et al. (2004) and Stockwell et al. (2009) it was demonstrated that the recovery of surgeonfish was slower than that of parrotfish with recovery occurring after 8 and 4 years respectively. Alcala et al. (2005) also described surgeonfish as long-lived with low recruitment and natural mortality rates. Stockwell et al. (2009) saw surgeonfish abundance increase exponentially up until the twelfth year of the study. Their study however does not show results past 12 years of protection and so they do not provide any evidence for what happens to surgeonfish abundance after that time.

The study by Russ et al. (2004) also showed different results to this Napantao study in that for their reserve, for the 18 years of assessed protection, the biomass of surgeonfish increase by 3 times. If this is used to predict the outcomes of the Napantao study then there should have been an increase between 2008 and 2012, and although the decrease seen on figure 2 was not significant, the results do not demonstrate the increase that would have been expected.

As the results for the Napantao MPA are not in accordance with other studies in the area in terms of abundance increase, there is the possibility that this management technique is simply not working for this family. Another reason that could explain this trend is natural variability in the dynamics of the surgeonfish population. Hixon and Carr (1997) commented that there is strong variation in the year to year recruitment of juveniles and so there could have been a poor year for juveniles previous to the data collection in 2012 which would have decreased the abundance.

In respect to size distribution, in 2012 there is a more even distribution compared to in 2008, with more surgeonfish at both ends of the scale. Unlike the size results for the grouper and parrotfish families, this correlates much better with the literature concerning the reestablishment of surgeonfish populations. As population recovery of surgeonfish is relatively slow (Russ et al. 2004; Alcala et al. 2005), it can be expected that an increase in size will still be seen long periods of time after reef closure. Like parrotfish, as prey to grouper, the larger fish will have been taken as prey and so resulting in the smaller, juvenile fish taking up a larger proportion of the overall surgeonfish abundance.

6 Limitations and Further Study

Although sufficient analysis was carried out to answer the aims and objectives set out by this study, the associated limitations revolve around the data that was available for analysis.

- To discount natural variation and to see natural population fluctuations within the MPA, data encompassing all the years from implementation to the current date would be required.
- For the grouper family in particular, a larger data set is required to increase the validity of the statistical tests used to determine changes in fish size.
- A larger data set would also reduce the risk of skewed data as a result of observer error.
- The data provided was mainly only collected through September and October and so to gain a wider and more comprehensive understanding of the implications of the MPA throughout the year, data sets taken on a quarterly basis, as suggested by Hill and Wilkinson (2004), would be required.
- Other physical factors such as weather and climate would need to be considered in order to understand the wider factors that could influence the MPA.

The assessments and observations revolving around the success of MPAs need constant revaluation due to the consistent changes that are seen within ecosystem populations. To fully quantify the success of marine protected areas in the long term, regular surveys need to be taken throughout the year on a consecutive basis to get a full understanding of the process occurring. Further work to gain a broader and more global understanding of the impact of small-scale MPAs, would include comprehensive studies carried out from initial implementation over a long period of time to assess the changes in dynamics with age.

7 Conclusions

The literature demonstrates how important marine ecosystems are to the local communities that depend on them, as well as to the global population. Protection mechanisms are therefore needed to minimise and potentially reverse the damaging impacts that humans have had on them, so that they are not lost forever.

Marine protected areas have been praised for their conservation attributes, yet it is not always the case that success is seen from them. In response to this, assessments of existing MPAs need to be undertaken, with particular attention to the impacts that they have in the long term. The MPA in Napantao is a prime example of the need for more studies. This is because the results produced from analysis of the reserve did not fully correspond with what is expected from the literature, although the overall outcome showed positive results.

With respect to the aim to determine the impact that the Napantao MPA has on fish communities, although factors such as natural variability and human error could have impacted the results, the overall conclusion reached is that the MPA is showing conservational success. Although there is no increase in abundance from 2008-2012, this is expected and so demonstrates that the ecosystem has reached equilibrium. The increase in diversity is very promising as it shows the MPA is having positive affects on a diverse range of fish families, and not just favouring one resulting in ecosystem imbalance. Although the analysis showed the MPA to be favouring fish in the smaller size categories, this can largely be attributed to observer error and natural variability and so does not detract from the overall positive outcomes from the Napantao MPA.

To fully quantify whether or not MPAs are the most successful management tool, further research needs to be undertaken. Overall, for small-scale marine conservation, this study adds to the literature showing positive results from marine protection.

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