

Coral reef biodiversity and ecosystem resilience in a community based marine protected area post hurricane event

Abstract

Coral reefs are facing unprecedented change on a global scale. The synergistic nature of anthropogenic stressors, those linked to climate change and localised pressures such as fishing, threaten the biological diversity of these ecosystems. Understanding the interactions of these disturbances is a key element in the future conservation of coral reefs, which represent some of the most ecologically and socio-economically vital habitats on Earth. This study considered a data set spanning seven years to investigate whether a community based marine protected area in the rural Philippines improves biodiversity and consequently coral reef resilience against disturbance, with particular interest in year's pre and post a major hurricane event. Univariate and multivariate measures of the diversity of coral reef biota and assemblage composition were analysed to determine temporal and spatial variation in the overall assemblage of reef organisms, including specific indicator taxa. Results showed that the mean percentage cover of hard corals was significantly higher inside the marine protected area across the years and that the protected area successfully promoted a higher level of richness, diversity and abundance of reef fish, although in the case of butterflyfish (an indicator organism) despite a positive trend, the effect of the MPA was not strong enough to show statistical significance in three out of four diversity measures. Significant differences were found in the overall assemblage composition for all taxa inside compared to outside the MPA yet no significant difference was seen in assemblage in the year's pre and post the hurricane event. The only notable variation in pattern followed a change in survey methodology by the managing organisation. Despite this the local conservation benefits of the MPA are apparent, although further research will be required to establish whether the MPA can contribute to broader scale biodiversity protection objectives.

Keywords: coral reef, community based MPA, hurricane, disturbance, resilience, diversity, conservation, Philippines.

31 Introduction

32 Situated in the heart of the Coral Triangle, the Philippines archipelago is recognised as a
33 global priority for marine conservation (Veron et al. 2009, Weeks et al. 2010). It is an area of
34 dense human population with many coastal communities relying heavily on fishing for
35 income and food security (Cabral et al. 2013). Coral reefs support fisheries that millions of
36 people depend upon (Cruz-Trinidad et al. 2014), but low lying coastal regions in the tropics
37 are some of the areas predicted to be most heavily impacted by climate change and associated
38 extreme weather events (McGranahan et al. 2007). Anthropogenic stressors have been shown
39 to reduce coral cover and associated diversity worldwide (Ainsworth & Mumby 2015) and
40 with marine biodiversity in decline on a global scale and the subsequent reduction of vital
41 ecosystem services (Worm et al. 2006), successfully managing and sustaining ecologically
42 and economically important habitats such as coral reefs is becoming ever more imperative.
43 The intensity of tropical storms and cyclones is predicted to increase in the face of global
44 climate change (Emmanuel 2005); therefore understanding the mechanisms by which large
45 scale anthropogenic impacts act in synergy with local pressures such as overfishing to affect
46 coral reefs is critical in order to effectively manage marine resources for the future
47 (Blackwood et al. 2011).

48 Typhoon Yolanda, which struck in November 2013, was one of the most powerful tropical
49 storms on record and the most deadly and destructive ever to hit the Philippines (UNICEF
50 2014). This study uses a community based marine protected area (MPA) in Southern Leyte,
51 approximately 160 km south of the capital Tacloban where the eye of the storm struck, to
52 assess the ability of an MPA to increase overall biodiversity of a coral reef, this diversity will
53 be used to infer maintained resilience of the ecosystem against disturbance. Biological
54 diversity has been identified as a key component of ecosystem resilience (Tilman et al. 1996,
55 Peterson et al. 1998) and changes in this biodiversity can alter responses to environmental
56 perturbation, potentially with profound consequences for ecosystem services that support
57 human well-being (Chapin et al. 2000). Therefore, managing the resilience of ecosystems is
58 becoming a central focus in conservation planning, particularly in response to global climate
59 change (Mumby et al. 2013). Ecological resilience is generally defined as the ability of a
60 system to remain within its region of stability before a tipping point is reached where it
61 alternates to another state (Holling 1973). Coral reefs have been frequently cited as
62 alternating between coral dominated healthy states, and algal dominated states that reduce
63 ecosystem function and productivity (Hughes et al. 2003, Mumby et al. 2013). These “phase

shifts” from a healthy to an algae dominated reef system are accompanied by loss of coral cover and diversity of associated reef organisms, affecting the livelihoods of the people relying on the ecosystem services of coral reefs (Ainsworth & Mumby 2015). Community based MPAs have become a popular management tool for coastal resources in the Philippines (Horigue et al. 2012) and are often advocated as the most effective means of conserving over exploited coastal habitats in developing tropical countries, however there is evidence to suggest that only around 20-25% of MPAs in the Philippines are successful (Pollnac et al. 2001). In light of this information evaluating the effectiveness of these management systems to strengthen biodiversity and consequently the resilience of threatened ecosystems is essential.

MPAs are often used in an attempt to control the adverse effects of anthropogenic stressors such as overfishing on coral reef habitats (Ladd & Collado-Vides 2013). There is suggestion that MPAs can promote the resilience of coral reefs by preserving herbivorous fish species (Game et al. 2009), reducing competitive exclusion of corals by algae which in turn increases coral abundance and diversity (Lirman 2001). Herbivory prevents the proliferation of algae that otherwise outcompetes the reef building corals affecting their settlement, growth and survivorship (Adam et al. 2015); the subsequent reduction in algal cover generated by herbivores creates more space for coral recruits to settle after a disturbance (Hughes 1994) resulting in a higher diversity of structurally complex coral habitat and associated species (Verges et al. 2011). Edwards et al. (2011) have previously illustrated that coral reefs can maintain themselves under all levels of hurricane disturbance provided that grazing levels remain high. The ‘diversity–stability hypothesis’ states that higher species diversity within biological communities buffers the risk of ecological collapse (MacArthur 1955, Mellin et al. 2014); therefore MPAs may afford coral reefs resilience against large scale disturbance events if they succeed in mitigating the impacts of local anthropogenic stressors such as exploitation of herbivorous fish.

This study seeks to determine whether a small community based marine protected area can enhance the resilience of a coral reef by increasing overall diversity of the reef assemblage. It investigates the effect of the MPA on the overall assemblage of corals and associated taxon over a data set spanning seven years and aims to assess differential change inside and outside the MPA in years pre and post a disturbance event in the form of Typhoon Yolanda. The abundance, diversity and richness of reef organisms will be explored by surveying corals and reef fish, in particular butterflyfish species of the family *Chaetodontidae*, as well as

determining the coverage of fleshy macro-algae, the latter two being indicators of coral reef health (Linton & Warner 2003). It is proposed that there will be significantly higher measures of biodiversity inside compared to outside the MPA across the years, suggesting enhanced reef resilience and positive impact of the protected area against disturbance. It is also expected that any impact of the typhoon will be greater outside the MPA, shown as a greater decline in biodiversity out of the boundaries of the protected area due to a higher level of ecological resilience afforded by the MPA. Consequently butterflyfish species, many of which are closely associated with coral reef health, will be more abundant and diverse inside the MPA and there will be significantly higher cover of fleshy macro algae on the reef outside the MPA, due to the protection the MPA offers herbivorous fish species.

Materials and Methods

Field site and survey design

All surveys were undertaken at sites inside and directly adjacent to a community based marine protected area (MPA) currently managed by Coral Cay Conservation (CCC), a UK based non-governmental organisation (NGO), situated in the barangay of Napantao, part of the municipality of San Francisco in Sogod Bay, Southern Leyte, Philippines (10° 3' 45.0072" N/125° 8' 10.8132" E). The MPA (Fig. 1) is part of the Southern Leyte Coral Reef Conservation Project, a joint venture between CCC, the Philippines Reef and Rainforest Conservation Inc. (PRRCFI) and the Provincial Government of Southern Leyte (PGSL). Established in 2002 the project aims to scientifically assess the coral reefs and associated habitats of Sogod Bay whilst working with local government, organisations and communities of Southern Leyte to implement and support the sustainable management of these vital ecosystems (CCC, 2014). Twenty three MPAs have now been established in Sogod Bay covering an area of approximately 170 ha; the study site at Napantao was set up in 1996 and covers 5 ha, the median size for an MPA in Sogod Bay (CCC, 2013).

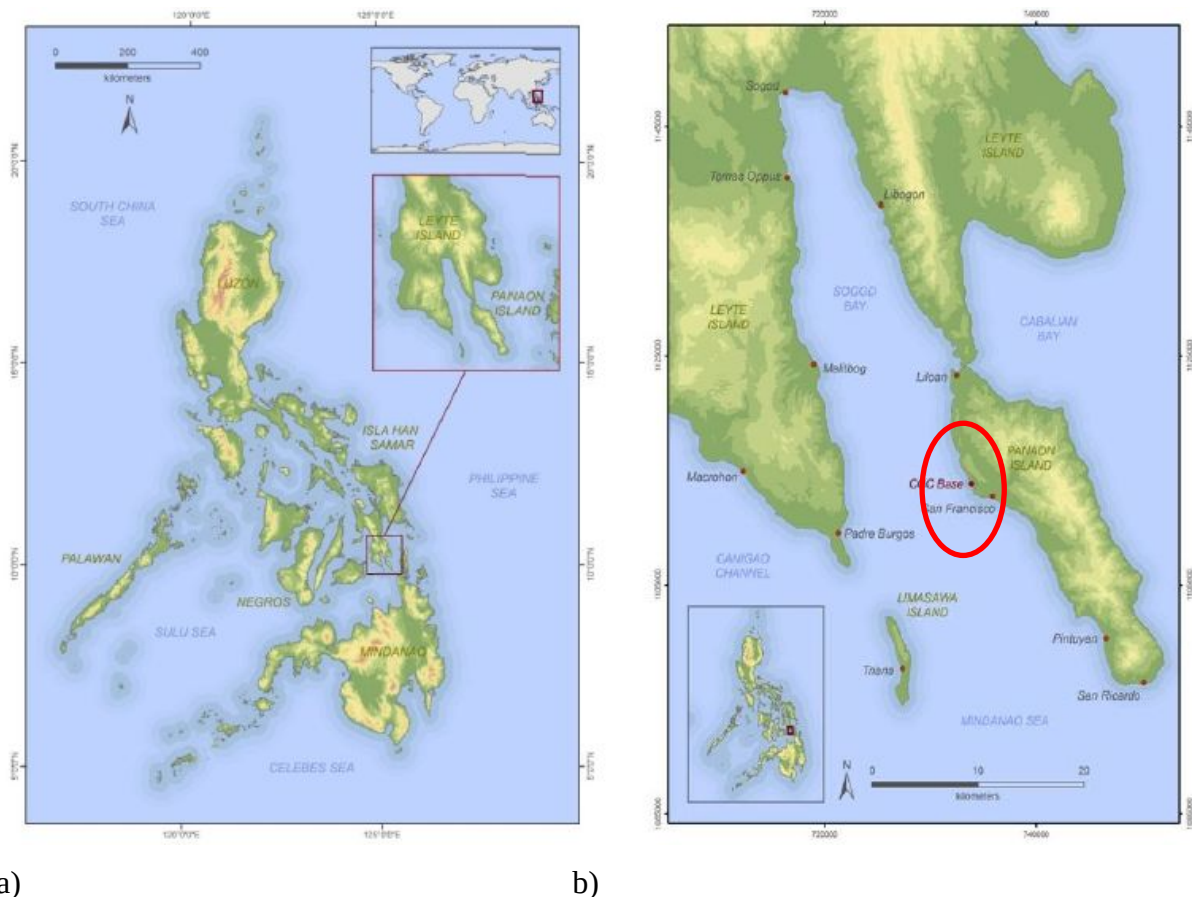


Figure 1: a) Map of the Philippines with Southern Leyte Province and Panaon Island highlighted **b)** Sogod Bay with the field site circled in red (adapted from Coral Cay Conservation, 2012).

All surveys were designed and implemented by CCC and carried out by volunteers fully trained by scientists at the Napantao site. CCC introduced a new survey design in 2013 moving the purpose of their research programme from gathering baseline data of the reefs of Sogod Bay towards ecological monitoring of established MPAs and proposals for new protected areas in the region (CCC, 2013). CCC began managing the MPA at Napantao in 2008 as part of their baseline survey research; the MPA is a complete no-take zone.

Baseline Survey Technique

Surveys prior to 2013 were conducted using CCC's Baseline Survey Technique, designed to allow trained recreational (volunteer) divers to collect data on the biological and physical characteristics of coral reef communities (CCC, 2008). Surveys were composed of plot-less transects and were carried out at a depth of 12 metres. Two permanent transect (PT) lines 50 metres in length were set within the MPA (PT 1 and 2) and three (PT 3, 4 and 5) set outside the boundary of the protected area to the North. Each transect line was surveyed a minimum

of five times per year with the greatest sampling effort being eleven times in one year (2009 PT 2 and 3). For estimating the relative abundance of hard corals benthic point-intercept transects surveys were carried out by SCUBA divers. Benthic coverage observations were recorded every 50 cm along the transect with a total of 100 observations made, this allowed the percentage cover of the various substrate types to be calculated. For the purpose of this study only hard corals, turf algae and fleshy macro-algae data was used from the substrate surveys. Hard corals were recorded as life form as described by English et al. (1997), with twelve life forms noted in total during the surveys (Appendix 1). Fish families and butterflyfish species were recorded along the same transect line. Using a belt transect method all target fish families or species were recorded along the transect within an area 2.5 metres either side of the line and 5 metres above the line. Target fish families were selected as good indicators of coral reef health or because they are commercially important in the local area, therefore very low observations may indicate overfishing while high numbers may point to population recovery (CCC, 2008).

Reef Check Methodology

In 2013 CCC adopted an enhanced Reef Check methodology for their survey design. The Reef Check method is widely recognised and used to carry out surveys of the status of coral reefs worldwide and assess human impacts to these ecosystems allowing contribution to a global database (Hodgson 1999). The CCC survey design incorporates further target species in addition to those suggested by Reef Check to give a comprehensive overview of the ecology and health of the coral reef (CCC, 2013). Surveys taking place from 2013 onwards incorporated a third permanent transect line inside the MPA at Napantao so an equal number of transect lines (three) are now situated both inside and outside the MPA. All other transects are located at the same sites as pertaining to CCC's original base line methodology and all transects are situated at a depth of 12 metres. Each transect line is now 100 metres long (consisting of 2 x 50 metre survey lines) in accordance with Reef Check's methodology and each transect is divided into four distinct 20 metre replicates with each consecutive replicate's start and end point separated by a minimum gap of 5 metres, these gaps ensure independence between the samples. Under this survey design each permanent transect is surveyed twice per year, in March/April and August/September, totalling 24 replicate samples inside and outside the MPA per annum. Fish families and butterflyfish species are recorded using the same belt transect method as prior to 2013. Hard corals and algae are also recorded using the same point intercept method every 50 cm along the line. The 100 metre

survey line is split into 2 x 50 metre lines with 100 points along each line therefore an estimate of hard coral percentage cover per 50 metre line can be made. This survey design records the majority of target hard corals to species level and records a further 3 life forms in addition to those in 2008-12. Additional fish families and butterflyfish species are also recorded (Appendix 1).

Data Analysis

CCC updated their survey design in 2013 and thus one historical data set was obtained from surveys conducted from 2008 to 2012 and a second from surveys during 2013 and 2014. The two data sets were initially treated separately when considering patterns in the rate of change in diversity, abundance and coral reef assemblage across the years whilst comparing data obtained from sampling within the MPA (experimental sites) against that recorded outside the MPA (control sites). The scale of change between 2013 and 2014 (surveys taken in the year of occurrence and directly following the hurricane) was compared against any changes between preceding pairs of years previously surveyed. Further multivariate investigations were performed on the merged data sets to compare variation in the assemblages of each taxon across all years.

All univariate and multivariate analysis was carried out in the PRIMER V6.1.13 software package (Clarke & Gorley 2006) with the PERMANOVA + V1.0.3 add on (Anderson et al. 2008). Permutational Multivariate Analysis of Variance (PERMANOVA) is robust to samples containing many zero counts and survey designs with unbalanced sampling effort (Anderson 2001), it also makes no assumption about the underlying distribution of the data (Walters & Coen 2006). The software was used to assess for change in overall assemblage composition of the coral reef community as well as species richness, abundance of individuals, Shannon-Weiner diversity (H') and Pielou's evenness (J) of pre-selected coral reef taxa inside the MPA compared to outside the MPA over successive years (all four diversity indices were calculated in PRIMER). To maintain continuity, corals from both data sets were analysed according to life form (rather than species) in accordance with CCC's original methodology. Due to the number of additional species recorded in some fish family groups in the new methodology, and CCC now counting individuals of certain species by size class, groupers, snappers, spine cheeks and parrot fish were amalgamated from the raw data set (Appendix 1). Counts of gobies and blennies were removed entirely on advice from CCC's Project Scientist on site in the Philippines as these families are easy to miscount due

to their cryptic nature which could lead to skewed results. Turf algae as well as fleshy macro algae were considered in the analysis of 2008-12 data with both being indicators of poor reef health (Lirman 2001) and analysed as one group. All algae recorded as Nutrient Indicator Algae (N.I.A) in the 2013-14 methodology were analysed as algal types recorded in this grouping include fleshy macro algae and turf algae >3 cm, along with others such as *Padina* sp., which may not only indicate nutrient enrichment on the reef but may also suggest a lack of herbivory, due to this algal type being consumed by some species of Philippine reef fish e.g. *Siganus canaliculatus* (Mantyka & Bellwood 2007). Only algae which may respond to nutrient enrichment are grouped as N.I.A, this category does not include any calcareous algae or encrusting coralline algae which may contribute to the overall reef structure.

Univariate Analysis

A univariate PERMANOVA with 2 fixed factors of MPA designation (Levels: inside/outside) and year (levels: 2008, 2009, 2010, 2011, 2012) was performed on data from the initial methodology to test for differences in each diversity index across the years and between the two designations. Abundance data (counts of species and individuals) were first transformed (using the fourth root) to down-weight the influence of more frequently observed species whilst preserving information on relative abundance (Somerfield et al. 2008). A resemblance matrix was then constructed using Euclidean distance to calculate distance between differences in total abundance, richness, diversity and evenness between samples (Sheehan et al. 2013). Data collected using CCC's current methodology were analysed using a PERMANOVA design with two fixed factors of MPA designation (levels: inside/outside) and year (levels: 2013, 2014) which also incorporated a random factor of 'site' nested within the designation; this represented the repeated replicates within each transect line in the new survey design. To maintain continuity and more readily compare trends across the years, each pair of replicates within a 100 metre transect was merged to form two 50 metre replicates conforming to CCC's original baseline methodology. Significant results from either data set were further analysed by applying the appropriate post-hoc pairwise comparisons (Bacher et al. 2012).

Multivariate Analysis

PERMANOVA was used to test the differences in overall composition of the reef assemblage in each MPA designation across the years for data from each taxon and data set using the same designs as the univariate analysis. Data was first transformed using the fourth root to

allow rare species to contribute to the results and a resemblance matrix constructed using Bray-Curtis similarity (Somerfield et al. 2008). A dummy variable of 1 was added to the original abundance matrix to account for this similarity measure being undefined for two samples which have paired zeros and in order to generate meaningful non-metric multidimensional scaling (nMDS) (Clarke et al. 2006). nMDS ordinations were produced to enable visualisation of the multivariate patterns in variation of the coral reef assemblage across the years and between the two MPA designations based on the composition of the observations in each sample (Anderson 2001). Statistical significance was tested using 9999 permutations and a reduced model and type III sum of squares (Bacher et al. 2012). Significant terms were again investigated using the appropriate PERMANOVA pairwise tests (Sheehan et al. 2013). Merged data from both methodologies were first standardised in PRIMER to account for the additional sampling replicates of the current methodology, ensuring that the different scales of measure contributed equally to the analysis.

Results

Species Richness, Abundance and Diversity

Hard Corals

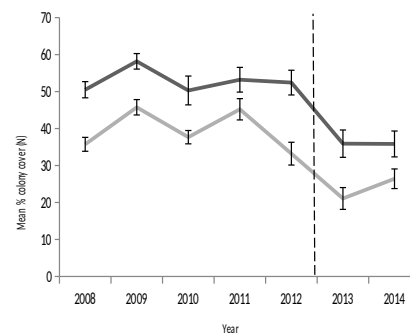
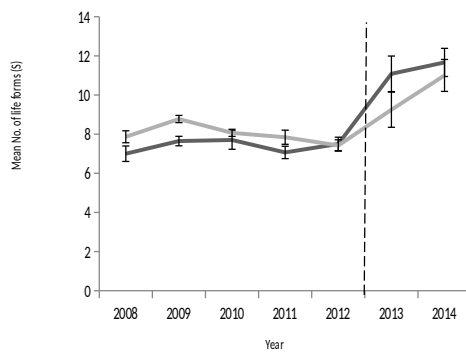
2008-12

Univariate analysis of distinct hard coral life forms indicated significantly higher numbers of life forms outside the MPA compared to inside across the years (Table 1, Fig. 2a). No significant interaction was found between years or MPA designation. Conversely, mean percentage cover of hard coral showed significantly higher numbers of individual colony counts inside the MPA across the years (Table 1, Fig. 2b). Across all years (in both data sets) highest percentage cover was recorded inside the MPA in 2009 ($58.18\% \pm 2.1$); no significant interaction was found between year and MPA designation. Pairwise tests of richness (number of distinct coral life forms recorded) across successive pairs of years found a significant difference between 2008 and 2009 ($P = 0.0066$) but between no other successive pair of years. A significant difference was found in abundance (percentage cover) of hard corals between 2008 and 2009 ($P = 0.0001$), 2009 and 2010 ($P = 0.0013$) and 2011 and 2012 ($P = 0.0249$). H' and J were found to be significantly higher outside the MPA (Table 1, Fig. 2c and d) but there was no significant difference between the years. No significant interaction was found between year and MPA designation for either.

268 **Table 1:** PERMANOVA of richness, abundance, diversity and evenness of hard coral life forms, based on Euclidean distance measure
 269 (significant results in bold type).

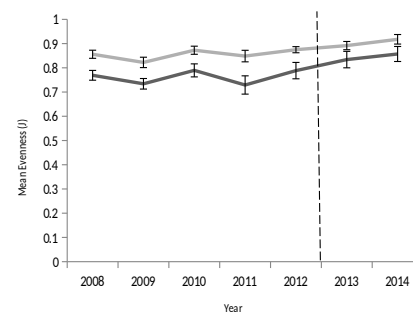
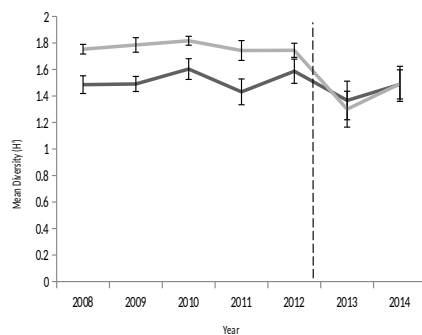
Coral Life Forms					
2008 – 2012					
Source	<i>df</i>	SS	MS	F	P
Year	4	5.2036	1.3009	2.8626	0.0253
I/O	1	4.1807	4.1807	9.1996	0.0033
Year x I/O	4	2.0891	5.2228	1.1493	0.3351
Residual	146	0.66349	4.5444		
Total	155	0.7868			
2013 – 2014					
Year	1	0.12978	0.12978	2.5999	0.1854
I/O	1	0.13148	0.13148	0.48611	0.6109
Site (I/O)	4	1.0819	0.27047	7.2779	0.0001
Year x I/O	1	4.0765	4.0756	0.81668	0.4127
Year x Site (I/O)	4	0.1966	4.9915	1.3431	0.2498
Residual	84	3.1217	3.7163		
Total	95	4.7053			
% Cover					
2008-12					
Source	<i>df</i>	SS	MS	F	P
Year	4	0.54003	0.13501	5.3576	0.0003
I/O	1	1.4589	1.4589	57.894	0.0001
Year x I/O	4	0.18332	4.583	1.8187	0.1231
Residual	146	3.6791	2.5199		
Total	155	6.0083			
2013-2014					
Year	1	0.19838	0.19838	2.344	0.189
I/O	1	1.512	1.512	1.635	0.376
Site (I/O)	4	3.6691	0.92478	12.258	0.001
Year x I/O	1	0.18254	0.18254	2.1568	0.226
Year x Site (I/O)	4	0.33853	8.4633	1.1218	0.369
Residual	84	6.3372	7.5443		
Total	95	12.268			
Diversity (H')					
2008-2012					
Source	<i>df</i>	SS	MS	F	P
Year	4	0.24272	6.068	0.87443	0.4786
I/O	1	2.2765	2.2765	32.806	0.0001
Year x I/O	4	0.12885	3.2214	0.46421	0.7674
Residual	146	10.132	6.9394		
Total	155	12.925			
2013-2014					
Year	1	0.80549	0.80549	4.1771	0.1167
I/O	1	8.0616	8.0616	5.0347	0.8994
Site (I/O)	4	6.4049	1.6012	10.13	0.0001
Year x I/O	1	9.2196	9.2196	0.47811	0.5274
Year x Site (I/O)	4	0.77134	0.19283	1.22	0.3034
Residual	84	13.277	0.15806		
Total	95	21.432			
Evenness (J)					
2008-2012					
Source	<i>df</i>	SS	MS	F	P
Year	4	7.6742	1.1985	2.1302	0.0834
I/O	1	0.31603	0.31603	35.089	0.0001
Year x I/O	4	7.197	1.7992	0.19977	0.9379
Residual	146	1.3149	9.0064		
Total	155	1.7389			
2013-2014					
Year	1	0.14984	0.14984	5.0387	0.0902
I/O	1	3.7383	3.7383	0.4622	0.6047
Site (I/O)	4	0.32353	8.0881	2.7931	0.0266
Year x I/O	1	1.0824	1.0824	0.36398	0.569
Year x Site (I/O)	4	0.11895	2.9738	1.027	0.415
Residual	84	2.4324	2.8957		
Total	95	3.0729			

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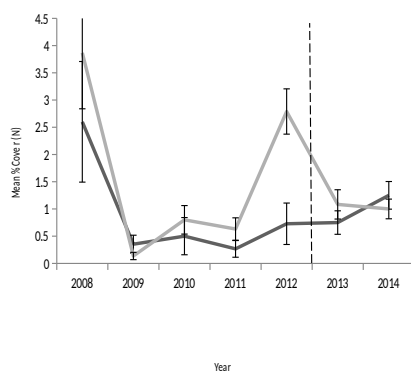
271 a)

b)



272 c)

d)



273 e)

Figure 2: Graphs show mean ($\pm$ SE) **a)** distinct hard coral life forms, **b)** % cover of individual hard coral colonies, **c)** Shannon-Weiner diversity for hard corals, **d)** Pielou's evenness for hard corals and **e)** % cover of algae recorded over a 50 metre transect. Dark grey line shows data from inside the MPA, light grey line shows data from outside the MPA. Vertical line denotes change in methodology.

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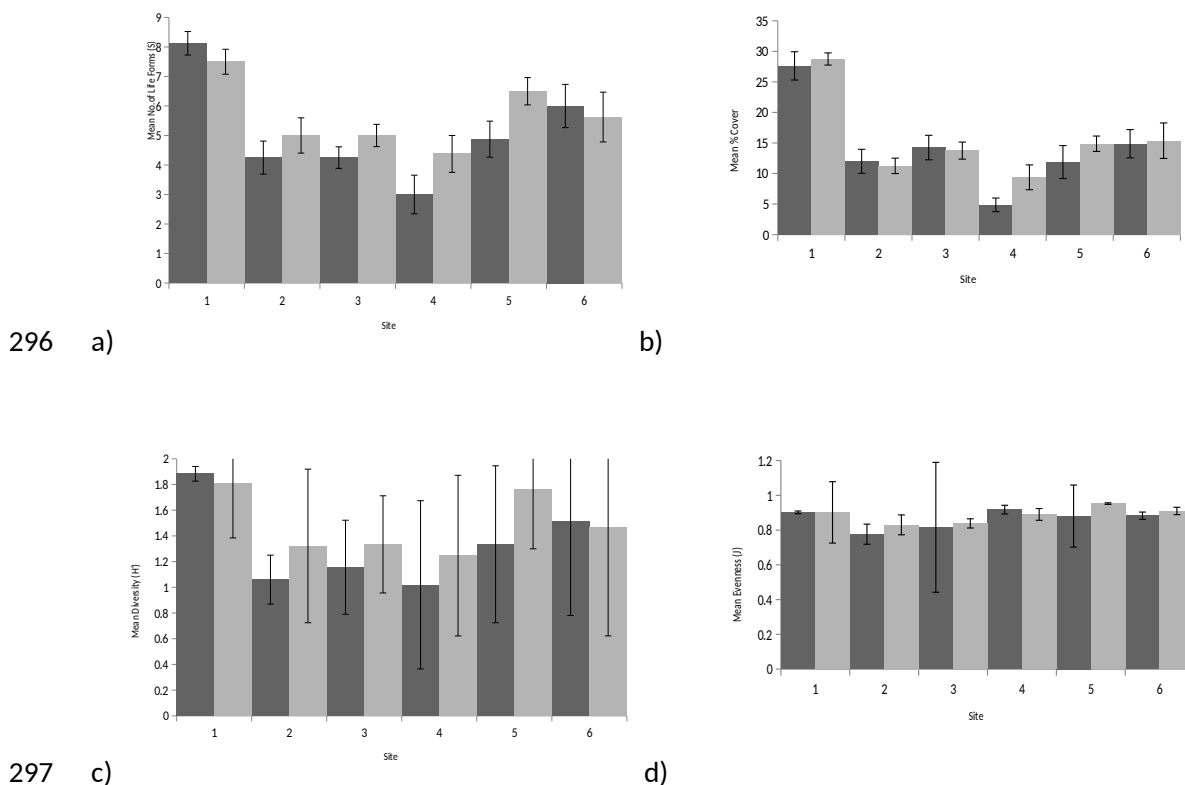
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282 2013-14

283 Following the change in methodology in 2013 the number of hard coral life forms increased
 284 in both designations and was higher inside compared to outside the MPA (Fig. 2a) with the
 285 highest counts of life forms recorded (over both data sets) inside the MPA in 2014 ($11.67 \pm$
 286 0.79), although this was not found to be statistically significant. Percentage cover of hard
 287 corals remained higher inside the MPA compared to outside (again not statistically
 288 significant) despite individual colony counts declining both inside and outside the MPA
 289 (52.42% to 35.91% inside and 33.21% to 21.08% outside) and then appearing to stabilise
 290 (Fig. 2b). No significant difference was found in H' or J between the MPA designations or
 291 across the years; however all four diversity indices were found to be statistically significant
 292 across the six different sites nested within the designations (Table 1), indicating that the inter-
 293 site variation may be so great that it masks any pattern occurring in the designations and
 294 years (Fig. 3).

295



298 **Figure 3:** Histograms display variation between sites (100 metre transects comprised of 4 x 20 metre replicates) 2013-14 ($\pm$
 299 SE). Sites 1-3 are located inside the MPA; sites 4- 6 are outside the MPA. Light grey bars show data from 2013, dark grey
 300 bars show data from 2014. Graphs show **a)** mean number of hard coral life forms, **b)** mean number of individual coral
 301 colony counts/ % cover, **c)** mean H' diversity and **d)** mean J evenness.

Algae2008-12

Total percentage cover of algae on the reef was found to be significantly different across the years (Table 2) with a higher cover outside compared to inside the MPA (Fig. 2e), although difference between the two designations was not significantly different. Pairwise tests of successive pairs of years showed a highly significant difference in the total coverage of algae between 2008 and 2009 ($P = 0.0002$) and 2011 and 2012 ($P = 0.0001$). No significant interaction between the year and MPA was detected. Indicator algae (turf and fleshy macroalgae) were analysed as one taxon therefore algal diversity, evenness and species richness were not tested.

Table 2: PERMANOVA of algal abundance based on Euclidean distance measure (significant results in bold type).

% Cover					
2008-12					
Source	df	SS	MS	F	P
Year	4	20.121	5.0302	18.43	0.0001
I/O	1	0.86536	0.86536	3.1705	0.0762
Year x I/O	4	1.22	0.30499	1.1174	0.3453
Residual	146	39.849	0.27294		
Total	155	62.691			
2013-2014					
Year	1	0.18879	0.18879	1.0296	0.3673
I/O	1	1.5504	1.5504	1.4803	0.9029
Site (I/O)	4	4.1895	1.0474	2.7283	0.0366
Year x I/O	1	8.5425	8.5425	0.46589	0.5164
Year x Site (I/O)	4	0.73344	0.18336	0.47764	0.7612
Residual	84	32.247	0.38389		
Total	95	37.459			

2013-14

A slight increase in algal cover was found from 2013-14 inside the MPA (Fig. 2e) but the difference between the years and MPA designations was not statistically significant. Despite mean overall algal cover being extremely low ($\leq 4\%$) the difference was found to be statistically significant across the six sites (Table 2) in the two MPA designations.

Reef Fish Families

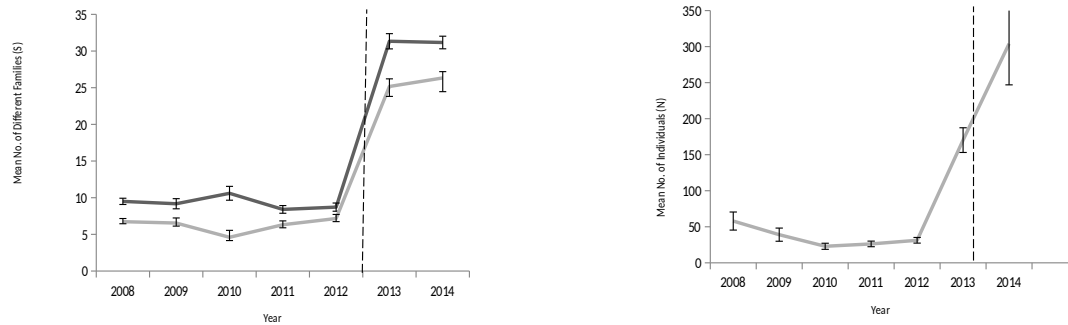
2008-12

The difference in mean number of reef fish families was found to be significantly higher inside compared to outside the MPA (Table 3) and this trend continued across the years (Fig. 4a); the pattern in years was not statistically significant. The interaction between MPA designation and year was found to be statistically significant (Table 3). The difference in the total number of individual fish recorded on the reef was found to be highly significant inside compared to outside the MPA and also significant for the total number of fish recorded across the years (Table 3). There is a suggestion that the significant differences found between the MPA designations and across the years are not consistent but the interaction was not found to be statistically significant ($P = 0.0504$). Pairwise tests of the mean number of individual fish recorded across successive pairs of years were significant between 2008 and 2009 ($P = 0.0078$). Analysis of H' diversity showed that diversity of fish families was significantly higher inside the MPA as well as across the years (Fig. 4c), but no significant interaction was found between the two. Pairwise comparisons of H' across successive pairs of years showed a significant difference between 2009 and 2010 only ($P = 0.0332$). No significant difference was found for J which remained somewhat constant across the years inside and outside the MPA (Fig. 4d).

353 **Table 3:** PERMANOVA of richness, abundance, diversity and evenness of reef fish families, based on Euclidean distance measure
 354 (significant results in bold type).

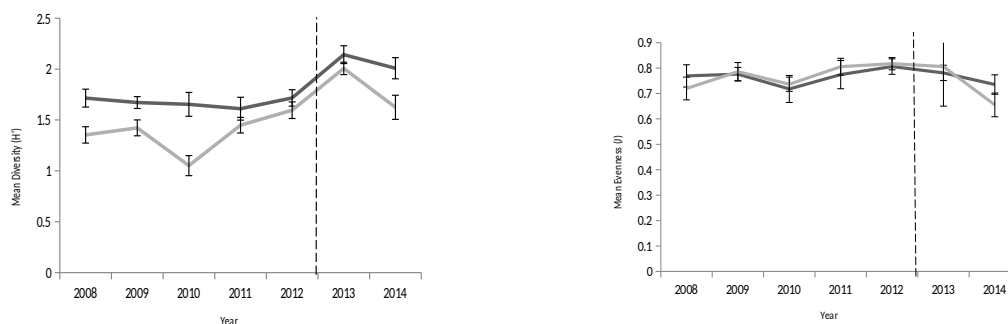
Family Richness					
2008 - 2012					
Source	<i>df</i>	SS	MS	F	P
Year	4	6.777	1.6943	1.2654	0.2821
I/O	1	1.0392	1.0392	77.163	0.0001
Year x I/O	4	0.28646	7.1614	5.3486	0.0006
Residual	146	1.9548	1.3389		
Total	155	3.3144			
2013 - 2014					
Year	1	6.1008	6.1008	0.27238	0.6275
I/O	1	0.2856	0.2856	3.6681	0.1932
Site (I/O)	4	0.31145	7.7862	5.8044	0.0004
Year x I/O	1	9.2858	9.2858	0.41458	0.547
Year x Site (I/O)	4	8.9593	2.2398	0.16697	0.9537
Residual	84	1.1268	1.3414		
Total	95	1.7344			
No. of Individuals					
2008-12					
Source	<i>df</i>	SS	MS	F	P
Year	4	4.6383	1.1596	5.5598	0.0012
I/O	1	7.1204	7.1204	34.14	0.0001
Year x I/O	4	2.0148	0.5037	2.4151	0.0504
Residual	146	30.45	0.20856		
Total	155	42.97			
2013-2014					
Year	1	0.76456	0.76456	3.8767	0.1195
I/O	1	0.52736	0.52736	0.43828	0.4069
Site (I/O)	4	4.813	1.2033	3.8732	0.0065
Year x I/O	1	0.31379	0.31379	1.5911	0.2933
Year x Site (I/O)	4	0.78889	0.19722	0.63485	0.6293
Residual	84	26.095	0.31066		
Total	95	33.303			
Diversity (<i>H'</i>)					
2008-2012					
Source	<i>df</i>	SS	MS	F	P
Year	4	1.2798	0.31994	2.7186	0.0327
I/O	1	3.2824	3.2824	27.891	0.0001
Year x I/O	4	0.99171	0.24793	2.1067	0.0804
Residual	146	17.182	0.11768		
Total	155	22.901			
2013-2014					
Year	1	1.5996	1.5996	31.254	0.0061
I/O	1	1.6128	1.6128	6.3387	0.0985
Site (I/O)	4	1.0177	0.25444	1.1398	0.3474
Year x I/O	1	0.37249	0.37249	7.2799	0.0565
Year x Site (I/O)	4	0.20472	5.1181	0.22927	0.9218
Residual	84	18.751	0.22323		
Total	95	23.559			
Evenness (<i>J</i>)					
2008-2012					
Source	<i>df</i>	SS	MS	F	P
Year	4	0.19835	4.9588	1.966	0.1055
I/O	1	1.127	1.127	4.4682	0.8353
Year x I/O	4	3.0384	7.5959	0.30115	0.8785
Residual	146	3.6825	2.5223		
Total	155	3.9413			
2013-2014					
Year	1	0.23194	0.23194	19.499	0.0135
I/O	1	1.8237	1.8237	0.56776	0.5016
Site (I/O)	4	0.12848	3.2121	1.0908	0.3724
Year x I/O	1	6.6055	6.6055	5.5532	0.0796
Year x Site (I/O)	4	4.758	1.1895	0.40396	0.8081
Residual	84	2.4735	2.9446		
Total	95	2.9658			

355



356 a)

b)



357 c)

d)

358 **Figure 4:** Graph shows mean ($\pm$ SE) number of **a)** different reef fish families recorded, **b)** mean number of individuals, **c)**
 359 mean Shannon-Weiner Diversity of reef fish families and **d)** mean Pielou's evenness of reef fish families recorded over a 50
 360 metre transect. Dark grey line shows data from inside the MPA, light grey line shows data from outside the MPA. Vertical
 361 line denotes change in methodology.

362 2013-14

363 The number of individual reef fish families, and subsequently the number of individual fish
 364 recorded, rose in 2013 following the change in methodology with the highest number of
 365 distinct family groups recorded inside the MPA in 2013 (31.33 ± 1.04). The number of
 366 families recorded remained higher inside the MPA, although the highest number of individual
 367 fish across the families was recorded outside the MPA in 2014 (303.92 ± 56.96) (Fig. 4b).
 368 Neither the difference between the designations nor years was found to be statistically
 369 significant; however the variation between the six sites was (Table 3, Fig. 5). This small
 370 spatial scale variation may again be masking larger scale differences between the
 371 designations and across the years. H' diversity remained higher inside the MPA (Fig. 4c)
 372 although again this was not found to be statistically significant however there was a
 373 significant difference detected between 2013 and 2014 (Table 3); the same trend was seen in
 374 Pielou's evenness which did decline slightly outside the MPA between the two years (Fig.
 375 4d). No significant difference was found across the six sites for H' or J .

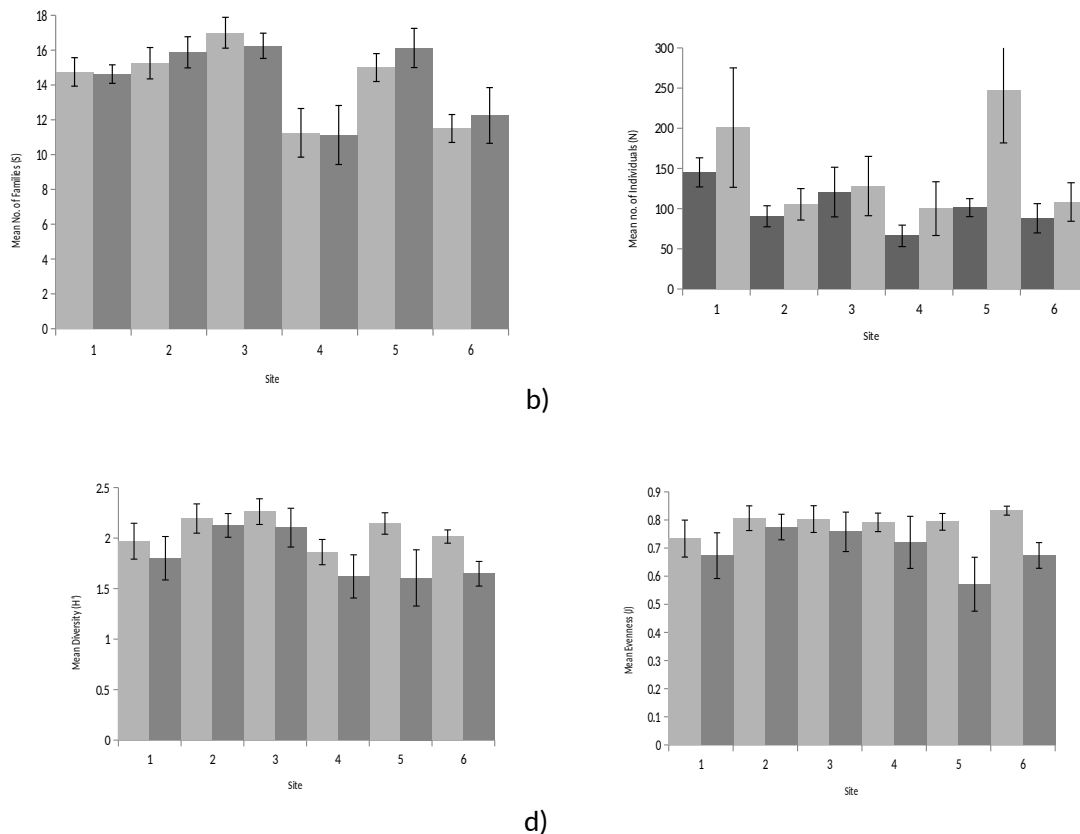


Figure 5: Histograms display variation between sites (100 metre transects comprised of 4 x 20 metre replicates) 2013-14 ($\pm$ SE). Sites 1-3 are located inside the MPA, sites 4-6 are outside the MPA. Light grey bars show data from 2013, dark grey bars show data from 2014. Graphs show **a)** mean number of reef fish families, **b)** mean number of individual fish, **c)** mean Shannon-Weiner diversity and **d)** mean Pielou's evenness.

Butterflyfish Species

2008-12

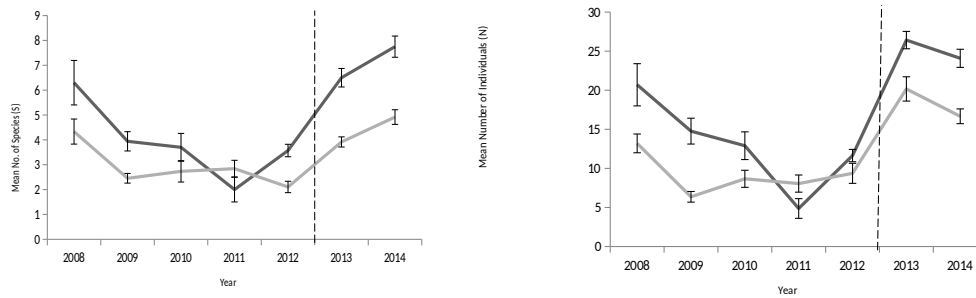
The number of butterflyfish species were significantly different across the years (Table 4) and was generally higher inside compared to outside the MPA (Fig. 6a) although the difference in the designations was not found to be statistically significant. Pairwise comparisons showed significant differences between 2008 and 2009 ($P = 0.0001$), 2010 and 2011 ($P = 0.0009$) and 2011 and 2012 ($P = 0.0051$). There was a significant difference in the interaction between the two factors (Table 4) which may represent a lack of consistency in the significant difference across the years and between designations, the same overall trend was seen in the number of individual butterflyfish recorded (Table 4, Fig. 6b). Pairwise comparisons of numbers of individual butterflyfish showed significant differences between 2008 and 2009 ($P = 0.0001$), 2010 and 2011 ($P = 0.0009$) and 2011 and 2012 ($P = 0.0003$). H' diversity was significantly different inside compared to outside the MPA (Table 4) and was generally found to be higher inside (Fig. 6c), this was also statistically significant across

the years (Table 4). Pairwise comparisons of H' across the years showed significant difference between 2008 & 2009 only ($P = 0.0005$). A significant interaction was also found between year and inside versus outside the MPA (Table 4). A general decline in the number of butterflyfish species, individuals and H' diversity seemed apparent from 2008-2011 but then began to rise again (Fig. 6). No significant difference in the evenness of butterflyfish species distribution was found across the years or inside versus outside the MPA; however a significant interaction between year and designation was detected (Table 4).

426 **Table 4:** PERMANOVA of richness, abundance, diversity and evenness of butterflyfish species, based on Euclidean distance measure
 427 (significant results in bold type).

Species Richness					
2008 - 2012					
Source	<i>df</i>	SS	MS	F	P
Year	4	3.7788	0.94471	10.934	0.0001
I/O	1	6.3448	6.3448	0.73436	0.3943
Year x I/O	4	1.8367	0.45919	5.3148	0.0007
Residual	146	12.614	8.6398		
Total	155	17.754			
2013 - 2014					
Year	1	0.11528	0.11528	3.3455	0.1481
I/O	1	0.92346	0.92346	2.9681	0.1987
Site (I/O)	4	1.2445	0.31112	4.9134	0.0005
Year x I/O	1	1.2497	1.2497	0.36268	0.5641
Year x Site (I/O)	4	0.31783	3.4457	0.54416	0.7078
Residual	84	5.319	6.3321		
Total	95	7.7526			
No. of Individuals					
2008-12					
Source	<i>df</i>	SS	MS	F	P
Year	4	8.9637	2.2409	14.999	0.0001
I/O	1	0.24407	0.24407	1.6335	0.2022
Year x I/O	4	4.0557	1.0139	6.7861	0.0002
Residual	146	21.814	0.14941		
Total	155	33.841			
2013-2014					
Year	1	1.1076	1.1076	0.11688	0.745
I/O	1	1.4779	1.4479	1.7511	0.3038
Site (I/O)	4	3.3758	0.84396	6.9162	0.0002
Year x I/O	1	1.4436	1.4436	0.15233	0.7166
Year x Site (I/O)	4	0.37908	9.4771	0.77665	0.5418
Residual	84	10.25	0.12203		
Total	95	15.508			
Diversity (<i>H'</i>)					
2008-2012					
Source	<i>df</i>	SS	MS	F	P
Year	4	6.1998	1.5499	7.4536	0.0001
I/O	1	2.3139	2.3139	11.128	0.0016
Year x I/O	4	2.8546	0.71364	3.4319	0.0107
Residual	146	30.36	0.20795		
Total	155	41.821			
2013-2014					
Year	1	0.64128	0.64128	2.7935	0.1725
I/O	1	3.2978	3.2978	4.8001	0.1945
Site (I/O)	4	0.68704	0.68704	3.0129	0.0222
Year x I/O	1	6.157	6.157	2.682	0.956
Year x Site (I/O)	4	0.91826	0.22956	1.0067	0.4055
Residual	84	19.155	0.22804		
Total	95	26.761			
Evenness (<i>J</i>)					
2008-2012					
Source	<i>df</i>	SS	MS	F	P
Year	4	0.77963	0.19491	2.1999	0.0659
I/O	1	0.1525	0.1525	1.7213	0.1879
Year x I/O	4	1.2137	0.30344	3.4248	0.0111
Residual	146	12.935	8.8598		
Total	155	15.084			
2013-2014					
Year	1	2.0097	2.0097	0.16477	0.6684
I/O	1	0.44795	0.44795	2.3147	0.1945
Site (I/O)	4	0.7741	0.19352	1.8516	0.127
Year x I/O	1	0.12249	0.12249	1.0043	0.3679
Year x Site (I/O)	4	0.48787	0.12197	1.167	0.3442
Residual	84	8.7794	0.10452		
Total	95	10.632			

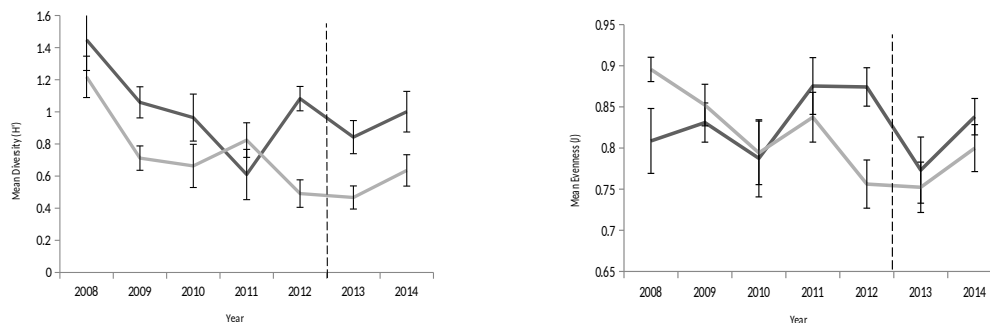
428



429

430 a)

b)



431

432 c)

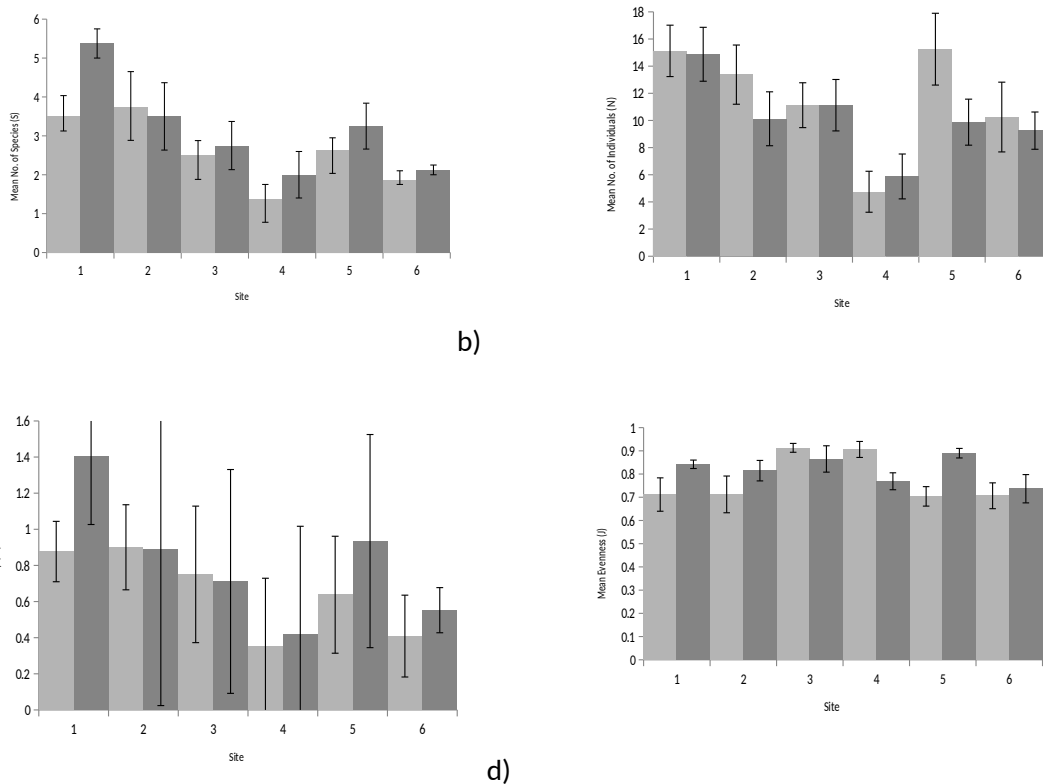
d)

Figure 6: Graphs shows mean ($\pm$ SE) number of **a)** Butterfly fish species, **b)** individual butterflyfish, **c)** Shannon-Weiner diversity of butterflyfish and **d)** Pielou's evenness index recorded over a 50 metre transect. Dark grey line shows data from inside the MPA, light grey line shows data from outside the MPA. Vertical line denotes changed in methodology.

436 2013-14

The total number of butterflyfish species recorded increased with the change in methodology as did the number of individual fish recorded (Fig. 6a and b). The highest number of butterflyfish species was recorded inside the MPA in 2014 (7.75 ± 0.42) and the highest number of individuals recorded in 2013 (26.41 ± 1.11), also inside the MPA. In general, both species richness and individual abundance were found to be higher inside compared to outside the MPA, although this was not statistically significant. No significant interaction was detected between designation and year but the variation between sites was found to be statistically significant and a similar trend was seen for H' diversity (Table 4, Fig. 7). No significant difference was detected in Pielou's evenness. The most frequently observed species of butterflyfish was *Chaetodon baronessa* with a total of 1487 individuals recorded in total across both data sets, this was followed by *Chaetodon trifasciatus* with 236 individuals

448 recorded in total and *Chaetodon klenii* with 203 individuals recorded in total. The mean total
 449 number of any one species recorded was 65.825.



451 **Figure 7:** Histograms display variation between sites (100 metre transects comprised of 4 x 20 metre replicates) 2013-14 ($\pm$
 452 SE). Sites 1-3 are located inside the MPA, sites 4-6 are outside the MPA. Light grey bars show data from 2013, dark grey
 453 bars show data from 2014. Graphs show **a)** mean number of butterflyfish species, **b)** mean number of individual
 454 butterflyfish, **c)** mean Shannon-Weiner diversity and **d)** mean Pielou's evenness.
 455

456 Overall composition of reef assemblage

457 The clearest pattern in each data set was seen between the two MPA designations. The nMDS
 458 plots for all taxon show the degree of spatial variability inside compared to outside the MPA
 459 across the years (Fig. 8) and while there is clearly some overlap in assemblage between the
 460 two areas they do still appear to be distinct, this is particularly evident in the reef fish families
 461 (Fig. 8c and d). Clear patterns in the variation in assemblage can be seen in the butterflyfish
 462 species between the two designations across the years (Fig. 8 e & f). Stress values range from
 463 0.2 (corals) to 0.28 (reef fish families) indicating that confidence in the interpretation of some
 464 of these plots cannot be absolutely accepted.

465 The difference in assemblages following the change in methodology after 2012 is
 466 conspicuous, particularly for hard coral life forms. The data from 2013 and 2014 shows less
 467 similarity to that recorded prior to the method change (Fig. 8a).

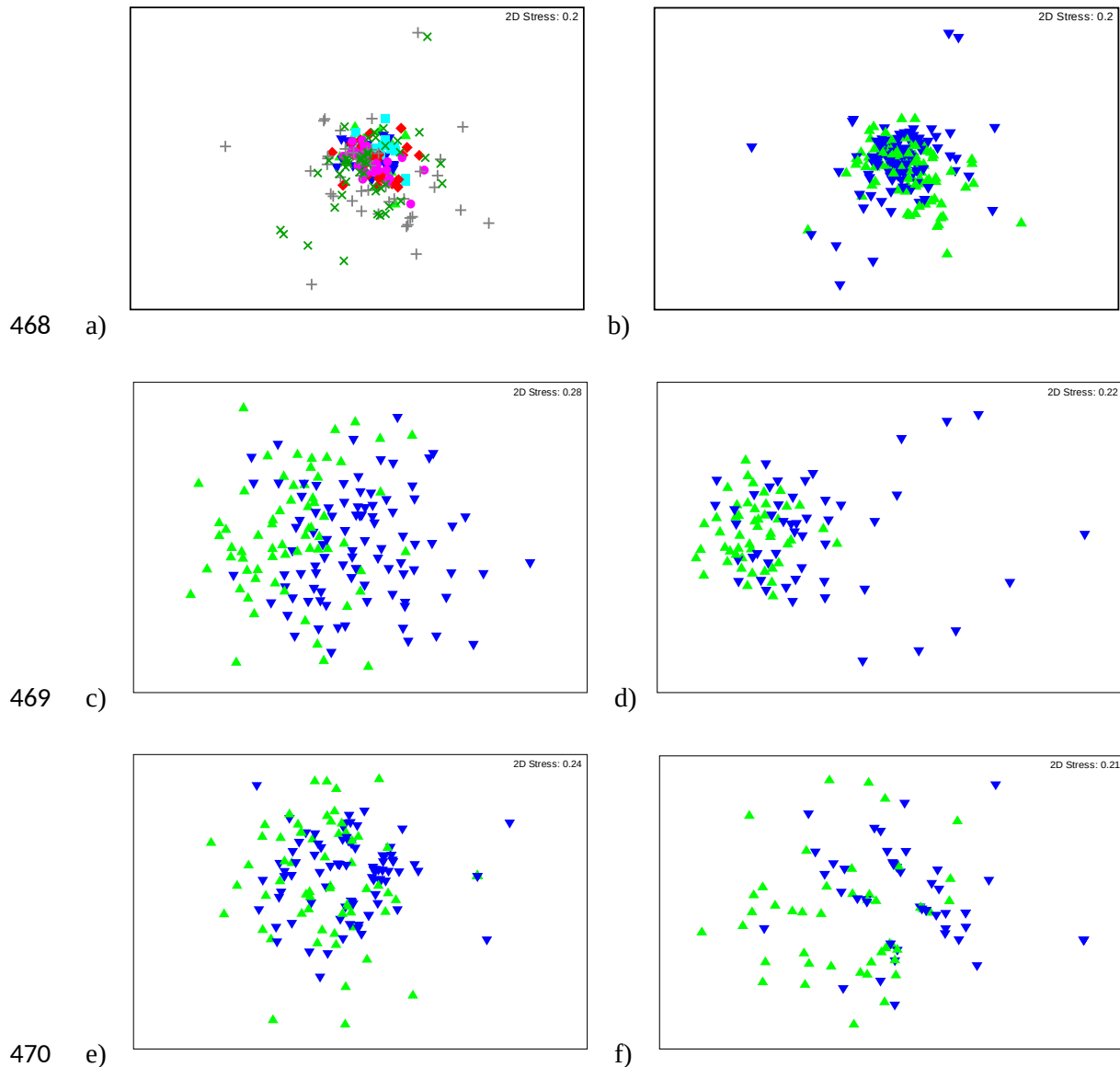


Figure X a-d: nMDS plots illustrate similarities between taxon assemblages **a)** in hard corals across all years. Solid shapes represent 2008-2012, $\square$ denotes 2013 and $\circ$ denotes 2014 (years following change in methodology) **b)** in hard corals between the two MPA designations across all years **c)** in reef fish families between the two MPA designations 2008-12 **d)** in reef fish families between the two MPA designations 2013-14 **e)** in butterflyfish species between the two MPA designation 2008-12 and **f)** in butterflyfish species between the two MPA designation 2013-14. Green $\triangle$ denotes inside the MPA, blue $\triangle$ denotes outside the MPA.

Hard Corals

Multivariate analysis showed that the overall assemblage composition of the hard coral community was significantly different across the years 2008-12 and between inside/outside the MPA (Table 5). The pattern of difference in the assemblage of hard coral life forms was consistent across the years (no significant difference found in the interaction). No significant difference was detected by pairwise comparisons of any successive pair of years between 2008 and 2012. Amongst sites inside and outside the MPA in the 2013-14 data a highly

significant difference was found in the overall assemblage of hard corals and across all sites and locations (I/O) there was a significant difference between years (Table 5) but no significant difference was detected between the two MPA designations, although the nMDS plot indicates a difference in the assemblage composition in both designations across all years (Fig. 8b). The significant difference in hard coral assemblage amongst sites within the respective MPA designations is consistent across the years as is the significant difference in hard coral assemblage between the years in the two MPA locations.

Reef Fish Families

Across all years from 2008-12, and between the two MPA designations, overall difference in the assemblage of fish families on the reef was found to be highly significant ($P = <0.001$) and was also significant for the interaction between both (Table 5). Pairwise tests between pairs of years showed significant differences between 2008 and 2009 ($P = 0.0314$), 2010 to 2011 ($P=0.0338$) and 2011 to 2012 ($P=0.0153$) but not between 2009 and 2010. Amongst the six sites in the 2013-14 data a highly significant difference in fish assemblage was detected (Table 5). There is a suggestion of a difference in the fish assemblage across the two years but it is not statistically significant ($P = 0.0549$), although there is some evidence of this in the nMDS plot, which shows a higher degree of variability outside the MPA between the two years (Fig. 8d). Across all years and sites there is no significant difference between inside and outside the MPA. As with the hard corals the significant difference in the assemblage between the six sites is consistent across the two years and the pattern of difference in the assemblage of reef fish families inside versus outside the MPA is consistent across the years.

Butterflyfish Species

A similar pattern to that of reef fish families was noted in overall assemblage of butterflyfish species in that a significant difference was apparent across years 2008-12 and between inside and outside the MPA (Table 5, Fig. 8e). Pairwise tests between successive pairs of years showed a significant difference in overall composition of butterflyfish species between 2010 and 2011 ($P = 0.0005$) and 2011 and 2012 ($P=0.0002$) but no significant difference between 2008 and 2009 or 2009 and 2010. No significant difference was found between 2013 and 2014, although there is some evidence of assemblage variation in the nMDS plot (Fig. 8f). Variation between the sites may be masking any overall significant difference between the two designations.

Table 5: PERMANOVA of assemblage composition based on Bray Curtis similarity measure (significant results in bold type).

Hard Coral					
2008 – 2012					
Source	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>P</i>
Year	4	3302.4	825.6	2.1548	0.007
I/O	1	1303.3	1303.3	3.4016	0.0133
Year x I/O	4	1993	498.24	1.3004	0.1961
Residual	146	55940	383.15		
Total	155	62768			
2013 – 2014					
Year	1	2932.5	2932.5	5.8163	0.0329
I/O	1	4430	4430	0.95029	0.3022
Site (I/O)	4	18647	4661.8	5.7377	0.0001
Year x I/O	1	192.16	192.16	0.38112	0.6936
Year x Site (I/O)	4	2016.8	504.19	0.62055	0.8304
Residual	84	68248	812.48		
Total	95	96467			
Reef Fish Families					
2008-12					
Source	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>P</i>
Year	4	10412	2603.1	3.4718	0.0001
I/O	1	12967	12967	17.294	0.0001
Year x I/O	4	6868	1717	2.29	0.0007
Residual	146	1.0947	749.77		
Total	155	1.398			
2013-2014					
Year	1	2116.9	2116.9	2.8932	0.0549
I/O	1	7100.8	7100.8	2.667	0.1006
Site (I/O)	4	10650	2662.5	3.8403	0.0001
Year x I/O	1	309.65	309.65	0.42321	0.7385
Year x Site (I/O)	4	2926.7	731.69	1.0554	0.391
Residual	84	58236	693.29		
Total	95	81340			
Butterflyfish Species					
2008-2012					
Source	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>P</i>
Year	4	19686	4921.5	4.5659	0.0001
I/O	1	6249.1	6249.1	5.7975	0.0001
Year x I/O	4	9973.7	2493.4	2.3133	0.0007
Residual	146	1.5737	1077.9		
Total	155	1.9322			
2013-2014					
Year	1	1543	1543	2.034	0.1639
I/O	1	6774.2	6774.2	3.1606	0.099
Site (I/O)	4	8573.3	2143.3	2.6911	0.0001
Year x I/O	1	317.85	317.85	0.41899	0.7676
Year x Site (I/O)	4	3034.4	758.6	0.95248	0.5273
Residual	84	66902	796.45		
Total	95	87144			

523 Discussion

524 The scale of change in assemblage composition between year's pre and post Typhoon
 525 Yolanda was not found to be significantly different inside the MPA nor in the control sites.
 526 This pattern was consistent across all taxa indicating that there has been no discernible effect
 527 of the hurricane on the coral reef biota in either designation. Bythell et al. (2000) found that
 528 hurricane disturbance varies spatially across a reef ecosystem, so it is possible that the small
 529 proportion of the reefs in Sogod Bay considered in this study were not affected by the storm
 530 compared to other nearby areas. However, the bay is also sheltered geographically and as the
 531 trajectory of the storm path gained strength in the Philippine Sea east of Panaon Island the
 532 coral reefs situated to the west of the island may have been afforded some protection from the
 533 force of the storm by the land mass. Therefore it is more probable that the study site located
 534 approximately 160 km south of where the eye of the storm struck was somewhat protected
 535 and perhaps too far out of the range of where the hurricane would have had any significant
 536 impact on the reef. As no change was seen in either the experimental sites or control sites it
 537 cannot be concluded that the MPA offered the reef resilience against the hurricane event in
 538 particular. However, significantly higher measures of diversity were identified inside the
 539 designated area compared to outside the MPA, although results were inconsistent between the
 540 different indices tested.

541 Results for reef fish families were particularly encouraging, with significantly higher
 542 abundance, richness and diversity found inside the MPA across the years. Percentage cover
 543 of hard coral life forms was also consistently recorded as significantly higher inside the
 544 protected area. This coincides with work by Walmsley & White (2003) who found that hard
 545 coral cover as well as reef fish abundance and species richness increased both inside and
 546 outside four community based MPAs in the rural Philippines and was generally found to be
 547 higher inside the protected areas. Greater abundance of fleshy macro-algae outside the MPA
 548 and low percentage cover of algae overall indicates a healthy reef system dominated by coral.
 549 This supports the findings of Edwards et al. (2011) who demonstrated that local conservation
 550 measures enhanced the resilience of Caribbean reefs by preserving herbivores, thus reducing
 551 algal cover and consequently increasing the ecosystem services provided by the coral reefs.
 552 Therefore, the exclusion of fishing in the protected area at Napantao and consequent higher
 553 abundance of reef fish families, many of which are herbivorous, is plausibly the cause of the
 554 positive trends observed.

These general trends continued across both data sets despite the lack of statistical significance in differences between the two MPA designations following the change in methodology by CCC. However, differences between the sites (transect lines consisting of repeated replicates) in each designation were found to be significantly different across all taxa, indicating that inter-site variation may be masking the differences between the two designations overall. Larval dispersal from MPAs has been documented in coral as well as fish and other reef organisms (Shanks et al. 2003) and may account for the slightly higher numbers of distinct coral life forms (and the resulting measures of diversity) outside the MPA. This “spill over”, in which adult organisms as well as larvae disperse across the boundaries of an MPA as a consequence of closing an area to fishing, can increase the biodiversity of nearby fished habitat, which can in turn have a positive impact on the services provided by the ecosystem to local coastal communities (Costello 2014). However, Moffit et al. (2013) have cautioned against the use of gauging MPA success on inside versus outside measures where the outside data is recorded at spatial scales not representative of an organisms full dispersal range. This is due to spill over increasing species density to several times higher than at its full dispersal distance, leading to an underestimation in the net difference in density inside an MPA compared to if control sites are placed at greater distances.

The pattern in hard coral life forms shifted after the change in methodology with higher numbers of life forms recorded inside the MPA in the final two years of the data set. The overall increase in hard coral life forms recorded both inside and outside the protected area is to be expected as on adopting the enhanced Reef Check methodology CCC now includes additional life forms, therefore the likelihood of recording higher mean numbers in both designations rises. The decline in the percentage cover of hard corals after the change in methodology despite additional target life forms being added may be associated with the modifications to the survey design. The extension of the transects by another 50 metres may incorporate other substrate types that are recorded by CCC yet were not considered in this study, such as sand, anemones and soft corals; despite the permanent transects now covering a larger area the hard coral life forms that can potentially be recorded may not be encountered there. The sharp increase in the number of reef fish families and the number of individual fish observed post 2012 can also be attributed to the change in methodology which records additional fish families.

When considering species of butterflyfish exclusively the effect of the MPA was largely not strong enough to show a statistically significant difference between the two designations,

despite the values of the diversity measures generally being higher inside compared to outside. Recordings were dominated by just a few species, this is evident in the fact that the highest mean number documented across the entire data set was just 7.75 (± 4.92) out of a possible 48 target species; the recurrent sightings of low numbers of species may represent the contrasting associations of butterflyfish with the reef. Pratchett et al. (2008) illustrated that species such as *Chaetodon baronessa* are highly associated with the reef as they feed predominantly on live coral tissue yet other butterflyfish such as *Chaetodon vagabundus* are more generalist feeders and have limited reliance on the reef. These species show a markedly different distribution to those that predate corals which live in close association with the shallower reef areas; generalists are more widespread so it is possible that although present they were not observed as frequently during the surveys. The apparent decline observed in butterflyfish species and number of individuals from 2008-11 reflects the natural stochasticity of populations, 2008 may have been a particularly rich year for butterflyfish which makes the following years appear more depauperate when they in fact may represent more probable values. Species abundance of coral reef fish can be altered by environmental disturbance or competitive interactions; both of which may influence the recruitment of juveniles (Ault & Johnson 1998). Strange et al. (1993) found that stream fish communities showed contrasting states rather than persistent equilibrium; due to natural fluctuations in the structure of wild populations potentially similar processes underlie the dynamics of the butterflyfish assemblage on the reef at Napantao.

The results of this study illustrate that small-scale community based MPAs can meet local conservation aims but their effectiveness in terms of enhancing biodiversity is variable depending on the taxa and diversity measures considered. Walmsley & White (2003) used similar survey methods and found that although coral cover was at times recorded higher outside a protected area and fish abundance and species richness differed due to numerous ecological, biological and physical factors community based MPAs were still largely successful in improving overall ecological condition of coral reefs, although community involvement was shown to be essential in the success of these small-scale MPAs. The Philippines has a long history of establishing community based marine protected areas and NGOs (such as CCC) play an important role in the implementation and management of these reserves (Horigue et al. 2012). These small scale MPAs can be effective in achieving local conservation and fisheries objectives but may not contribute to broader scale targets as they often show a lack of consideration for wider scale ecological processes (Weeks et al. 2010).

Weeks et al. (2014) suggested that if well designed and managed community based MPAs in the Philippines are “scaled up” as part of an ecologically representative network they can contribute to larger scale biodiversity protection. Weeks et al. (2010) concluded that distances between current MPAs were sufficient enough to provide the opportunity for regional-scale MPA networks to be developed in the Philippines. It has been proposed that NGOs can play a key role in the implementation of these networks through assisting in the collaboration of neighbouring local governments of the provinces within which they operate (Horigue et al. 2012). The work of NGOs can help to ensure the success of MPA networks through promoting community stewardship of marine ecosystems and associated resources and engaging local people in conservation initiatives, although this must be coupled with strong political will from local and state government to ensure that resilient socio-economic MPA networks can be achieved and maintained (Jones et al. 2013).

Long term monitoring and further examination of the data from the recently extended transect lines is required to ensure that the observed changes in assemblage pattern stabilise and are a result of the revision in methodology, not a larger ecological occurrence. Additional analysis may need to be considered to account for the apparent masking of differences between the two designations by the addition of replicates within transect lines and a smaller, more efficient list of butterflyfish indicators used for this study site. Placing control sites further from the MPA, as suggested by Moffit et al. (2013), to better gauge the effect of the MPA on species with greater dispersal ranges is recommended. It is suggested that that the connectivity of the established MPAs in Sogod Bay be investigated to evaluate their efficiency in terms of contributing to an ecologically coherent network and broader scale conservation objectives. Comparative studies of year’s pre and post Typhoon Yolanda on other MPAs in Sogod Bay are necessary to determine if the reef ecosystem in the bay was affected at different spatial scales and whether these MPAs increased resilience against the hurricane; this can allow for contingencies to be implemented in the face of increasingly intense future storm events.

On investigating the effects of the community based marine protected area at Napantao an overall positive impact on the biodiversity of the coral reef assemblage within the MPA and adjacent fished areas was found. This increased diversity infers enhanced resilience of the reef although in terms of Typhoon Yolanda it cannot be concluded that the MPA offered the ecosystem resilience against this hurricane event as there was no discernible effect in either the experimental or control sites. Marine protected areas such as this have been shown to be

an important tool in meeting local conservation goals and harnessing community support for coral reef conservation in developing countries, where reefs provide services essential to the well-being of the local human population. However the “scaling up” of community based MPAs is necessary to form an ecologically coherent network of protected areas that genuinely contribute to broader conservation objectives for the marine ecosystem at large. This is essential to conserve declining marine resources and biodiversity, not just in the Philippines but on a global scale.

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Appendix 1: Hard coral life forms, reef fish families and butterflyfish species recorded by Coral Cay Conservation and used in analysis. Coral Cay refers to organisms by their common name as presented here.

Table 1: Hard coral life forms used in analysis. Bold type indicates additional life forms recorded by CCC and included in 2013-14 analysis.

Branching	Foliose	<i>Acropora tabulate</i>
Massive	Mushroom	<i>Acropora digitate</i>
Sub – massive	<i>Acropora branching</i>	<i>Acropora bottlebrush</i>
Encrusting	<i>Acropora sub-massive</i>	<i>Acropora encrusting</i>
Millepora – Fire coral	Heliopora – Blue coral	Tubipora

NB: CCC ceased recording *Acropora* bottlebrush in 2012 so this was not included in the 2013-14 analysis.

Table 2: Reef fish families used in 2008 – 12 data analysis

Barramundi Cod	Two-spot snapper	Jacks	Angel Fish
Blacktip Grouper	Black and White Snapper	Fusiliers	Humphead Wrasse
Peacock Grouper	Chequered Snapper	Spinecheeks	Bumphead Parrot Fish
Coral Grouper	Sweetlips	Goat fish	Surgeon fish (other)
Lyretail Grouper	Emperors	Trigger fish	Unicorn fish
Rabbit fish	File fish	Moorish Idol	Butterflyfish

Table 3: Reef fish families used in 2013-14 analysis

Total grouper	Sweetlips	Jack/Trevally	Angel Fish
Total snapper	Emperors	Fusiliers	Humphead Wrasse
Total Surgeon fish	File fish	Spinecheeks	Total Parrot fish

Anemone Fish	Sergeant Damsel fish	Goat fish	Rabbit fish
Cardinal Fish	Pufferfish	Trigger fish	Butterflyfish
Trunk/Box fish	Sand Perch	Moorish Idol	Red Breasted wrasse
Barracuda	Pipefish	Crescent wrasse	Moray Eel
Spade/Bat fish	Toby	Porcupine Fish	Squirrel fish
Lizard Fish	Scorpion fish	Ray	Sweeper
Lion fish			

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894 Table 4: Butterflyfish species used in analysis. Bold type indicates additional species recorded by CCC and used in 2013-14
895 analysis.

Panda Butterflyfish	Racoon Butterflyfish	Blue spot Butterflyfish	Red fin Butterflyfish	Big long nose Butterflyfish
Thread Fin Butterflyfish	Black-backed Butterflyfish	Spot-banded Butterflyfish	Pacific double-saddled Butterflyfish	Long fin Bannerfish
Eastern Triangle Butterflyfish	Merten's Butterflyfish	Latticed Butterflyfish	Teardrop Butterflyfish	Pennant Bannerfish
Bennett's Butterflyfish	Meyer's Butterflyfish	Reticulated Butterflyfish	Vagabond Butterflyfish	Singular Bannerfish
Speckled Butterflyfish	Spot-tail Butterflyfish	Yellow dotted Butterflyfish	Yellow tail Butterflyfish	Humphead Bannerfish
Saddled Butterflyfish	Eight-banded Butterflyfish	Dotted Butterflyfish	Copper-banded Butterflyfish	Ocellate Coralfish
Klein's Butterflyfish	Ornate Butterflyfish	Oval spot Butterflyfish	Yellow long nose Butterflyfish	Orange banded Butterflyfish
Lined Butterflyfish	Spot nape Butterflyfish	Chevron Butterflyfish	Pyramid Butterflyfish	Two eyed Coralfish
Asian Butterflyfish	Masked Bannerfish	Spotted Butterflyfish	Burgess' Butterflyfish	High fin Coralfish
Dot and Dash Butterflyfish	Brown banded Butterflyfish	Other Butterflyfish		

896 NB: From 2013 CCC recorded both Long nose Butterflyfish as one species