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Spatio-Temporal Patterns of Reef Fish Communities in Selected Marine Protected Areas in Iligan Bay, Northern Mindanao

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Abstract

The establishment of marine protected areas (MPAs) is a management strategy to avert the downward trend of capture fisheries by protecting critical spawning stock biomass that, in turn, can populate fished areas via larval dispersal or adult spillover. This study evaluates the effectivity of MPAs in improving community structure of reef fish in three sites in Iligan Bay. Spatial and temporal variations in species richness, abundance and biomass of fish communities inside MPAs and open access areas are also investigated. Results reveal that fish diversity inside the three MPAs was significantly higher ($p<0.05$) in Puting Balas Fish Sanctuary (PBFS) than in Capayas Island Marine Sanctuary (CIMS) and Tubajon MPA (TMPA). No clear spatial pattern in fish abundance was observed across sites, however, overall density decreased from its 2006-08 levels ($P<0.05$) especially in CIMS despite having been protected for five years. On the other hand, significantly higher ($p<0.05$) fish biomass occurred inside CIMS than in unprotected reefs. Overall biomass inside the MPAs did not differ significantly between periods, although a slight decrease in abundance was observed in PBSF while increasing slightly in the other sites. Across sites target food fish had significantly higher ($p< 0.001$) species richness, density and biomass than major demersal and indicator species group. Results of the study indicate generally positive, albeit inconclusive, responses of reef fish communities to protection from fishing. This study has shown that as a management tool MPA alone cannot ensure full recovery of fish stocks of a protected reef. Other factors such as climatic conditions, natural ecosystems dynamics, and human-associated impacts can shape reef fish community structure. Active involvement of all stakeholders in the MPA project is strongly recommended to ensure the sustainability of the ecological and economic benefits of reef protection.

Keywords: Marine protected areas, fish biomass, species diversity, management, Iligan Bay

INTRODUCTION

Coral reef ecosystems support a wide variety of marine life forms, particularly fish communities, providing habitat, source of food, and breeding ground for about 25% of all marine fish species (Bryant *et al*., 1998). Damage to reef ecosystems would result in a swift and dramatic reduction of the overall coastal fisheries which depend largely on the biomass of target food fish or predators. The establishment of protected zones or areas in the marine environment called marine reserves or marine protected areas (MPAs) which are free from any form of resource extraction is a management strategy to avert the downward trend of capture fisheries. MPA establishment sustained over many years will allow build-up of spawning stock biomass within boundaries and benefit nearby fishery yields (Gell and Roberts, 2002).

The expected benefit of MPAs on adjacent fisheries works through two mechanisms: (a) net migration of adults and juveniles across boundaries, and (b) export of pelagic eggs and larvae (Dalby and Sorensen, 2002). Inside MPAs fish populations increase in size; individuals grow larger, live longer and develop increased reproductive potential (Bohnsack, 1998 as cited by Gell and Roberts, 2003). In many parts around the world, well enforced MPAs have consistently contributed to biomass build-up and enhanced recruitment capability. In Kenya's Mombasa Marine National Park, reproductively active fish biomass is higher inside marine reserve (70%) than in nearby fishing grounds (20%) (Rodwell *et al.*, 2003). Many local communities of tropical countries have established marine reserves or fish sanctuaries to ensure the sustainability of fish stocks that support municipal or reef fisheries (de Guzman, 2004). In the Philippines, observation of sustained biomass build-up was reported by Russ and Alcala (1996) who documented a sevenfold increase in larger predatory reef fish after 11 years of protecting the coral reefs at the Apo Island Marine Reserve.

A major objective of MPAs as a fisheries management tool is the protection of a critical spawning stock biomass that will ensure supply of fish recruits to fished areas via larval dispersal (Dalby and Sorensen, 2002). Another strategic goal is the possible maintenance or enhancement of yields in areas adjacent to reserves by adult movements, also known as the 'spillover effect' (Russ et al., 2004). The popular concept of biomass spillover from MPAs and its efficacy in enhancing the surrounding fisheries has been the subject of many investigations (de Guzman, 2004). Scientists believe that target species spillover into fishing areas likely occurs closer to the MPA boundaries than farther away (ISRS, 2004; Russ et al., 2004). The distance traversed by moving fish in and out of MPAs, will vary among species depending on their mobility. Fish tagging and movement data demonstrate that spillover extends to a few kilometers from MPAs to fished areas particularly for more mobile species moving across ecosystems (Russ, 2002). In the Baliangao Protected Landscape and Seascape, Philippines, the potential spillover rate of target fish species from inside the core of MPA into adjacent reef area was estimated to be around 12.43% (de Guzman, 2004).

The concept of establishing a portion of a coral reef under protection is mainly a response to the decreasing trend in fish diversity, density, and body size observed in many reefs – largely attributed to overfishing and the use of destructive fishing methods. A successfully implemented MPA would lead to improvement of habitat conditions and build up of critical spawning stock biomass inside the reserve leading to increased recruitment in fished areas via larval dispersal. Fished areas adjacent to marine reserves will also benefit from MPA establishment through outward adult movements or spillover resulting in maintenance or enhancement of fishery yields.

Many coastal local government units (LGUs) invest in establishment of MPAs that often are not monitored due to lack of technical capability or insufficient funds. This study aims to investigate changes in fish community structure inside selected MPAs in Iligan Bay and in nearby unprotected areas as a means of evaluating the success of MPAs in enhancing fish diversity and abundance in the protected reef. Information generated by this study could be useful to LGUs in improving MPA management in order to maximize the ecological and economic benefits of this intervention.

METHODS

Assessment of fish communities in both protected and unprotected coral reefs was conducted in three marine protected areas in Iligan Bay (Fig. 1), namely, the Capayas Island Marine Sanctuary (CIMS) in Lopez Jaena, Misamis Occidental; Puting Balas Fish Sanctuary (PBFS) in Panaon, Misamis Occidental; and Tubajon MPA (TMPA) in Laguindingan, Misamis Oriental. These three MPAs were chosen as study sites because of their relative maturity (at least 10 years) and sustained, strict enforcement of MPA rules and regulations. Moreover, these MPAs have available historical data on diversity and abundance of fish communities inside the MPA and adjacent reefs from past assessments. These baseline data are relevant in comparing past and updated status of the reef's fish assemblages which can be used to improve management effectiveness and policy enforcement.

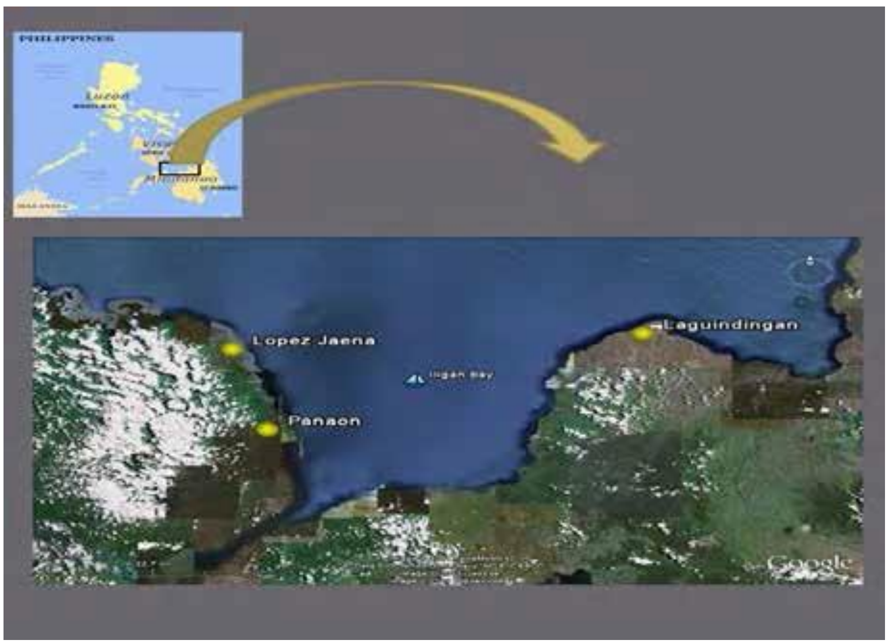

Figure 1. Map of Northern Mindanao showing location of study sites in Iligan Bay.

Assessment of reef fish communities

Raw data on reef fish assemblages were obtained from previous assessment reports in the three sites in order to determine temporal changes, if any, in fish community structure in the three MPA sites. Data on the 2006 and 2007 fish community survey in CIMS and PBFS, respectively, were available from the Participatory Coastal Resource Assessment (PCRA) report prepared by the PCAMRD Zonal Center IV for LGU-Lopez Jaena (MSU Naawan, 2006) and an assessment report prepared for LGU-Panaon by De Guzman *et al*. (unpub. data). Fish census data from the 2008 survey in TMPA were obtained with permission from the McKeough Marine Center, Xavier University as part of the Macajalar Bay Resource and Ecological Assessment (REA) project (Quiaoit *et al*. 2008).

Using the geographic coordinates obtained from previous assessments reports (MSU Naawan, 2006; De Guzman *et al*., unpub.; Quiaoit *et al*., 2008), the same reef sites were located using a Garmin eTrex global positioning system (GPS). The three MPA sites were assessed between the months of June and August 2011. Attributes of fish community structure, namely, species diversity, abundance and biomass, inside the MPA and in the adjacent unprotected reef neighboring fished area) was assessed using scuba following the daytime fish visual census (FVC) technique described by English *et al*. (1997) with appropriate modifications. Three 50 meter transects were established at two depth levels, namely, shallow (10-15 ft) and deep (33-35 ft) areas of the reef inside and outside the MPA. All species of fish found along a 10m-wide corridor along each transect (approximate area of $500m^2$) were identified using a field guide (Allen *et al.* 2003), counted, and their total length (in cm) estimated for later use in estimating fish biomass. Fish biomass was estimated using the length-weight model established for fish (Pauly, 1984) to convert size-frequency data into biomass. Values of the regression parameters a & b were obtained from the online Fishbase database (www.fishbase.org). Health of reef fish assemblages can be qualitatively described based on categories of species richness, abundance and amount of fish biomass (per $1000m^{-2}$) described by Aliño and Dantis (1999), Hilomen *et al.* (2000) and Nañola et al. (2006).

MPA Management Effectiveness

An interview with the management body and enforcing group in each site was conducted using an MPA Management Effectiveness Survey Questionnaire modified by the MPA Support Network (MSN) from the MPA Management Effectiveness Assessment Tool (MEAT) developed by CCEF ( ). The survey was made to identify past and current fisheries management practices and policies implemented in each site in line with the goals and objectives of MPA establishment. Between 12-15 respondents were interviewed in each site.

Data Analysis

The fish community structure in each site was described using different indices of species diversity (Shannon-Wiener index H') and similarity (Sørensen's similarity index) available in the PAST software using natural log-transformed data on importance value of each species (Shannon, 1948; Krebs, 1989) and similarity in species composition of fish assemblages (Odum, 1983; Magurran, 2004). Spatial differences in fish diversity, density, and biomass (inside and outside MPA), and among MPA sites were tested using one way analysis of variance (ANOVA) and t-test. Significant variations in fish diversity, density, and biomass inside the protected reef between two time periods, if any, were determined using t-test.

RESULTS AND DISCUSSION

Reef Fish Diversity

A total of 287 species of reef fishes belonging to 36 families were identified in the three study sites in Iligan Bay; 28 families were found in TMPA while 25 families were found in both CIMS and PBFS. Overall species richness was higher in PBFS (176 species) than in CIMS (133 species) and TMPA (130 species). In all sites the group of small, demersal fish had the most number of species (Table 1) with Pomacentridae (damselfishes) and Labridae (wrasses) the most diverse families. Target species commonly made up of important food fish (carnivores and herbivores) were consistently more diverse inside the MPA in all sites than in unprotected reefs.

Fish communities inside these MPAs were generally more diverse than in reefs found outside or in adjacent unprotected areas (Table 1), except in PBFS where a lower species richness was observed inside the MPA than in the reef outside. The Taytay reef outside the Panaon MPA is a naturally diverse and rich popular fishing ground of municipal fishers in this coastal municipality, however, due to its close proximity to the PBFS the local government considered it a buffer zone and enforced strict regulations. As a result fishers are discouraged from fishing here for fear of violating MPA boundaries, resulting in higher fish diversity. Analysis of species richness showed significant difference across MPA sites (ANOVA, P<0.05), most probably influenced by high species richness in PBFS compared to the other sites. Differences in species richness between MPA and non-MPA sites, however, are not significant (t-test, P>0.05). Calculated Shannon-Wiener index values indicate comparably high species diversity in all stations (H’ = 2.965 to 3.844), although did not vary significantly across sites nor inside and outside the MPA. The fish communities in the three MPA sites showed high similarity (65–73%) in species composition both inside and outside the MPA.

Table 1. Comparison of species richness of reef fishes across the three MPA sites in Iligan Bay.

	CIMS		TMPA		PBFS	
Group	Inside MPA	Outside MPA	Inside MPA	Outside MPA	Inside MPA	Outside MPA
Coral indicator	10	8	9	9	11	15
Major species	45	52	48	43	62	68
Target species	42	29	35	24	52	49
Total	97	89	92	75	124	132

MPA Codes: CIMS – Capayas Island Marine Sanctuary; TMPA – Tubajon Marine Protected Area; PBFS – Puting Balas Fish Sanctuary

Data from previous surveys in the three MPA sites were used to evaluate the changes in species richness through time. In all sites the overall species richness was higher in the 2011 assessment than in the earlier (2006-2008) surveys in both shallow and deep reef areas (Table 2). Species richness, however, was variable according to depth and site, where deeper parts of the reef had generally more species than in shallow portions. In CIMS all three fish groups (indicator species, major demersals and target species) clearly increased after five years of protection but this pattern was not consistent in the other sites (t-test, P>0.05).

Similarity indices between time periods (2008 and 2011) indicated that fish species composition in deep (34%) and shallow (44%) parts of the reef CIMS (both inside and outside the MPA) were considerably different. High similarity (59%) in species composition, however, was observed between shallow and deep areas inside the CIMS. The fish community found in TMPA 2011 had likewise a low similarity (45%) with the 2008 survey. Results suggest that fish communities inside the CIMS and TMPA had undergone a species changeover, *i.e.* some species previously found in the area are no longer found today while new species are now occupying the reef. The fish community in the PBFS remained stable with high similarity (57%) in species composition through time. On the other hand, many species of reef fish are highly mobile, and the observed changes in species richness may be attributed to difference in season, tidal pattern and time. Regular monitoring over a longer period would ascertain if these changes (increase and decrease) in fish diversity inside and outside the MPAs are indeed progressive.

Table 2. Comparison of species richness of reef fishes inside three MPA sites between two time periods.

Group	CIMS				TMPA			PBFS		
	2006[a]		2011		2008[b]	2011		2007[c]	2011	
	Deep	Shallow	Deep	Shallow	Deep	Deep	Shallow	Deep	Deep	Shallow
Coral Indicator	7	3	11	9	9	10	8	11	10	11
Major species	35	35	52	37	57	44	52	63	67	57
Target species	24	21	48	36	32	42	28	48	52	51
Total	66	59	111	82	98	96	88	122	129	119
Overall	102		135		96	130		120		176

Data sources: [a] MSU-Naawan,2006; [b] Quiaoit, et al., 2008; [c] De Guzman et al., (unpub.)

Abundance and Biomass

A spatial comparison of mean densities among fish groups (Fig. 2) shows more fish occur in the deep station of PBFS (2,672 ind.1000m^{-2}) which falls within the high abundance category according to Hilomen *et al.* (2000). Owing to the physical characteristics of the reef outside the PBFS no shallow station was identified. Fish abundance inside and outside the CIMS and TMPA sites were moderate (1100 - 1600 ind.1000m^{-2}. In all sites a similar pattern of higher density is observed in the deep than shallow stations (Fig. 2). The observed spatial differences in fish inside and outside (t-test; p>0.05) and across MPA sites (ANOVA; p>0.05), however, are not statistically significant.

Major demersal species are the most abundant in all three sites, but although abundant, most of these fishes are the commonly small-sized (<15cm) herbivores and omnivores (Fig. 3). Target food species have moderate abundance (<500 ind. 1000 m^{-2}) and are consistently higher inside the MPA than outside. This finding is consistent with observations that large-sized carnivores and herbivores (which are target of fishing) tend to increase under protection (Roberts, 1997; Russ *et al*., 2004).

On a temporal perspective, major demersal species still represented the most dominant fish group based on fish density (Fig. 4), and coral indicator species were the least abundant group. Fish density inside PBFS and TMPA after years of continued reef protection did not show significant differences (t-test; p>0.05). The decreasing pattern of density among fish groups in CIMS, on the other hand, was statistically different (t-test; p<0.05). These results seem contrary to expectations of increasing abundance of fish stocks under protection through time (Gell and Roberts, 2003; Ashworth, *et al.*, 2004). Several explanations are at once possible.

Some schooling planktivorous fish (e.g. Caesionids) are highly transient and were abundant in the 2006 survey in CIMS but were very few in the 2011 assessment. Other species are also cryptic and not so easily encountered during a fish visual survey. Still another possible reason is sporadic fishing violations in the MPA that occur despite the best efforts of the *Bantay Dagat* to guard it. These factors could lead to interannual population fluctuations in reef fish even inside protected areas.

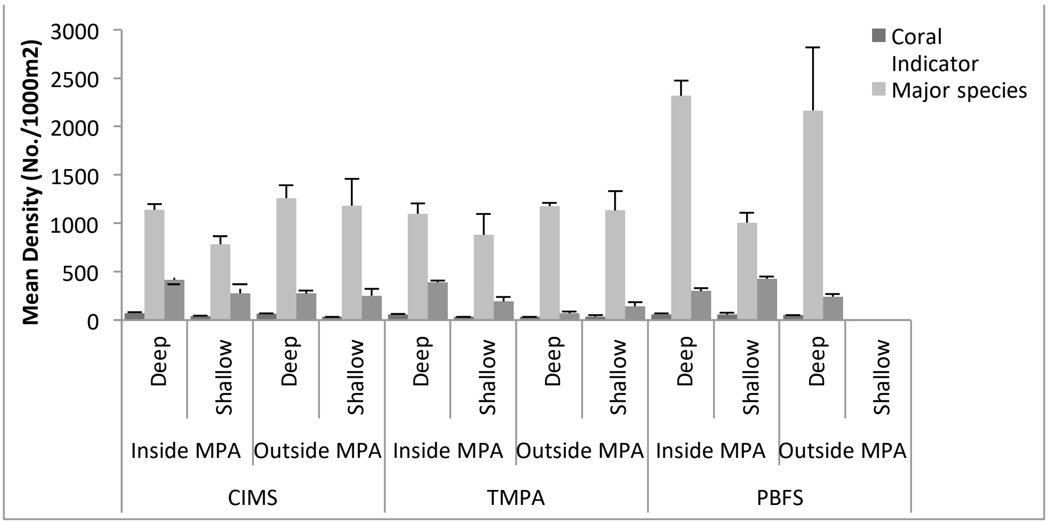

Figure 2. Spatial variation in abundance of fish groups inside and outside MPAs.

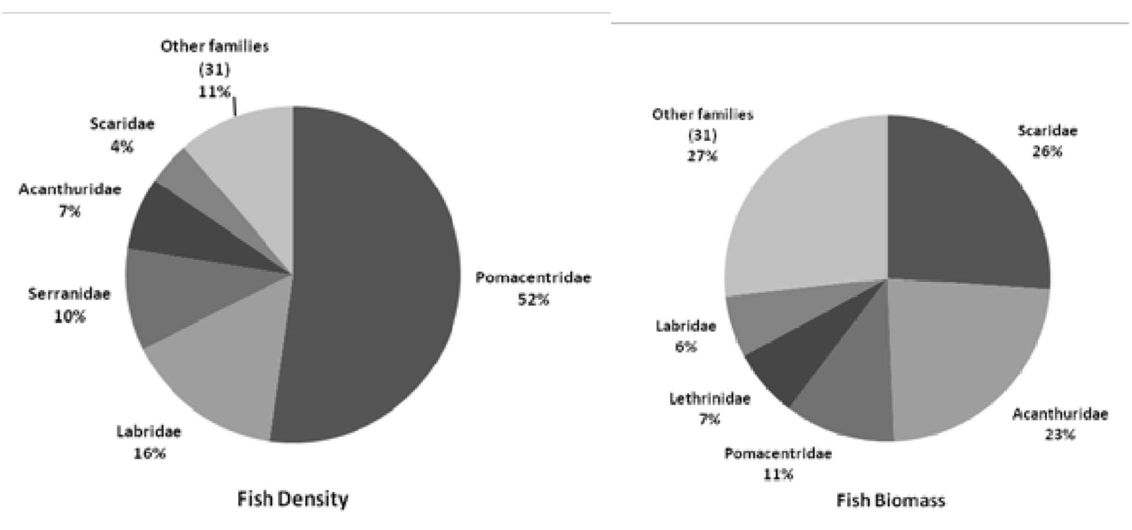

Figure 3. Top five reef fish families across MPA sites in Iligan Bay in terms of fish density (left) and fish biomass (right).

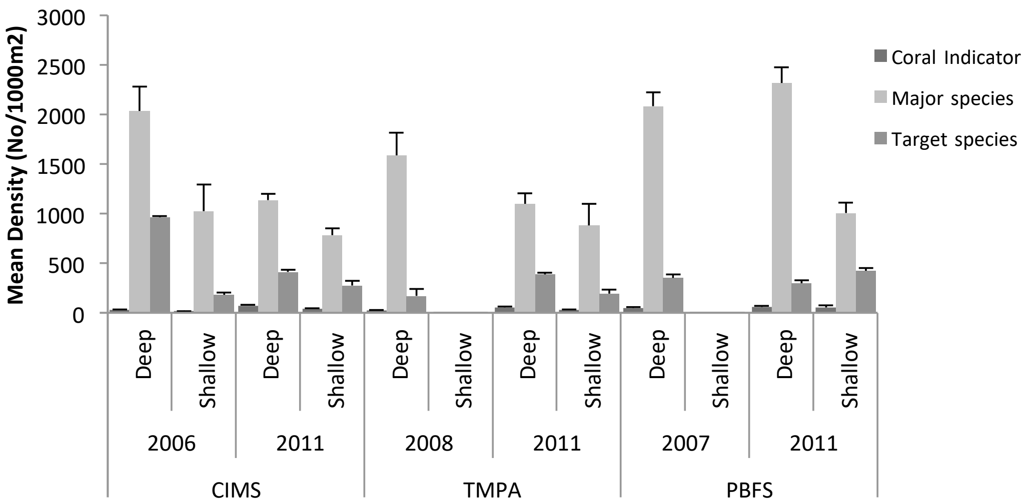

Figure 4. Temporal pattern of mean abundance of fish groups across three MPAs.

Reef fish biomass inside MPAs, in general, was relatively higher than on reefs outside the MPA. Very high biomass of reef fish (>50 kg 1000m^{-2}) was observed in the deeper parts of the CIMS and PBFS (Fig. 5). Moderate to high biomass (11-49 kg 1000m^{-2}) was found inside the TMPA but very low biomass (<10 kg 1000m^{-2}) was observed outside (Hilomen *et al.*, 2000). Target fish biomass was invariably higher (23-48 kg 1000m^{-2}) inside the protected reef, in all sites, indicating that the MPAs are successful in allowing build-up of large carnivores and herbivores. Mean biomass of target fish species was particularly high (>45kg.1000m^{-2}) inside CIMS - more than three times greater than mean biomass outside the MPA. Differences in fish biomass across depth gradients in both CIMS and TMPA sites were statistically significant (t-test; $p<0.05$).

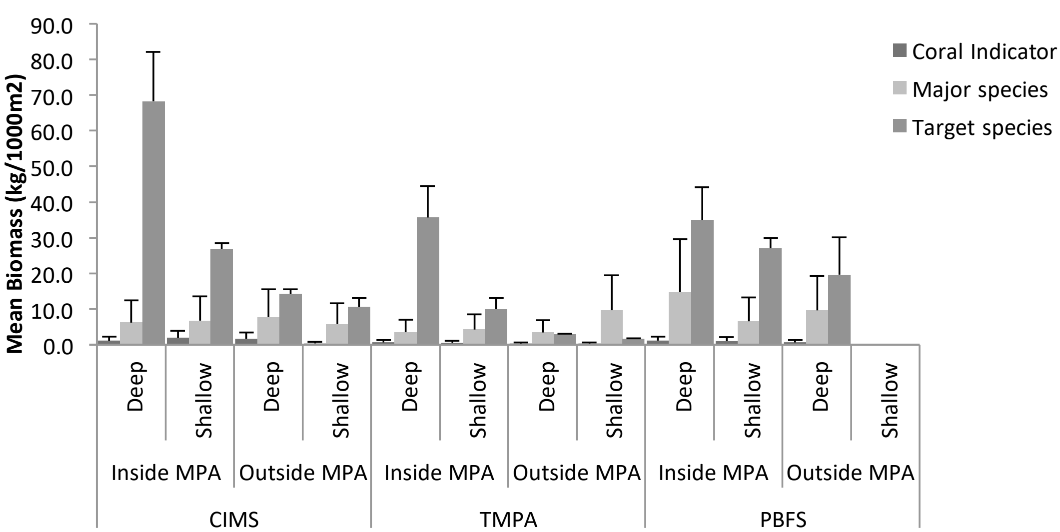

Figure 5. Spatial pattern of biomass of fish groups inside and outside the three MPA sites

Temporal patterns in mean biomass of different fish groups are variable among the three MPA sites (Fig. 6) but are not statistically significant (t-test; $p>0.05$). Mean biomass of reef fishes inside TMPA appears to have increased after three years of fishing closure since 2008, while fish biomass in both CIMS and PBFS indicated a decreasing trend after five years of reef protection (De Guzman *et al.* 2009). Once again this is a contrary result as explained in the earlier case of decline in abundance through time despite the protected status of these MPAs. Internal trophic interactions may have influenced the decreasing trends in mean population densities and overall fish biomass inside the CIMS. For example, a high proportion (33%) of carnivore species biomass (Lethrinids and Lutjanids) was observed inside the CIMS in 2011. In theory, reduced biomass of prey population in a reef is an indication of increased carnivory.

Fishing violations, albeit sporadic, can reduce the biomass inside the reef due mainly to removal of larger fish. Fish biomass can indeed build up rapidly inside MPAs but can also be fished down much faster once enforcement fails. Maliao et al., 2009 reported that the pattern of decreasing fish density inside a marine reserve after years of reef protection may suggest the prevalence of poaching. Interview with Bantay Dagat members, however, indicated that poaching violations inside the marine reserve have been stopped due to strict implementation and policy enforcement.

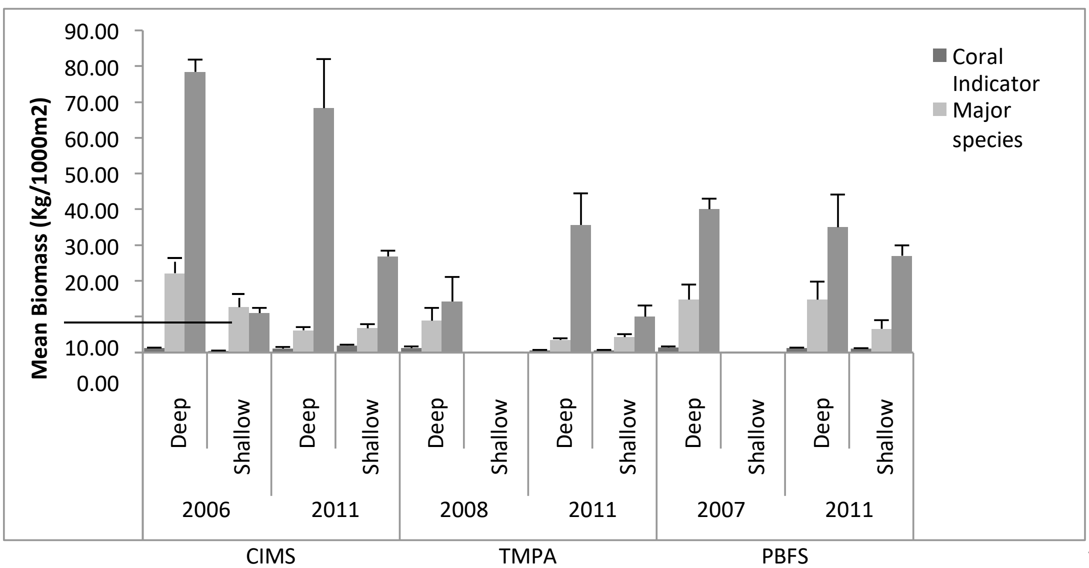

Figure 6. Temporal pattern of mean biomass of fish groups across three MPAs in Iligan Bay.

MPAs are expected to enhance or at least maintain fish populations inside their boundaries and, through spillover of adult fish, potentially enhance fish stocks in adjacent areas where fishing occurs (Gell and Roberts, 2003; Ashworth, et al., 2004). Large, commercially important fishes are preferentially fished and are, thus, expected to respond positively to reef protection because of the elimination of fishing mortality in the reserves (Roberts, 1997). In this study, however, no significant differences in mean abundance of fish groups inside and outside MPAs were observed. In fact, target fish groups have lower abundance relative to major (demersal) fish species in all survey stations. Increase in abundance of major demersal species or small-bodied reef fishes (damselfishes and fairy basslets) may be due to lower rates of exploitation, except where they are gathered for the aquarium trade which is rare in these areas at present. These fish are mostly coral-dwelling and are more reliant on the reef matrix for protection (Munday and Jones, 1998), thus, tend to exhibit high densities in many reef areas in Iligan Bay.

Effectively enforced MPAs can have a rapid impact on reef fish communities, particularly in building up biomass of target species in the absence of fishing. In this study, spatial patterns in fish biomass are more apparent than diversity and population density, with higher biomass estimates inside reserve than in fished areas. Overall high biomass estimates of target species inside the three MPAs in Iligan Bay, despite the low population density, suggest that fish inside the 'no take' areas are much bigger than in unprotected reefs.

MANAGEMENT IMPLICATIONS AND RECOMMENDATIONS

Current and historical data on reef fish community structure in the three MPAs generally support the assumption that MPA establishment can help enhance fish diversity, abundance and biomass which can be attributed to effective enforcement of 'no take' policy by the management body. Results of this study have illustrated that MPA alone as a management tool cannot ensure full restoration of habitat health and recovery of associated fish communities of a protected reef. Although MPAs have shown promising impacts, its gains can easily dissipate in the absence of strong enforcement of sanctuary regulations.

There is high premium in reef protection and enforcement of sanctuary rules. The monetary and effort investment in establishing and enforcing MPAs can be quite high; expenditure that many LGUs can ill afford. Sustained LGU support and active involvement of stakeholders in enforcing a round-the-clock protection of the MPA, are crucial to sustaining this management intervention and for fisherfolk to enjoy its ecological and economic benefits. A critical recommendation is the enforcement of a buffer zone around the core zone of MPAs. Continuing biophysical monitoring of LGU-managed or community-led MPAs should be integrated into the LGU agenda and implemented through partnership with local academic or research institution and non-government organizations.

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