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Community assemblages of commercially important coral reef fishes inside and outside marine protected areas in the Philippines

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HIGHLIGHTS

- Assessed assemblages of commercially important coral reef fishes in the Philippines.
- More diverse, higher fish density and larger fishes inside MPAs.
- Low density and highly restricted spatial distribution pattern of many species.
- More, larger, well-distributed all over the country and well-enforced MPAs needed.
- Other fishing regulation initiatives in addition to MPAs needed.

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ABSTRACT

Establishment of marine protected areas (MPA) is among the most commonly implemented initiatives for coral reef conservation and fisheries management in the Philippines. However, there are concerns that the MPAs in the country may not work because of their generally small sizes and high fishing pressures from the burgeoning highly resource-dependent population. In this study, we assessed the assemblages of seven commercially important coral reef fish families (Acanthuridae (excluding genus *Zebrasoma*), Labridae (subfamily Scarinae only), Lutjanidae, Serranidae (subfamily Epinephelinae only), Mullidae, Haemulidae and Lethrinidae) inside and outside MPAs in 37 coastal municipalities in the Philippines. A total of 12,354 individuals belonging to 114 species (33 species of Acanthuridae, 27 species of Scarinae, 17 species of Lutjanidae, 16 species of Epinephelinae, 9 species of Mullidae, 6 species of Haemulidae, and 6 species of Lethrinidae) were recorded. Overall, reef fishes inside MPAs were more diverse than outside MPAs based on Shannon–Wiener index of diversity. Reefs inside MPAs had an average of four more fish species than outside MPAs. Both inside and outside MPAs had comparable equitability values which are characterized by fish communities that are largely dominated by few species only. Higher fish densities, especially fishes with $\geqslant$25 cm (total length), were also recorded inside MPAs. However, we also found some patterns suggesting that more efforts must be made in order to effectively protect many of the commercially important coral reef fishes from the impacts of fishing. Our study provides valuable science-based insights that can be used to improve coral reef conservation and fisheries management initiatives in the country. Moreover, it can also serve as crucial information that can be used for monitoring and evaluation of MPA effectiveness, particularly on commercially important coral reef fishes in the country.

1. Introduction

Coral reefs, while occupying only less than 0.1% of the ocean floor, are the world's most diverse marine ecosystems (Gattuso et al., 2014). The global center of coral reef biodiversity is found

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in the Coral Triangle region, which covers part or the entire seas of six Indo-Pacific countries that include the Philippines, Malaysia, Indonesia, Timor Leste, Papua New Guinea and Solomon Islands. Unfortunately, the coral reefs in the Coral Triangle also happened to be the most threatened coral reefs in the world, particularly from anthropogenic disturbances (Roberts et al., 2002; Nañola et al., 2011; Burke et al., 2012). Overexploitation by tens of millions of heavily resource-dependent coastal populations, the prevalence of destructive fishing practices, the widening poverty and lack of alternative livelihoods in the region, which are further aggravated by climate change stressors, are seriously undermining the future of these valuable ecosystems (Roberts et al., 2002; Green et al., 2003; Halpern et al., 2008; Cabral et al., 2013; Mamauag et al., 2013; Muallil et al., 2014a; Teh et al., 2013; Cinner, 2014).

Located at the apex of the Coral Triangle is the Philippines, where the highest concentration of marine fish diversity is found (Carpenter and Springer, 2005). Nañola et al. (2011) documented a total of more than 700 coral reef associated fish species (205 genera and 52 families) from underwater surveys undertaken from 1991 to 2008 on coral reefs all over the Philippines. Unfortunately, one of the major findings of the study was the apparent local extinction of fishes in heavily populated areas in central Philippines that used to be the center of fish diversity in the country. Other studies have also documented either complete disappearance or severe biomass reduction of some large-bodied and commercially important fishes in the country (Maypa et al., 2002, Lavides et al., 2009, Mamauag et al., 2009). There have also been various reports about drastic declines in fisheries catches over the past few decades in major fishing grounds in the country (Green et al., 2003; SuPFA, 2006; Muallil et al., 2014b). Anthropogenic disturbances, particularly overfishing from a rapidly increasing fishing population and the rampant destructive fishing methods such as blast and poison fishing, were attributed as the major causes of fishery decline (White et al., 2010; Muallil et al., 2014b). Some studies suggest that the coral reefs in major coastal fishing grounds in the country can no longer produce enough fish to meet the current protein needs of the increasing coastal population (Newton et al., 2007; Licuanan et al., 2008; Muallil et al., 2014a).

Establishment of marine protected areas (MPA) is among the most commonly implemented initiatives in the Philippines to reverse habitat degradation and the declining coral reef fisheries productivity. MPAs are thought to enhance local fisheries outside MPAs either by net movement of adults (''spillover effect'') or net export of larvae (''recruitment effect'') from MPAs (Russ, 2002). In fact, the number of MPAs in the Philippines has increased from less than a hundred in 1990 to around a thousand in 2008, or equivalent to an increase from ∼2000 km^2 to ∼15,000 km^2 of total MPA area (Weeks et al., 2010). Currently, there are already more than 1600 MPAs in the country, mostly community-based or locally managed (Cabral et al., 2014; White et al., 2014). Establishment of MPAs was further accelerated by the enactment of the Fisheries Code of 1997, also known as the Republic Act 8550, which calls for all coastal municipalities to allocate 15% of coastal waters as MPA. Active support from various NGOs also played a vital role in the expansion of MPAs. There have also been recent initiatives toward collaborative efforts through establishment of MPA networks to enhance both physical (i.e. larval dispersal) and social (i.e. sharing of experiences and costs) connectivity for more effective MPA management (Melbourne-Thomas et al., 2011; Horigue et al., 2012). There are also incentive systems for MPA best practices in the country such as the biannual MPA awards and recognition (Para el MAR) sponsored by the Marine Protected Area Support Network (MSN) since 2007.

However, there are concerns that MPAs in the country may generally be too small to be effective for biodiversity conservation and fisheries management (Edgar et al., 2014; Green et al., 2014), especially in the face of high fishing pressure from the burgeoning highly resource-dependent coastal population (Muallil et al., 2013, 2014a). Almost 90% of all the MPAs in the country have less than 1 km^2 area (White et al., 2014), which is much smaller than the recommended MPA size based on the predicted distance of larval dispersal (Shanks, 2003; Edgar et al., 2014; Green et al., 2014).

This study assessed the status of commercially important reef fishes on coral reefs all over the Philippines. Specifically, we described coral reef fish assemblages such as diversity, species composition, density, size characteristics, spatial distribution and determined whether fish assemblages differ between reefs inside and outside MPAs. The study was based on systematically collected data from all over the Philippines, which can provide valuable insights for effective management of coral reef fisheries in the country.

2. Materials and methods

2.1. Study sites

The study was conducted in 37 coastal municipalities or sites covering all the six biogeographic regions in the Philippines (Aliño and Gomez, 1994) (Fig. 1). All the sites lie within 6°30′–17°30′ N to 119°00′–127°00′ E coordinates. Each municipality had at least one established locally-managed MPA where reef fish surveys were conducted. Surveys were also conducted on reefs outside MPAs with a distance of at least 200-m from the boundaries of MPAs. All surveys were performed from 2012 to 2013, mostly during the transition period, between Northeast and Southwest monsoons, when weather condition is calm and most ideal to perform underwater surveys.

2.2. Underwater surveys

Reef fishes were surveyed by SCUBA diving along 50-m long by 10-m wide belt transects established randomly in upper slope of reef crests with depths ranging from 6–12 m. This was done by searching first for the reef crests then randomly laying the transects along an isobath. In each site, 8–12 transects were surveyed, half of which were established inside MPAs and the other half outside MPAs. All underwater surveys were conducted between 9:00–16:00 h.

Data were collected using a non-destructive fish visual census (FVC) technique (English et al., 1997) where a diver swam slowly and stopped every 5 m to record all of the fish within a 5 m-long × 10 m-wide area (Nañola et al., 2011). Each fish was identified to the species level and total length (TL) was estimated to the nearest 1.0 cm. Only fishes with more than 5.0 cm TL were included in the analysis. Most of the FVC data were collected by the second and third authors, who combined already had over five years of experience of actively performing FVC. Three other professional divers, who had occasionally been performing FVC surveys together with the two main divers mentioned above, also helped in the data collection.

2.3. Analyses

Generally, small-scale fishers in the Philippines are increasingly becoming less selective in their target fish (Muallil et al., 2014b), which makes it difficult to classify each species based on whether it is commercially important or not. Further, aquarium fishing is an important fishery in some areas. Thus, for simplicity, only species belonging to major fish families of commercially important coral reef associated demersal fishes such as Labridae (subfamily Scarinae or parrotfishes only), Acanthuridae (surgeonfishes),