Evaluating the Conservation Effectiveness of Partially Protected Marine Areas for Commercially Important Fishes in Bicol Region, Philippines

（フィリピン・ビコール地方における部分禁漁区の魚類資源保全効果に対する評価）

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Marine Protected Areas (MPA's) known as no-take zones (fully protected areas) that are closed to fishing have been widely promoted in the last few years as a powerful tool to prevent the overexploitation of fish stocks (Roberts and Polunin, 1991). Evident manifestation of the acceptance of MPAs as a fisheries management approach for combating the threats to the marine environment is the exponential increase in the number of MPAs throughout the world (Pauly et al., 2002). The threats to the marine environment comprise the overexploitation of marine resources, habitat degradation, destruction, pollution, and recent climate change (Halpern et al., 2008). A global assessment of coral reef MPAs has shown that the problem is related to inadequate management. In particular, the management of MPAs is very limited in the Southeast Asia region (Mora et al., 2006), which contains the most diverse marine ecosystem throughout the world. Indeed, the Philippines are considered epicenter of global biodiversity (Carpenter and Springer, 2005), unfortunately, the marine resources in the Philippines are experiencing the highest level of anthropogenic and climatic threat (Roberts et al., 2002; Burke et al., 2012). In addition, more than two million people in the Philippines depend on fisheries for their employment, where approximately one million are directly dependent on reef fisheries (Barut et al., 2003). Therefore, the pressure imposed by fishing on the marine environment is very high. The establishment of MPAs is considered one of the most achievable protection methods, particularly for coastal resource management in the Philippines (White et al., 2002).

The main goals of the MPAs in the Philippines are biodiversity conservation and protection, enhancing fisheries, and promoting eco-tourism. There are four types of MPAs: 1) marine sanctuaries or no-take zones (fully protected areas) where all activities are prohibited except for educational and research purposes; 2) marine reserves (partially protected areas) where extractive and non-extractive activities are regulated, including the traditional forms of fishing specified in the local fishery ordinance of each MPA site; 3) marine parks to manage ecosystem protection by providing recreational and tourism facilities, including recreational fishing; 4) protected landscapes and seascapes where the protection extends beyond the marine environment, including rivers and mountains (Miclat and Ingles, 2004). The first two types of MPA mainly aim to enhance fisheries in adjacent fishing grounds whereas the other types are for recreational purposes. Among the MPAs in the Philippines, 70% aim to protect resources within the MPA in order to enhance fisheries in neighboring waters (Campos and Aliño, 2008). In the Philippines, the typical MPA model comprises both fully protected and partially protected areas (Philippine Coastal Management Guidebook No. 5, 2001). In the region 980 MPAs were established from 1970 to 2008, covering a total area of 14,943 km^2, with 942 MPAs incorporating regions of complete protection with a combined area of 1495 km^2 (Weeks et al., 2010). While the remaining 90% of the total area of MPAs are partially protected area, the effectiveness of partially protected marine area for conservation of marine resources targeted by fishery received slight attention in this country probably because of difficulty in investigating both biological (species richness and abundance) and social (fishing activity, gear types and catch) aspect of MPA.

The main objective of the study was to evaluate the effectiveness of partially protected areas at conserving commercially important fishes. I considered the following three main research questions.1) Is the typical size partially protected area (~1 km^2) in the Philippines effective as conservation tool for commercially important fishes? 2) What are the features of effective partially protected areas? 3) What are the management issues related to institutional arrangement of partially protected area. In this study, first I summarized the issues of MPAs as fisheries management approach in global scale and in the Philippines (chapter 1). Next I evaluated the conservation effectiveness of partially protected area in San Miguel Island (SMI) MPA, a typical size of MPA (~1 km^2) in the Philippines (chapter 2). Then, I investigated other MPAs with varied features such as the size (large or small), age (old or young) and design (conventional or non-conventional) as factor that might affect partially protected area effectiveness as conservation tool (chapter 3). Finally, I interviewed key players in the MPA management to identify salient information on management issues (chapter 4).

Chapter 1. General Introduction

Various works on MPAs in the Philippines and in other regions were reviewed (Chapter 1). The effectiveness of no-take MPAs (fully protected areas) in the Philippines is well documented, e.g., the Apo and Sumilon marine reserves (Russ and Alcala, 1996, 2003, 2004; Russ et al., 2005). Unambiguous empirical studies revealed that application of no take zone marine reserve (fully protected areas) increases exponentially the fish biomass and removal of the reserve status (open to fishing) reduces fish biomass dramatically. On the other hand, application of partially protected areas status results to equivocal findings of varying magnitude. Some studies found that partially protected areas enhance fish abundance of commercially important fishes, while other found no substantial benefits over open fishing areas. Beukers-Stewart et al. (2005) found that partially protected areas enhanced the abundance and reproductive potential of exploited species, whereas Denny and Bobcock (2004) found no substantial benefits compared with open fishing areas for commercially important fish. The establishment of partially protected areas is an ecologically sound and effective fisheries management approach in areas where total fishing restrictions are not suitable due to socioeconomic constraints, and where increasing the area to > 1000 km^2 would render it ineffective (Sciberras et al., 2013, 2015). There were many studies on effectiveness of fully protected areas in the Philippines (e.g., Apo and Sumilon marine reserve) but not in partially protected areas despite of significant proportion of MPAs total area in the Philippines are partially protected marine areas.

Chapter 2. Partially protected marine area renders non-fishery benefits amidst high fishing pressure: A case study of San Miguel Island MPA

The study (Chapter 2) evaluated the conservation effectiveness of typical size MPA in the Philippines (~1 km^2). Although a degree of protection exists in a partially protected area, whether this protection is effective in promoting a significant increase of species richness and fish abundance of commercially important fishes as compared to an adjacent open fishing zone remains to be assessed, particularly given the influence of high fishing pressure/intensity in the area. To test the hypothesis, the principal investigator compared the two zones of MPA and the adjacent unprotected area for the following: (1) the characteristics of the benthic environment; (2) species richness, abundance, and distribution of body size of commercially important fishes; (3) fishing activity in the partially protected area of MPA was compared with that in the adjacent unprotected area.

Visual transect survey were conducted by snorkeling in continuous coral reef habitats in the back reef zone of the San Miguel Island MPA in Lagonoy gulf, Bicol Region (an MPA with the typical size found in the Philippines). The size of the reserve MPA (1 km^2 completely protected zone and 1.25 km^2 partially protected area) is the typical size of an MPA in the Philippines, 90% of all MPAs having a total area of < 1 km^2 (Weeks et al., 2010). The San Miguel Island MPA was recognized as the second best-managed reef in the Philippines in 2001 by PhilReefs, a consortium of conservationist organizations in the Philippines working for the protection, rehabilitation, and management of coral reefs. For this reason, the MPA was considered a suitable site for the current study. Species richness, abundance, and body size distribution of commercially important fishes were quantitatively compared among the three zones (sanctuary, reserve, and buffer) of the San Miguel Island MPA and the adjacent unprotected area using the underwater visual belt transect survey method. In each zone, a total of ten belt transects (1 x 50 m; n = 3 during May 2009, n = 3 during May 2010, and n = 4 during December 2014) were laid haphazardly at least 10 m apart in continues coral reef habitat of the back reef zone. Benthic points were recorded every 1 m along each transect (total 51 points per transect from 0 to 50 m). Hard corals were classified as live or expired. Other benthos and benthic substrates such as seagrass, *Sargassum*, coral rubbles, and sand were additionally recorded. Raw benthic community data in each zone were expressed as percentage cover.

Interview survey were also conducted to clarify differences in the fishing pressure in partially protected and open fishing areas. Fifty percent of artisanal fishers in MPA site were selected as respondent to determine their fishing activities in both zones. Artisanal fishermen were the respondents of the survey, primarily due to their fishing activity, concentrated mainly in the nearby area including the reserve zone of MPA and the unprotected area. Information including the age and years of experience as a fisherman were collected from the village. The questionnaires were developed to investigate the characteristics of the fishery and the species composition of fishes caught in the reserve zone of MPA and the unprotected area.

During the study period, 75 species in 13 families of commercially important fishes were observed in the three zones of the San Miguel Island MPA and the adjacent unprotected area. Species richness and abundance of target size commercially important fishes or size above the minimum catch size of the fishers in fully protected area were significantly higher than those in partially protected area, and open fishing area. On the other hand, no significant difference was found between partially protected area and open fishing area. Non-target size fish or size below the catch size of the fishers were not significantly different among the three zone.

The sanctuary and the unprotected area were characterized by a high percentage cover of live coral (cover of 50% by *Acropora* and non-*Acropora* species), 20%–30% of dead corals, and < 20% coral rubble and sand. The reserve zone was largely characterized by the presence of *Sargassum* bed (cover > 40%), with a low live coral cover (8%), 21% dead corals, < 14% of coral rubble, seagrass, and sand, whereas the buffer zone was mostly composed of dead corals (49%), coral rubble (22%), sand (14%), and merely 15% live corals. Benthic character among the three zones were not different, particularly the percentage cover of live coral in fully protected and open fishing area.

The type of fishing gear used in the reserve and non-reserve area were the same, consisting of traditional and passive fishing gear (characterized by the absence of mechanics and/or the pursuit of the target species). A combination of gill net and spear fishing constituted ~50% of fishing activity in the reserve and the unprotected area. Fishing indices (e.g. type of fishing gear, fish catches, and number of fishing days) that indicate fishing pressure between partially protected and open fishing area were not significantly different.

The results indicated that partially protected areas rendered ineffective amidst high fishing pressure. I looked into the various MPAs with varying features (e.g. young and old; large and small; conventional and non-conventional design MPAs) that might affect the conservation effectiveness of partially protected areas in Lagonoy gulf, Bicol region of the northeastern Philippines (Chapter 3). The study was conducted in the Bicol region, which is one of the few areas of the Philippines with several types of established partially protected areas (Weeks et al., 2010).

Chapter 3. Partially Protected Marine Areas as Conservation Tool for Commercially Important Fishes in the Philippines: Do Age, Size and Design Matters?

Theoretically, a large partially protected area should be more effective than a small area because the density of fisherman will be higher in small MPAs, thereby increasing the fishing pressure. Moreover, older partially protected areas are expected to be more effective than newer ones because they contain higher numbers of larger adults, which might increase the production of propagules (eggs/larvae) of the target species (Claudet et al., 2008). Finally, conventionally designed MPAs should be more effective than non-conventional designs because the fully protected area is surrounded by a partially protected area in the conventionally designed MPA, which reduces edge effects. The non-conventional design exposes greater amounts of edge habitat, which can also have negative effects on "interior" target species (Kritzer, 2004). This may occur when MPA boundaries are highly fished and the adjacent habitats do not offer the same refuge for fishery target species as those near the center of the MPA. To evaluate the potential effectiveness of partially protected areas, I compared two MPA zones (fully protected and partially protected areas) and the adjacent open fishing area in four functional MPAs by assessing the following based on an underwater visual transect survey: (1) the characteristics of the benthic environment; (2) species richness, abundance, and size distribution of commercially important fishes (e.g. fishery target and non-target size); and interview survey of artisanal fishers for; (3) fishing activity in the partially protected area and adjacent open fishing area.

Four MPA sites in Lagonoy gulf were investigated using similar methodology in the previous study (Chapter 2), but the transect number in each site were increased (1 x 50 m, n = 15 per zone). The area of the gulf is 3701 km^2 and it contains eight established MPAs. Of these, four are functional MPAs while the others are considered paper MPAs. The mean sea surface temperature in the gulf varies from 26.5 °C during June–October to 28.5°C during November–May, and the mean salinity ranges between 33–34 ppt. Each MPA contains both fully protected and partially protected areas, and they differ in terms of their size, year of establishment, and design, despite having similar fishing restrictions. The MPA designs in the study area were divided into two types: (1) the conventional type with a fully protected area in the center surrounded by the partially protected area, and (2) the non-conventional type with a fully protected area adjacent to the partially protected area. Agojo and Tiwi are large with the conventional type of MPA design, where Agojo is old whereas Tiwi is relatively new. Atulayan and SMI are both small with non-conventional designs, where Atulayan is old whereas SMI is relatively new. In the gulf, the MPAs are either single small partially protected area with non-conventional design and single large partially protected area with conventional design MPA.

The underwater visual belt transect survey method was conducted during December 2014 in SMI with four transects in each zone, and from April to October during 2015 and 2016 at the other sites, including the remaining 11 transects of SMI. These periods were the onset and conclusion of the recruitment season for many fishes in this region (Dioneda et al., 2004). Each census was conducted between 9:00 h and15:00 h by snorkeling (Agojo and SMI) or using SCUBA gear (Atulayan and Tiwi), which depended on the water depth at the study site, and each transect was surveyed once.

Interview survey were conducted in the fishing villages adjacent to the location of each MPA. Artisanal fishermen were the respondents in the survey, mainly because their fishing activities were concentrated in the nearby area, including the partially protected area of the MPA and the open fishing area. Information including the ages of fisherman and their number of years' experience were collected from key informants in the village. According to information obtained from the artisanal fishermen at each MPA site, 50% of the population was identified as respondents based mainly on their fishing experience, which ranged from 5–30 years.

The results showed that in terms of species richness for the target size fish per family, Labridae was the most dominant in the three zones (Agojo: 1.4–3.0 species per 50 m^2, 6.7–14.3%; Atulayan: 0.9–4.4, 3.3–16.4%; Tiwi: 2.0–4.3, 8.6–18.5%; SMI: 1.3–4.5, 6.7–23.2%), except Acanthuridae was dominant in the fully protected area of Agojo (3.1, 14.8%) and in the open fishing area of Atulayan (2.2, 8.2%). Scaridae was the most dominant in the partially protected area of Atulayan (1.9, 7.1%). In terms of the abundance of target size fish per family, Acanthuridae was the most dominant in the three zones (Agojo: 0.7¬–11.7 fish per 50 m^2, 1.2–19.3%; Atulayan: 5.0–11.8, 7.5–17.7%; Tiwi: 8.5–14.3, 10.4–17.4%; SMI: 1.5–9.1, 2.7–16.1%), except for Scaridae in the fully protected area of Atulayan (12.1, 18.1%). Similarly, Siganidae was dominant in the partially protected area of Agojo (8.2, 13.5%) and SMI (4.5, 8.0%), and Labridae in the open fishing area of Agojo and SMI (Agojo: 2.2, 3.6%; SMI: 3.0, 5.3%). Species richness and abundance of commercially important target size fish were significantly higher in fully protected area than those in partially protected and open fishing area in each MPA site. On the contrary, partially protected area was significantly higher than open fishing area only large and conventional design partially protected area (Agojo and Tiwi). No significant difference was observed in non-target size fish among the three zones in each MPA site. A comparison of the size distributions of the four fish species (*A. nigrofuscus*, *C. sordidus*, *S. rivulatus*, and *S. spinus*) showed that they were larger in the older MPA (Agojo) than the relatively new MPA (Tiwi)

The fully protected areas in the four MPAs were characterized by a high percentage cover with live hermatypic coral (cover > 50% Acropora, non-Acropora, and Porites species), 22–46% dead coral, < 10% cover with other fauna and abiotic components. In the partially protected areas, the percentage cover of live coral was more than 50%, except in Agojo (44%) and SMI (20%), followed by 31–48% dead coral, 3–25% other fauna, and only 4–24% abiotic components. In the open fishing areas, the cover percentages were 45–51% live coral, 29–51% dead coral, 0.8–3.7% other fauna, and only 3–18% abiotic components. Benthic character among zones in each MPA site were the same, in particular live coral (*Acropora,* non-*Acropora* and *Porites*).

The types of fishing gear used in the partially protected and open fishing areas in each MPA site were the same, where they comprised traditional and passive fishing gear (characterized by the absence of mechanics and/or the pursuit of the target species). Most fishermen used hook and line, and gill net combinations (~50%) as gear in the four MPA sites. In addition, fishing indices between partially protected and adjacent open fishing areas were not significantly different in each site.

This study showed that the species richness and abundance of commercially important target size fishes were significantly higher in the fully protected areas than the partially protected and open fishing areas in the four MPA sites. The species richness and abundance of target size fish were significantly higher in the partially protected areas than the open fishing areas of large MPAs with the conventional design (Agojo and Tiwi), which might not have been due to the lower fishing intensity in the partially protected areas of Agojo and Tiwi because the fishing intensity was the same in the partially protected and open fishing areas. Large with conventional design and manage for longer period partially protected area are probably effective conservation tool for commercially important fishes because it harbors larger fish individuals, despite of high fishing activity.

Chapter 4. Institutional Organization and Management Issues Affecting Partially Protected Marine Areas in Lagonoy Gulf, Bicol Region, Philippines

Given the numerous studies of biological aspects of MPAs (e.g., partially protected areas), there is no doubt that they yield huge benefits. In the Lagonoy gulf, partially protected marine areas are effective as a conservation tool for commercially important fishes (see Chapter 3), where their effectiveness is attributed to the features of the MPAs, which are large with a conventional design (e.g., Agojo and Tiwi) rather than small with a non-conventional design (e.g., Atulayan and

San Miguel Island). Thus, not all partially protected areas are effective at all times. Compliance with fishery ordinance is another issue that can influence the effectiveness of MPAs. The International Union for the Conservation of Nature and Natural Resources suggests that the success or failure of MPAs depends on the specific objectives of the stakeholders (Pomeroy et al., 2004), but the effectiveness of MPAs actually depends mainly on compliance, particularly by fishermen because fishing can greatly degrade global marine ecosystems and biodiversity (Pauly et al., 2002). MPAs are expected to satisfy both biological and socioeconomic needs, and thus the success of an MPA can be ensured by combining community participation, environmental education, economic incentives, and legal mandates in an appropriate manner for a specific site with long-term institutional support from government, non-governmental groups, and academic or other institutions (White and Green, 2003).

In this study, key informant interview (e.g. Chief local executive, Fishery law enforcement team and Municipal agriculturist) were conducted to collect vital information in MPA management. Examination of documents such as ordinances was done to enhance the accuracy of information gathered. Pertinent information's were identified that play crucial role in the perceived success of partially protected area and MPA management.

Management issues identified were categorically grouped into biophysical level which involved direct influence to the biological integrity of MPAs (e.g., habitat condition, fish species richness and abundance) and societal and enforcement level which directly involved in societal perception, behavior of stakeholders and resource manager that indirectly affect the MPA functionality. Management issues related to biophysical level in partially protected area were the use of illegal fishing gears and non-sustainable fishing practices, diminishing public awareness of laws and consequence of illegal activities and intrusion of fishers from other fishing municipality/villages. Societal and enforcement level involves lack of monitoring mechanism of marine resources, efficient communication between key players of management. Management issues identified directly connected to lack of alternative source of income of stakeholders, proper implementation of fishery ordinances and logistic support from the government. Management issues arises in each MPA site cannot be dichotomized into institutional arrangement related e.g., Local Government-initiated (Agojo and Atulayan) and Community-initiated (SMI and Tiwi). This study suggests that the diversity of socio-political condition of stakeholders might affect the attainment of partially protected areas as conservation tool for commercially important fishes. In addition to the fishers and community-led participation and discussions about partially protected area adequacy also can led to more realistic expectations about what those areas can achieve. Economic intervention provided to the affected stakeholders and resolution of conflict between key players of MPA management will ensure the attainment of MPA objectives. A poorly managed social dynamics have real consequences for biological resources.

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