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Effect of the creation of a marine protected area on populations of Coral Trout in the coral triangle region

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HIGHLIGHTS

- Evaluated marine protection area on population recovery of Coral Trout.
- The population of Coral Trout recorded higher inside marine reserve.
- Low compliance and illegal fishing inside marine reserve impact on fish abundance and biomass.

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ABSTRACT

Reef fish respond differently to reserve protection. The abundance and biomass of sedentary species and those with limited mobility should be higher inside the marine reserve and decline with increased distance from the center of the reserve. Reserve protection reduces fishing mortality and allows recovery or maintains fish population abundance within the reserve. We assessed the effects of protection on reef fish, including three species of Coral Trout (*Plectropomus* spp.), and hard coral cover at a marine reserve surrounding Lankayan Island, Sabah Malaysia, after 11 years of a 'no-take' policy. Underwater visual census conducted at 8 closed sites and 4 open sites indicated that total reef fish biomass and abundance, and *Plectropomus* spp. biomass were significantly higher inside the reserve. Eleven years of no-take policy appears to maintain *Plectropomus* spp. biomass up to 5 km from the reserve center. Hard coral cover influenced reef fish abundance and biomass but it did not affect the presence of *Plectropomus* spp. Our findings suggest that the effectiveness of a no-take marine reserve not only requires consideration of ecological connectivity, reserve size and location, but also socio-economic factors including compliance, enforcement availability and community participation to achieve greater benefits.

1. Introduction

Many of the world's tropical reef fisheries are overexploited and are in danger of collapse (Agardy, 2000; Zeller and Russ, 2004) from unsustainable fishing practices, increased pressure from human population growth, and economic development that has led to higher fishing effort (Palumbi, 2004) and habitat degradation. No-take marine reserves or strict Marine Protected Areas (MPAs) have been used worldwide as a fisheries management tool to reduce the impact of overfishing and to allow restoration of fish populations (Agardy, 2000; Ormond and Gore, 2003; Mar Lopez-Rivera and Sabat, 2009). Protection from fishing pressure is one of the strongest factors affecting fish abundance and diversity in the marine reserve (McClanahan and Arthur, 2001). Effectively managed no-take marine reserves maintain sufficient biomass of reproductively active fish within the reserve to replenish fish stocks (Roberts, 1997; Rodwell et al., 2002; Sale et al., 2005). Several studies have indicated fishery benefits of MPAs, as evidenced by an increase in total biomass and species richness of reef fish within the MPAs. For example, species richness of fish community and biomass of many reef fish families were higher at Seychelles' marine protected areas where protective regulations were effectively enforced (Jennings et al., 1996). After more than 18 years of protection at Apo Island, Philippines, Russ et al. (2004) documented significantly higher hook and line catch per unit effort (CPUE) of surgeonfish (Acanthuridae) and jackfish

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(Carangidae) outside of the reserve, indicating a potential spillover effect. Furthermore, a small no-take reserve (∼500 m length) at Wakatobi National Park demonstrated an increase in several populations of grouper species over 5 years of protection effort (Unsworth et al., 2007). Moreover, abundance, biomass and species richness of large edible species such as Serranidae, Lutjanidae and Lethrinidae were also reported to increase within 5 protected islands in New Caledonia (Wantiez et al., 1997).

No-take marine reserves are predicted to benefit adjacent fisheries through two mechanisms: (1) net emigration of adult and subadult specimens and (2) export of pelagic eggs and larvae to areas outside the reserve (Gell and Roberts, 2003). Protection from fishing pressure increases the abundance and biomass of fish inside the reserve but whether it benefits fish catch in adjacent areas requires more empirical study (Crowder et al., 2000; Sale et al., 2005). No take marine reserves play a critical role inside the designated reserve areas and promoting emigration of adult or sub-adult specimens as well as spillover of larvae to areas outside the reserve. Several studies have looked at patterns in fish abundance across no-take area boundaries to deduce evidence of spillover (Rakitin and Kramer, 1996; Ormond and Gore, 2003). For example, a decreasing gradient of fish biomass across a no-take area boundary may indicate export (Forcada et al., 2008). Spillover can occur when fish density per unit area in the reserve exceeds the maximum carrying capacity, leading to a positive gradient of migration of fish towards the adjacent area (Rodwell et al., 2002; Pérez-Ruzafa et al., 2008). Furthermore, several studies have evaluated the benefits of marine reserves based on the duration of protection, size of the area under protection, distance from the no-take zone (Claudet et al., 2010; Vandeperre et al., 2011), species behavior and mobility (Claudet et al., 2010), habitat continuity (Hackradt et al., 2014) and results from effective management (Maypa et al., 2012).

Several marine parks and marine conservation areas have been established in Malaysia for biological, fishery, and cultural conservation and management. However, there is no empirical study yet to demonstrate the potential effectiveness of these measures on fisheries enhancement in Malaysia. Reef fish contribute significantly to commercial fisheries in Sabah (Cabanban and Biusing, 1999). Several other developing countries also depend on reef fish as sources of protein and employment (Levin and Grimes, 2002). Surveys conducted in 2004 by Daw (2004) and 2002–2004 by Scales et al. (2007) indicated that reef fish populations have declined in Sabah, Malaysia. Massive harvesting of large-sized groupers (Serranidae), wrasses (Labridae) and snappers (Lutjanidae) that support the Live Reef Food Fish Trade (LRFFT) is of serious concern because it threatens the sustainability of the fishery (Sadovy and Vincent, 2002; Gillett, 2010). Sadovy et al. (2003) estimated that to support the fishery, the yield of groupers reached about 0.4 tons km^2 year. The exploitation of groupers is excessive, resulting in the absence of adult reproductive fish in many reefs (Daw, 2004). Humphead Wrasse (*Cheilinus undulatus*) and Coral Trout (*Plectropomus leopardus*) are highly prized in the LRFFT and cannot be cultured (Gillett, 2010). Thus, these species are sourced from the wild. Several species of *Plectropomus* spp. are the main targets for the LRFFT besides the humphead wrasse (*Cheilinus undulatus*) and the mouse grouper (*Cromileptes altivelis*). In the past decade, the LRFFT has caused severe depletion of *Cheilinus undulatus* and led to an export ban on this fish in Sabah in January 2010 (Poh and Fanning, 2012). Extensive LRFFT may result in a similar fate for *Plectropomus leopardus* if the level of exploitation persists.

Not all species benefit from reserve protection (Halpern et al., 2010). For example, *Choerodon rubescens* in Western Australia did not respond to protection (Nardi et al., 2004). Several studies indicated that groupers (Serranidae) respond positively to reserve protection (Nardi et al., 2004; Samoilys et al., 2007; Unsworth et al., 2007; Mar Lopez-Rivera and Sabat, 2009; Anderson et al., 2014; Hackradt et al., 2014). Smaller species which are sedentary may respond more effectively and quickly compared to larger species which are generally more mobile (Molly et al., 2009). For example, the smaller grouper species *Cephalopholis cyanostigma* and *Ephinephelus fasciatus* that are reef residents reacted positively even after 5 years of protection at a small no-take area at the Wakotobi National Marine Park (Unsworth et al., 2007). While Claudet et al. (2010) found that mobile species with wide home ranges also benefit from reserve protection. The *Plectropomus* spp. may respond differently to protection. For instance, Wantiez et al. (1997) detected no change in the average size of *Plectropomus leopardus* after five years of protection at 5 protected islands in New Caledonia. Furthermore, movement patterns of fish between reefs also determines if emigration will occur (Rodwell et al., 2002).

In this study we examined the effect of protection on the abundance and biomass of 22 families with 139 species of reef fish and *Plectropomus* spp. (*Plectropomus leopardus*, *P. oligacanthus* and *P. maculatus*) in the no-take marine reserve around Lankayan Island in Sabah, Malaysia. The study addressed two questions: (1) Do reef fish and *Plectropomus* spp. benefit from reserve protection at Lankayan Island? and (2) What is the spatial distribution of *Plectropomus* spp. at Lankayan Island? To answer these questions, three specific objectives were defined. The first was to determine if there is higher reef fish abundance and biomass inside the reserve, and whether these indicators decrease with increasing distance from Lankayan Island. The second objective was to determine the spatial distribution of *Plectropomus* spp. from Lankayan Island. The third objective was to determine whether percentage of hard coral cover affected reef fish abundance and total fish biomass. We tested two hypotheses: (1) Reef fish and *Plectropomus* spp. abundance and size are higher and larger at sites close to the island; and (2) substrate quality positively affects the abundance of reef fish.

2. Materials and methods

2.1. Study site

Sugud Islands Marine Conservation Area (SIMCA) is a no take marine reserve established in December 2001 under the Wildlife Conservation Enactment 1997 as a Category II Conservation Area, in accordance with the IUCN Protected Area Management Category for protection and conservation of marine biodiversity and for recreational purposes. SIMCA covers an area of approximately 467 km^2 in the Sulu Sea within the Coral Triangle region, which is the epicenter of global marine biodiversity (Allen and Werner, 2002). SIMCA is exposed to two prevailing monsoons: (1) the South-West monsoon from March to October that generally consists of sunny and humid weather and features calm sea conditions; (2) the North-East monsoon from November to February that experiences strong winds from the northeastern direction, excessive rains and rough sea conditions (SIMCA, 2008).

Lankayan Island (N06° 30.44, E117° 55.03) is located towards the southeastern end of the SIMCA. The island is enclosed by fringing reef flats that are 50 m to 1 km wide. The reef flats are about 0.5–2 m deep, with the outer slope ranging from 5 to 16 m depth. The island is also surrounded by ∼30 small (∼0.5 ha) to large (∼400 ha) patch reefs having an average depth of 13 m at the reef top and a maximum depth of 24 m at the sandy bottom (Fig. 1). In this study Lankayan Island was chosen as reserve center because of the enforcement presence on the island for the past 11 years. The assumption was made that the protection around the island is fully enforced and that fishing activities around the island are nil. However, as distance increased from the island, the level of protection decreased. For example, illegal fishing could