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Short term response of coral reef fish communities under customary management in New Ireland, Papua New Guinea

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Abstract. Papua New Guinea supports some of the most healthy and biologically diverse coral reefs. Coastal communities have customary tenure over fringing reefs and inshore fishing resources. Closure of an area of reef to harvesting (*tambu*) has historically been employed as a form of customary management. This study investigates the short-term response to this kind of management of moderately exploited coral reef fish communities. Fish biomass and abundance were surveyed by underwater visual census at three managed sites immediately before closure and at three nearby fished control sites at the 4m and 7m depth contours. This survey was repeated one year after closure. Our results display a significant increase in overall biomass within managed areas compared to control sites. We recorded significant increases in biomass and density of piscivorous fish at shallow transects in the managed areas, whilst piscivore biomass significantly decreased within shallow transects at control sites. Overall density of the fish communities remained largely unchanged. Serranids and Lutjanids showed the greatest change in biomass and density in managed areas. These short term positive results can be used to encourage communities to restore customary resource management.

Key words: Customary management, reef fish, Papua New Guinea, marine protected areas, no-take zones

Introduction

It is now well established on a variety of scales and in different regions of the world that marine protected areas (MPAs), in particular well enforced no take zones (NTZs) are effective at promoting recovery of reef fish populations (McClanahan 1994, McClanahan and Kaunda–Arara 1996, Halpern and Warner 2002, Russ et al. 2005). There remains some debate over the mechanisms and speed of recovery of a fish community from high fishing pressure (Halpern and Warner 2002, Russ et al. 2005). Often there is a large initial response to protection from harvesting (Halpern and Warner 2002), however studies in Kenya and the Philippines have indicated that the trajectory of recovery slows and full recovery from fishing may require more than a decade to occur (Russ and Alcala 2003, McClanahan and Graham 2005).

In Melanesia systems of customary marine tenure, heavy reliance on marine resources and heterogeneous perceptions of the status of marine resources (Cinner et al. 2005, Turner et al. 2007) have resulted in the failure of large-scale MPAs through top-down governmental processes as a conservation tool (McClanahan et al. 2006). In Papua New Guinea (PNG) historical and cultural factors have combined to form a regime of customary marine tenure that operates at the family, clan and village levels. This tenure and rights over the fishing resources within the tenure is legally recognised in PNG and provides a potentially useful tool in establishing small scale NTZs to protect reefs, provide refugia for fishery species and promote community involvement in conservation.

This study is part of ongoing research and monitoring of customary no harvesting (*tambu*) areas within the tenure of villages that are dependent on fishing. The work has been conducted by the Wildlife Conservation Society - Papua New Guinea Marine Program (WCS) in New Ireland Province in the Bismarck Archipelago (Fig 1.) Previous studies in the region have focused on spatial comparisons of *tambu* areas and other areas under management or open to fishing; this study is unique in the area, providing a temporal investigation into the effects of small-scale community managed areas in PNG.

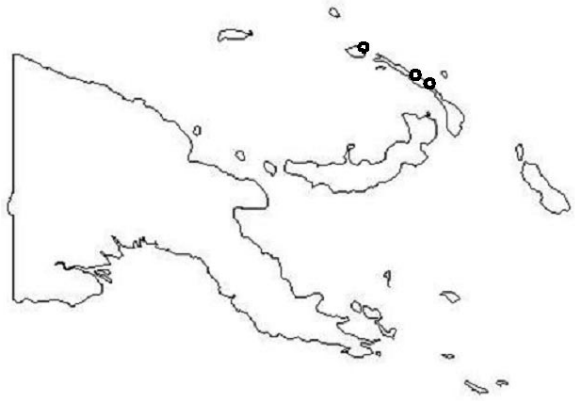

Figure 1. The three survey locations in New Ireland Province, PNG

Methods

Three subsistence fishing communities were identified within New Ireland Province, PNG by WCS in 2006 (Fig. 1). One (Ungakum) is situated in the Tsoi Islands approximately 35km Northwest of the provincial capital Kavieng, and the other two (Lasigi and Silom) are situated between 160 and 200km Southeast of Kavieng in central New Ireland. Criteria for selection of communities were that they were receptive to the reintroduction of customary fisheries management strategies, able to drive the process in partnership with WCS and were close to comparable communities that could be used as control areas. Each area (*tambus* and controls) stretches for between one and one and a half kilometres of fringing reef, and from the shoreline to the bottom of the reef slope or the 30m depth contour.

Through underwater visual census (UVC) the abundances of all non-cryptic, diurnal species of reef fishes >3cm total length (TL) were recorded along two 50m transects at the 4m and 7m depth contours at six sites within each area. At each transect two passes were made, the first recording large fishes (>10cm TL) 2.5m either side of the transect tape, the second recording small fishes (≤10cm TL) 1m either side of the transect tape. All individuals were placed within the appropriate 5cm size class (i.e. 3-5cm, 6-10cm, 11-15cm etc.). This survey method was employed across three customary managed no-take reserves, initially during September/October 2006 (prior to closure to harvesting) followed by a repeat survey twelve months later. Each managed area of reef was paired with a control (fished) area selected on the grounds of being ecologically and geomorphologically similar and situated between 1 and 5km from the managed site. These control sites were surveyed immediately after each adjacent managed area in both 2006 and 2007.

Biomass estimates were obtained using length-weight conversion factors obtained from Fishbase (Froese and Pauly 2006). Length data used in biomass calculations used the midpoint of size classes. Before any parametric statistical test, data met all assumptions for normality.

Results

After 12 months of closure our results showed six major trends:

1. After one year of closure at the managed areas we recorded a highly significant increase in overall mean fish biomass (one way ANOVA P=0.001) (Fig. 2a) compared with no significant change at the fished control areas (P= 0.537).
2. Overall fish community density showed no significant change in managed areas or corresponding control areas over the same time period (Fig. 2 b).

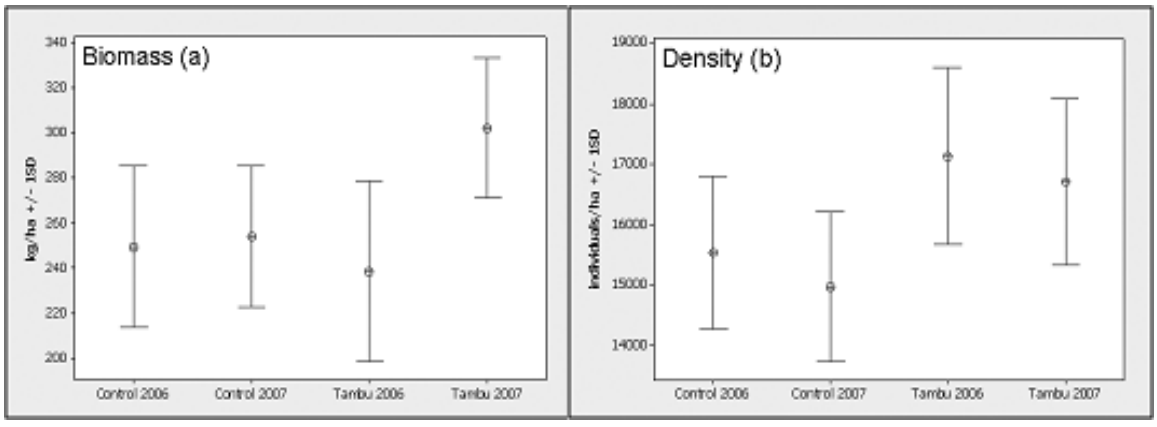

Figure 2. Overall coral reef fish community biomass (kg/ha ±1SD) (a) and density (individual fish/ha ±1SD) (b) at customary managed areas (*tambu*) (2006 and 2007), compared with the three control areas (2006 and 2007).

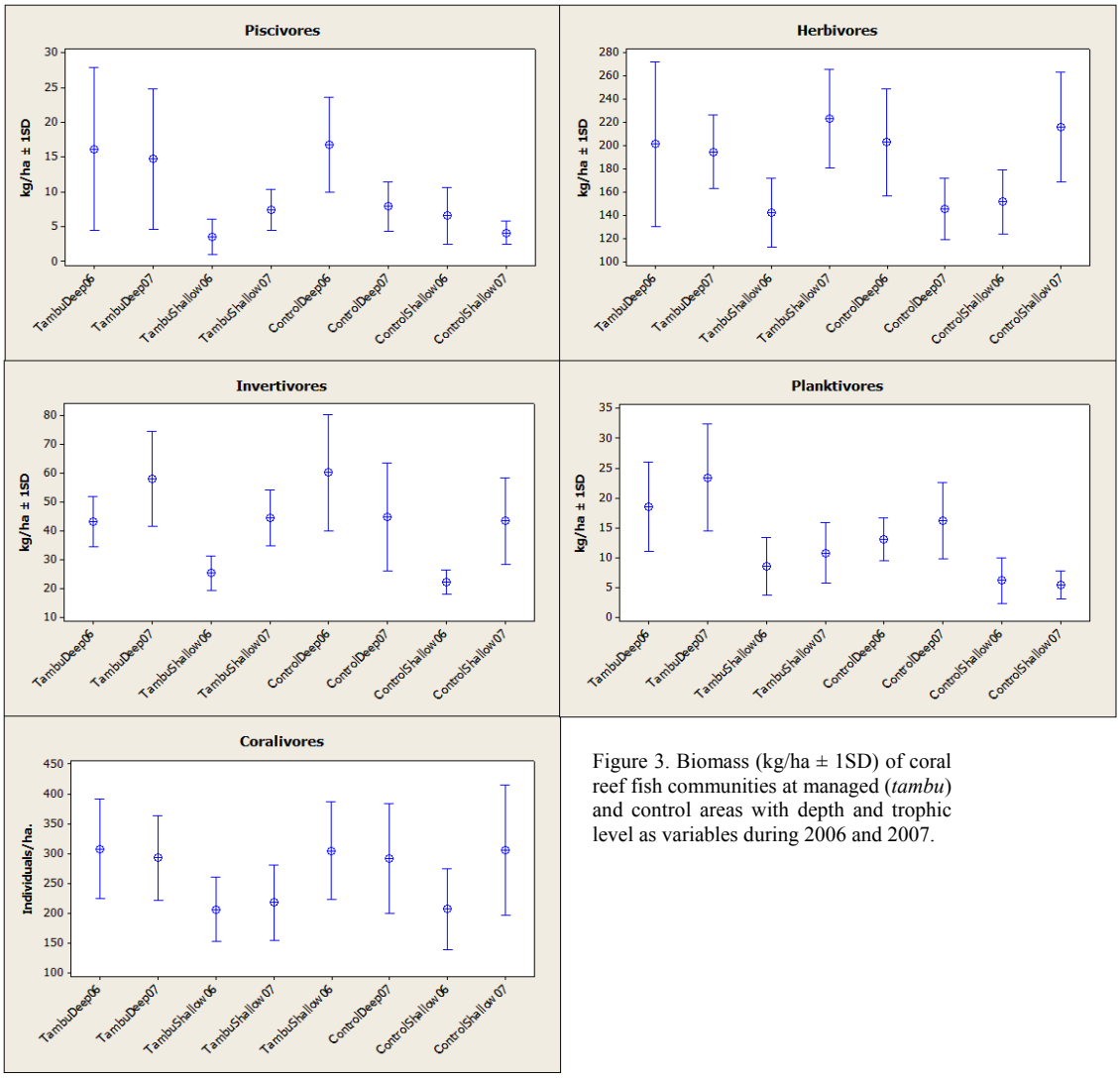

Figure 3. Biomass (kg/ha ± 1SD) of coral reef fish communities at managed (*tambu*) and control areas with depth and trophic level as variables during 2006 and 2007.

Table 1. *P* values (one way ANOVA) of coral reef fish community biomass (kg/ha) displayed in Figure 3 (2006 vs 2007), at trophic level for shallow and deep sites. All assumptions of normality were met for data.

	Tambu	***Control***	***Tambu***	***Control***	***Tambu***	***Control***	***Tambu***	***Control***	***Tambu***	***Control***
	Piscivores		***Herbivores***		***Invertivores***		***Planktivores***		***Coralivores***	
Deep	0.693	0.284	0.220	0.026	0.118	0.061	0.993	0.871	0.090	0.952
Shallow	<0.000	0.228	0.003	0.019	<0.000	0.001	0.414	0.887	0.001	0.007

3 The greatest change in biomass occurred within piscivores at shallow sites. We recorded a highly significant mean increase of 3.83 kg/ha at the managed shallow sites (P<0.000), compared to a non-significant mean decrease of 2.43 kg/ha recorded at the shallow control sites (Fig 3, Table 1). Other changes in biomass were evident across the trophic structure of the fish community, including significant increases in invertivore biomass at both *tambu* and control areas, however none displayed such a large variation between the managed areas and control areas (Fig. 3).

4 There was very little change in the density of the fish population at the trophic level, with the exception of a highly significant mean increase of 115.5 individuals/ha of piscivores (P=<0.000) (Fig. 4, Table 2) at the shallow managed sites.

5 There was a 91.33% dissimilarity between the piscivore community biomass structure at the shallow managed sites between 2006 and 2007 (SIMPER; Table 3).

Table 2. Resulting *P* values (one way ANOVA) of coral reef fish community density (individuals/ha) displayed in Figure 4 (2006 vs 2007), at trophic level for shallow and deep sites. All assumptions of normality were met for data.

	Tambu	*Control*	*Tambu*	*Control*	*Tambu*	*Control*	*Tambu*	*Control*	*Tambu*	*Control*
	Piscivores		*Herbivores*		*Invertivores*		*Planktivores*		*Coralivores*	
Deep	0.061	0.334	0.608	0.179	0.547	0.125	0.532	0.433	0.774	0.834
Shallow	<0.000	0.101	0.091	0.350	0.446	0.123	0.620	0.459	0.777	0.124

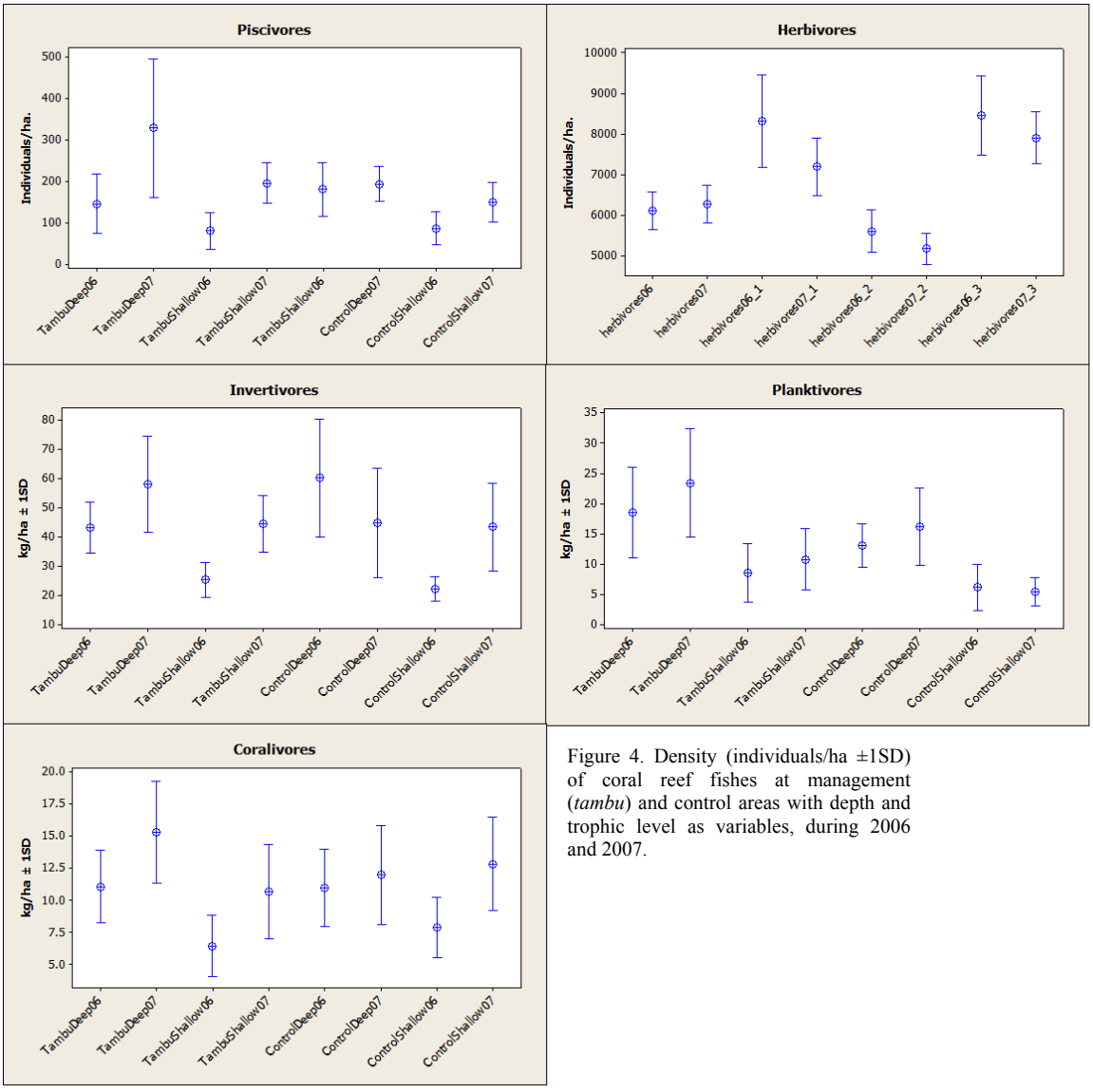

Figure 4. Density (individuals/ha ±1SD) of coral reef fishes at management (*tambu*) and control areas with depth and trophic level as variables, during 2006 and 2007.

6 Serranidae and Lutjanidae contributed 45.01% and 41.46% respectively of the dissimilarity in biomass, with very similar results for fish density (SIMPER; Table 3).

Discussion

Our results support the claims that the biological responses as a result of implementing NTZs appear to develop quickly in some cases. Indeed, Halpern and Warner (2002) state this is often the case and in their review show that NTZs can support higher than average values of density, biomass, average organism size and diversity inside reserves (relative to controls) within a short (1–3yr) time period. Our results are comparable with results from the Great Barrier Reef collated by Evans *et al.* (2006). This study showed

Table 3. SIMPER output of data for biomass of piscivorous families at the shallow managed sites showing change in the percent make up of the community structure between closure (2006) and after one year of closure (2007).

Average dissimilarity = 91.33						
	Group 2006	**Group 2007**				
Species	*Av. Biomass*	*Av. Biomass*	*Av. Diss*	*Diss./SD*	*Contrib.%*	*Cum.%*
Serranidae	0.31	0.4	41.1	0.93	45.01	45.01
Lutjanidae	0.18	0.47	37.87	0.88	41.46	86.47
Lethrinidae	0	0.12	6.76	0.28	7.4	93.87
Haemulidae	0	0.1	5.6	0.27	6.13	100

that after just 21 months of closure to fishing, the density and biomass of coral trout (*Plectropomus* spp., family Serranidae), and the lutjanid *Lutjanus carponotatus* had increased by up to a factor of 1.7 in areas that had been closed to fishing, while density and biomass decreased slightly over the same period in the areas that remained open to fishing. If organisms respond quickly to protection, initial rates of change should be greater than later rates. For the seven studies of reserves reviewed by Evans *et al.* (2006) that recorded temporal data, the rate of change for density, calculated as the ratio of the values at one time step divided by the value at the previous time step, was significantly greater for the first time step compared to all other time steps. Our recorded rapid increase in density and biomass at the shallower depths, compared with deeper sites could be attributed to relief from greater fishing pressure at these shallower depths. The most commonly used gears in the region are spear guns and hand lines, making shallow reefs more accessible to fishers. Overall, our results show a rapid, demonstrable, positive response of the targeted fish community to protection. This is a key element in maintaining support for community managed MPAs, particularly NTZs in rural subsistence fishing communities which have governance over their resources.

Acknowledgements
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