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Changes in reef fish biomass in Karimunjawa National Park: a test of the effectiveness of government gazetted marine parks in Indonesia

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Abstract. In June 2005, following extensive community consultation, national legislation was enacted to change the boundaries of zones that regulate fishing and other resource use in Karimunjawa Marine National Park in the Java Sea, Indonesia. The new park boundaries included five management zones ranging from no-take areas to open access. An initial increase in fish biomass in 2005 was not sustained and by 2007 there was no significant difference in mean biomass when compared to the initial surveys in 2004. Analysis by trophic groups suggested that the re-zoning was effective in protecting the biomass of many fishes. Indeed, only herbivorous fish biomass declined significantly within the park boundaries between 2004 and 2007; corallivore, omnivore and planktivore biomass increased while invertivore and planktivore biomass remained stable. However, similar patterns were evident outside the park boundaries, suggests other factors may be responsible for these patterns, such as a decline in effort throughout the region, perhaps as a consequences of a reduction in the number of people in the fishery. Some zones were more effective than others at protecting fish biomass. For example, increases in every trophic group, except herbivores, were recorded in the Core Zone and Tourism Zone. In contrast, most groups declined in the Protection Zone, perhaps as a result of a shift of fishing effort. Work in the park is continuing in an effort to identify the cause of these trends.

Keywords: Coral reef, Karimunjawa, management, marine protected area, , monitoring

Introduction

Between the years 2003-2004 the Wildlife Conservation Society (WCS) Marine Program Indonesia assessed the ecological condition of coral reef habitats, and evaluated socio-economic factors that constrain fisheries and conservation management in Karimunjawa National Park (KNP) in the Java Sea, Indonesia (Campbell 2006). In June 2005, following extensive community consultation, and using the data collected above, national legislation was enacted that changed the boundaries of zones to regulate fishing and the use of other marine resources in KNP. The park included five management zones ranging from no-take areas to open access. There were three Core Zones designated as no-take areas to protect three distinct reef habitats identified in the baseline surveys, 7 Protected Zones with limited access to resources, 7 Tourism Zones as no-take areas which nonetheless allowed for marine tourism, three Rehabilitation Zones (designed to allow degraded reefs identified in the baseline survey to recover and four Aquaculture Zones (for sea-weed farming, fish culture, etc.). The remaining areas within KNP were zoned Traditional Fisheries Utilization area (Utilization Zone) where fishing activity was unregulated.

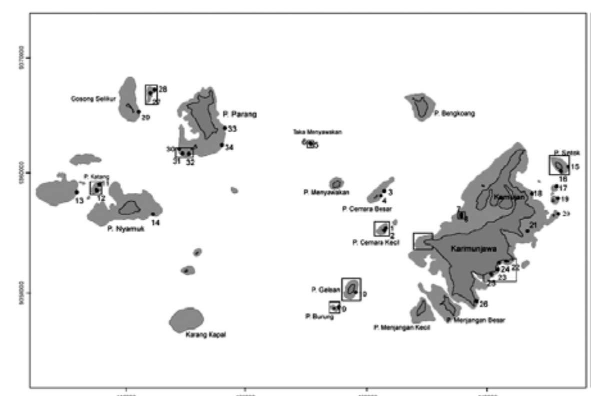

Figure 1. Map of Karimunjawa National Park and 43 survey sites within 5 management regimes.

As part of the ongoing evaluation of the new zoning scheme and as part of the adaptive management of KNP, monitoring has continued in the park. In total 43 survey sites were monitored during the transition time between the west and the east monsoon (April-May) in 2005, 2006 and 2007; The 2003-2004 baseline data (Ardiwijaya et al. 2007). plus surveys from areas outside of the KNP, which are open access, are included for comparison.

Materials and Methods

Fish abundance and biomass were collected using visual surveys at two depths (1 and 7 m) using two replicate 50m transects. A 5m width was used for fish whose Total length (TL) > 10cm and 2m for fish with TL $\leq$ 10cm. Fish TLs were classified into 9 size classes (see Fig. 3). Fish were identified to species following, Myers (1999) and Allen and Steene (1999). Fish data were analyzed using two-way ANOVA to test for significant differences between years and management regimes.

Fish from the family Pomacentridae (damselfish) were eliminated from the analyses to enhance precision since they are found in high and highly variable abundance within all survey sites. In 2005, there was no data collected outside the KNP. Consequently, the mean of sites of all other years was used as a baseline in ANOVA. All abundance and biomass values were $\log_{10}$ transformed.

Results

Mean fish abundance in the KNP fluctuated considerably among years and was significantly higher at the last census in 2007 when compared to 2004 (Fig.2a). In contrast, there was no significant increase in fish abundance outside KNP (Fig. 2a). Fluctuations in fish abundance in the KNP were driven mostly by changes in the Core Zone where a 100% increase in fish abundance occurred between 2004 and 2007 (Fig. 2a). Fish abundance did not vary significantly among years in any of the other zones (Fig. 2a). In contrast to abundance, fish biomass in KMP did not change between 2004 and 2007. An initial 20% increase in fish biomass in KNP in 2005 was not sustained. A significant increase in fish biomass in the Core Zone was counteracted by a significant decrease in the Protected Zone (Fig. 2b).

In general, an increase in abundance accompanied by decrease in biomass would suggest more small fish and/or less large fish. Yearly graphs of fish abundance in 9 size classes shows an increase in small (<10cm) and large fish (> 40cm) that was more than compensated for by an decrease in all size classes between 20 and 40cm (Fig. 3).

Benthic invertivore biomass was dependent on survey period and management zone (interaction term $F_{12,134}$=2.557; P=0.004). In the KMP as a whole there was no change in biomass of invertivores because significant increases in the Core and Tourism zones were counteracted by decreases elsewhere. (Fig. 4a).

Carnivorous fish biomass was dependent on survey period and management zone (interaction term $F_{12,134}$=2.267; P=0.012).

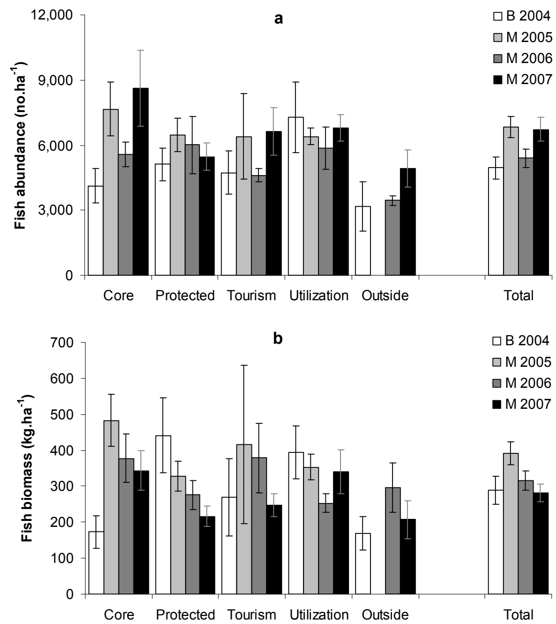

Figure 2. Mean (±SE) (a) abundance (no.ha^{-1}) and (b) biomass (no.ha^{-1}) of reef fish (excluding family Pomacentridae): comparison between management zones and survey periods.

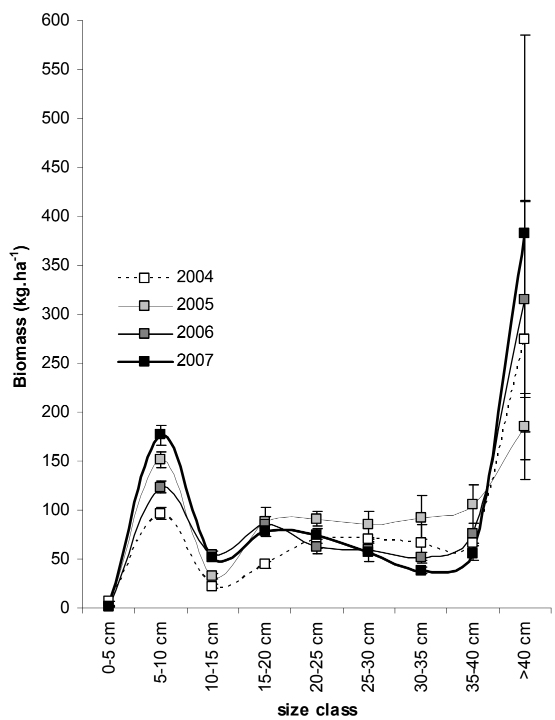

Figure 3. Mean (±SE) biomass (kg.ha^{-1}) of reef fish (Family Pomacentridae excluded): comparison between size classes.

In the KMP as a whole there was no change in biomass of carnivores because significant increases in the Core and Tourism zones were counteracted by decreases elsewhere (Fig. 4b). Similarly, the biomass of carnivores outside the KNP in 2007 was not significantly different to that in 2004 (Fig. 2b).

Corallivorous fish biomass was dependent on survey period and management zone ($F_{12,134}$=1.886; P=0.044). In the KNP as a whole, biomass increased between 2004 and 2007 by nearly 100% driven mostly by large increase in the Core and Tourism Zone (Fig. 4c). A similar increase was apparent outside the KNP (Fig. 4c).

Herbivorous fish biomass was dependent on survey period and management zone ($F_{12,134}$=2.616; P=0.004). Large increases in the biomass of herbivores in the Core and Tourism Zones between 2004 and 2005 where not sustained and were more than compensated for by a large decrease in biomass in the Protected Zone between 2004 and 2007. The result was a 20% decline in herbivore biomass in KNP between 2004 and 2007 (Fig. 4d). Further analyses of the grazing parrotfish family Scaridae where performed to see how this family contributed to the patterns in biomass of herbivores. The patterns in biomass of the scarids among zones and years are very similar to those of the trophic group as a whole suggesting fluctuations in the abundance of this family is driving the patterns in the group (Fig. 5).

Omnivorous fish biomass was dependent on survey period and management zone ($F_{3,134}$=15.047; P<0.05). In the KNP as a whole, biomass increased between 2004 and 2007 by nearly 100%, driven mostly by large increases in the Core and Protected Zones (Fig. 4e). A similar, but not significant, increase was apparent outside the KNP (Fig. 4e).

Planktivorous fish biomass was dependent on survey period and management zone ($F_{3,134}$=9.562; P<0.05) In the KNP as a whole, biomass increased between 2004 and 2007 by nearly 200% driven mostly by large increases in the Core and Tourism Zones (Fig. 4f).

The omnivore trophic group was dominated by the family Pomacentridae which made up 70% of total abundance and 26% of biomass from all families. The planktivore trophic group was dominated by the family Caesionidae which made up 20% of total biomass (Fig. 6).

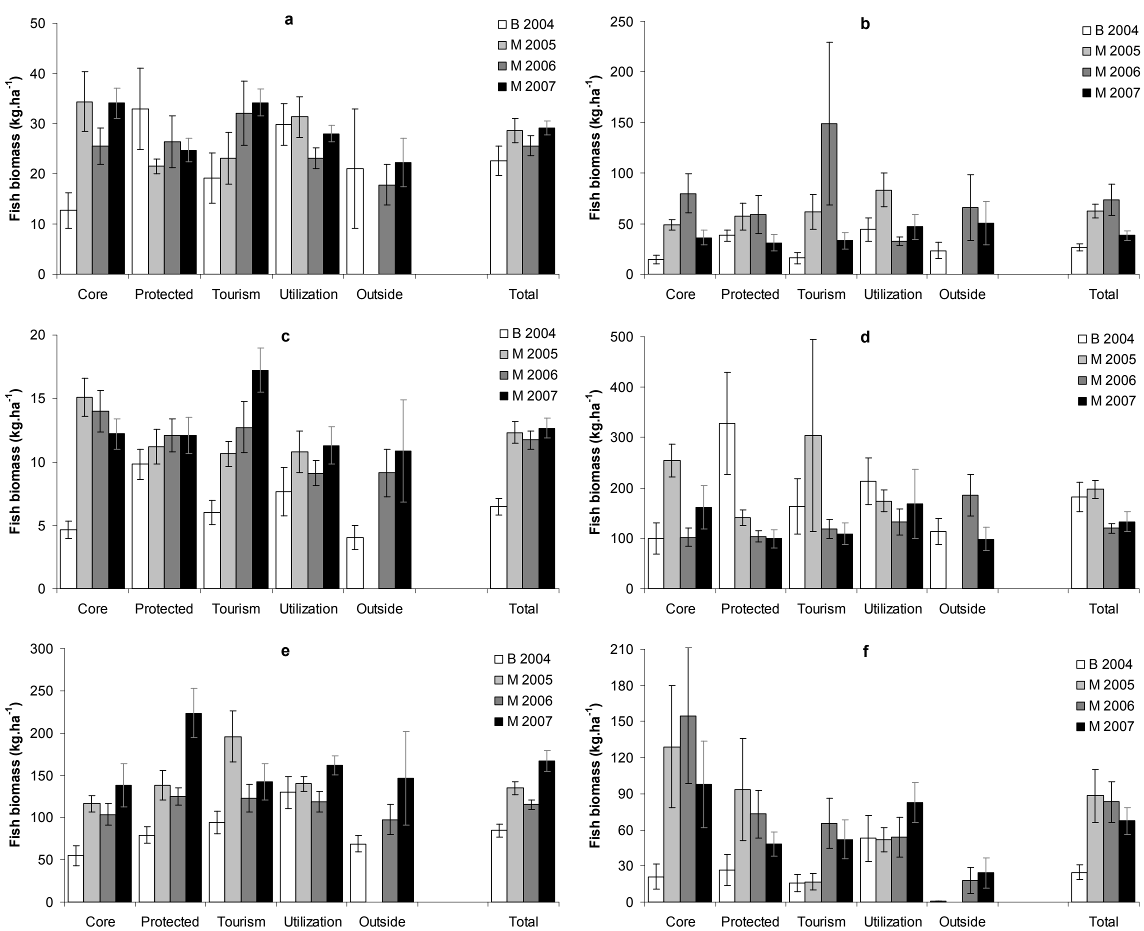

Figure 4. Mean (+SE) biomass (kg.ha^{-1}) of (a) benthic invertivore, (b) carnivore, (c) corallivore, (d) herbivore, (e) omnivore, and (f) planktivore: comparison between management zones and survey periods.

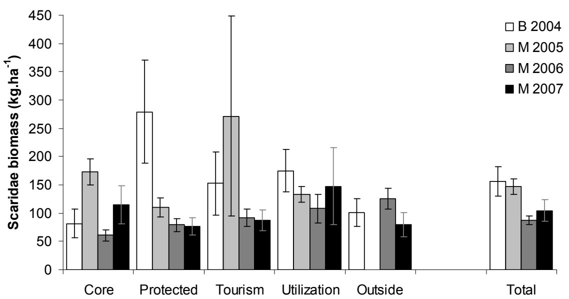

Figure 5. Mean (±SE) biomass ($kg.ha^{-1}$) of Scaridae (parrotfish): comparison between management zones and survey periods.

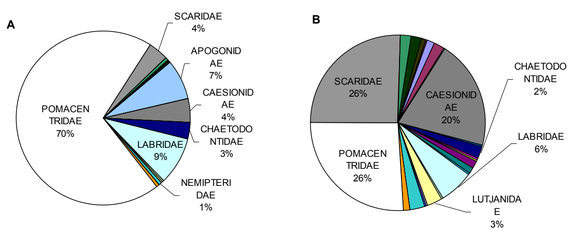

Figure 6. Composition of fish family by abundance (A) and biomass (B).

Discussion

Several interesting trends are apparent in these data. Slight increases in fish abundance has not delivered an increase in biomass, because the size structure of the assemblage now includes fewer fish in the size range from 20cm to 40cm. However, a number of trophic groups have increased in biomass since the re-zoning. In particular, the biomass of corallivores, omnivores and planktivores has all increased since the re-zoning in 2005. While these increases may not be of interest to fishermen, because few of these fish are targeted, they are potentially good news for the tourist industry. The corallivorous family, Chaetodontidae, are of particular interest to recreational divers. The biomass of invertivores and carnivores, the main target species for fisherman, remained stable within the KNP. Consequently, the re-zoning has been a partial success for these groups because it has prevented a decline in abundance while continuing to provide fishermen with access to the resource. Only the herbivores, driven mostly by a 20% decline in the biomass of scarids, have decreased in the KNP as a whole since the re-zoning. The loss of herbivores is of particular concern given the important role these fishes have in maintaining reef resilience (Hughes et al 2007). However, similar trends in the biomass of each trophic group outside the KNP suggest that factors other than the re-zoning may be causing these patterns. For example, fishing effort as whole may have declined in the region as fishermen, encouraged by the efforts of the local government and supported by international NGOs, move into other livelihoods.

Interestingly, some of the zones have been more effective than others in preserving or increasing biomass. In particular, the biomass of all trophic groups, except herbivores, has increased in the Core Zone. Similarly, the biomass of all groups, except herbivores and omnivores, has increased in the Tourism Zone. In contrast, the Protection Zone has been much less effective at protecting biomass, with large decreases in the biomass of most trophic groups. This suggests that fishing effort has increased in the Protected Zones as a result of fishermen shifting effort from the Core and Tourism Zones. Further research, documenting both fishing effort and location of catch will be required to explain the difference in the effectiveness of these Zones.

Fish biomass within KNP is lower than comparable MPA's in Indonesia, for example, the biomass per hectare is 50–100% lower than in similarly managed areas in Aceh (Fig. 7) suggesting the area may be over-fished and current fishing effort unsustainable over the long term.

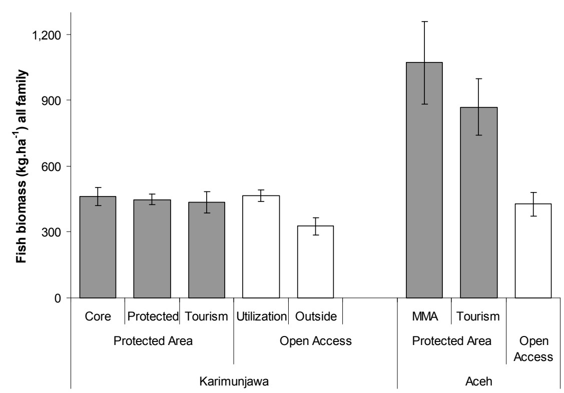

Figure 7. Mean (±SE) biomass ($kg.ha^{-1}$) of fish all family: comparison between Karimunjawa NP, and Aceh protected areas (Aceh Tourism and Aceh MMA).

The following recommendations have been made to the KNP authority

1. monitoring fish catch by documenting which fish are being caught and how many
2. evaluate fishing effort in each Zone and possibly restrict fishing gear especially nets
3. develop communication and awareness tools to enhance the perception of the benefits of marine parks in the local communities
4. patrol the KNP to measure compliance;
5. place more visible marking buoys to delineate Zones Boundaries to reduce non-compliance;

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