Possible effects of human impacts on the epibenthic communities and coral rubble features in the marine park of Bunaken (North Sulawesi, Indonesia)

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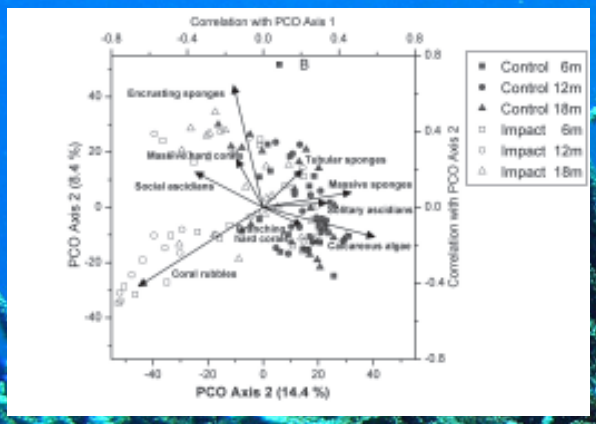
INTRODUCTION

Coral reefs have a high ecological, social and economic value with million of people depending on it for their sustenance (Costanza et al., 1997; Berg et al., 1998). Unfortunately reefs are affected by several human disturbances and the degree of degradation is increasing with time worldwide. The major anthropogenic physical disturbances are due to anchorages, destructive fishing practise, as blast fishing, and diving tourism (Chabanet et al., 2005). Assessment of anthropogenic disturbances is necessary to protect and manage these marine natural resources.

The aim of the present study is to analyse the possible effects of physical disturbance on epibenthic assemblages in term of their structural complexity and diversity. Moreover we used coral rubbles cover (Jameson et al., 1999; de Vantier and Turak, 2004) and its grain size as possible indicator of human physical impact in the Bunaken Marine National Park (1°37'N 124°45'E, North Sulawesi, Indonesia).

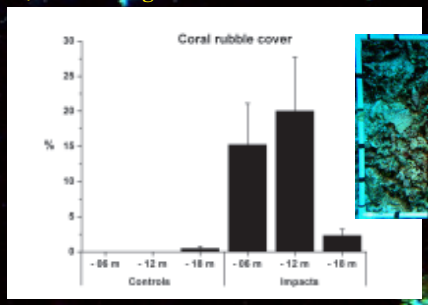


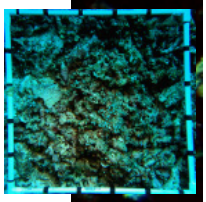
MATERIAL AND METHODS

Bunaken park, established in 1991, consists of five islands and coastal sections of Sulawesi and supports a local population of about 30 000 villagers.
Four study sites were randomly chosen in both impacted (I: Barat, Depan Kampung, Negeri, Onong) and control locations (C: Bango, Likuan 1, Likuan 2, Manadotua) where epibenthic assemblages were analysed at three depth (6,12,18 m), using a photographic sampling (Roberts et al., 1994).
Abundance of sessile organisms and coral rubble were quantified by visual percentage cover estimation superimposing a grid of 100 equal sized squares on each photo.
In the same sites, the size of rubble patches along 6 belt transects (10 x 1 m) at two depths (6-12 m) was also estimated. Moreover grain size of the rubble and the living coral fraction were evaluated collecting three replicate samples at three depths (6,12,18 m) in each site. Coral rubble was divided into 5 size classes using a nested series of sieves (meshes 0.1, 0.5, 1.0, 2.0, 4.0, 8.0 cm) and weighted, while living corals fraction was estimated as relative percentage.

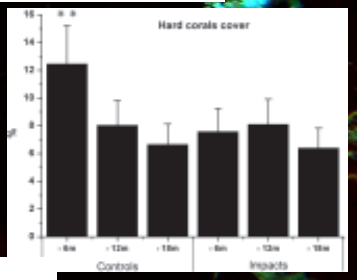
RESULTS

Epibenthic assemblages showed a high spatial heterogeneity among sites and depths, as well as the scattered points on the PCO ordination showed. Although this high heterogeneity, the differences between impacted and control sites were clearly detected and confirmed by PERMANOVA test, which indicated significant differences in relation to sites, depth and impacted vs. control sites ($p<0.001$). Multivariate multiple regressions indicated that the most important proportion of the variability is explained by coral rubble that clearly increased toward impacted sites together with encrusting sponges and massive hard corals while branching corals and tubular and massive sponges were higher towards controls.



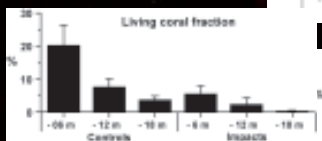


- The total hard coral percentage cover showed a significant interaction between I/C and Depth with a greater covering in control sites at 6 m compared to 12 and 18 m and also in the controls vs. impacts sites at 6 m in depth (SNK $p < 0.01$).

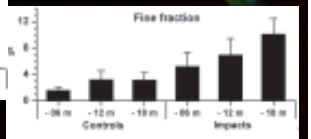


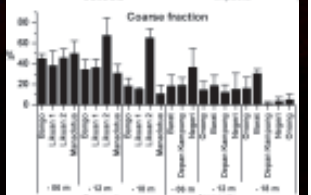
- Coral rubbles percentage cover showed significant differences in the interaction between I/C X Depth in particular at all depths the abundance of rubbles were greater in the impacted sites (SNK 6-12 m $p < 0.01$; 18 m $p < 0.05$) while within impacts the higher amount were at 6 and 12 metres (SNK $p < 0.01$).

- The average percentage of living corals within fragments was greater in control sites and it appeared strongly dependent from depth, indeeed in both impacted and control sites SNK test ($p < 0.05$) highlighted a higher amount at 6 m compared to 12 and 18 m.



- Coral rubble fine fraction (0.1-0.5 cm) was more abundant in impacted sites while coarse fraction (4-8 cm) prevailed at the controls (ANOVA $p< 0.05$) where differences between sites were detected higlighting a more heterogenety compared to the impacted sites.





DISCUSSION

Epibenthic assemblages seemed to shift their features in relation to physical disturbances that led to a loss of three-dimensional structural complexity (Aronson and Precht, 1995) negatively affecting ecosystem functioning (Pandolfi et al., 2005).
In the Bunaken Marine Park mechanical damages to coral reefs are generally associated with a reduction of the total hard coral cover in shallow water (6 metres) where the physical injuries are greater. In the impacted sites the amount of coral rubbles and the fine fraction are higher due to anthropic activities that led to a major fragmentation rate of hard corals and cause coral rubble rain so that its effects are vertically transferred along the reef wall. Moreover living coral fraction within coral rubbles in impacts are less aboundant probably owing to the high sedimentation that affected the survival of living fragment and their dipersal and growth. The high amounts of fine sediments present in impacted sites may negatively affect coral survivor, strongly decrease reef resilience and support pioneer and sediment-tollerant species. If a rigorous, ecologically grounded approach will demonstrate that sedimentation exceeds natural thresholds a more adequate management measures, such as the simple use of mooring buoys, should be developed.

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