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Organisms associated with live scleractinian corals as indicators of coral reefs status in the Wakatobi Marine National Park (SE Sulawesi, Indonesia)

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Abstract. Organisms associated with live scleractinian corals were studied on four sites located around Hoga and Kaledupa islands in the Wakatobi Marine National Park. The number of coral colonies infested by coral associates was estimated along 20 m long line intercept transects and the number of coral associates found on each coral colony was recorded. A 0.5 m point intercept transect method was used to describe the benthic cover. A total of 2815 associates were recorded infesting 376 coral colonies. The most conspicuous coral associates were lithophagid bivalves making up for 73% of total coral infestations. The highest number of infested colonies was found for the genera *Montipora*, *Pavona* and *Porites*. They represented 33%, 23% and 18% of the total number of colonies infested respectively. The number of infested coral colonies and the density of *Lithophaga* spp. were high in the most impacted site (Sampela) and one of the intermediately impacted site (Pak Kasim's) whereas they were low in the most pristine site (Kaledupa). Despite the high biotic cover of Pak Kasim's, this site suffers from a similar level of infestation as Sampela suggesting process of reef degradation previously experienced by the most impacted site. Our results suggest that coral associates can be used as indicators of coral reef status.
Key words: Coral, Macrobioeroders, Coral predators, Reef health, Indonesia

Introduction

Coral reefs are critically important for the ecosystem goods and services they provide to maritime and subtropical nations (Moberg & Folke 1999). Reefs are currently in serious decline (Bellwood et al. 2004) due primarily to over-harvesting (Jackson et al. 2001), pollution (McCulloch et al. 2003), disease (Harvell et al. 2002), and climate change (Wilkinson 2004; Hughes et al. 2003). Already 20% of the coral reefs have been destroyed (Wilkinson 2004) and show no immediate prospects of recovery, 24% are under imminent risk of collapse through human pressures and a further 26% are under a long-term threat of collapse. The worst scenarios, prospected by Woolridge et al. (2005), suggest that reefs will become devoid of significant coral cover and associated biodiversity by 2050. The managing and a strong focus of key functional groups have become today a priority as part of insurance for sustainability (Hughes et al. 2003).

Coral associates (bioeroder and coral predator organisms) represent one of these key groups. Bioerosion and predation on scleractinian corals are indeed an important part of coral reefs dynamics. Scleractinian corals provide microhabitats and are used by a large number of parasites and other associated organisms, which use the tissue and skeleton of the coral colonies as food or substrata (Frank et al. 1995; Floros et al. 2005). Many taxa are involved and most of these coral associates stress the coral to some degree. Any natural or anthropogenic disturbances that lead to the loss of live coral tissue will ultimately increase the chances of bioeroder invasion. The bioerosion process can lead to important coral damage and even, depending on the intensity, can lead to mortality of coral colonies (Kleemann 2001). Bioerosion plays an important part in the degradation of the reefs and affects coral reef health. Nevertheless, although very important, the community structure of organisms involved in this process is relatively poorly documented. The aim of this study was therefore to link the different assemblages of coral associates on reefs around Hoga and Kaledupa islands in Indonesia with the health of these reefs.

Study sites and methods

This study was conducted on the reefs around the islands of Hoga and Kaledupa in the Tukang Besi Archipelago of the south-eastern coast of Sulawesi in the Banda Sea, in Indonesia and took place in July and August 2005. Four sites were studied (Fig. 1) and were selected with a gradient of degradation (Table 1).

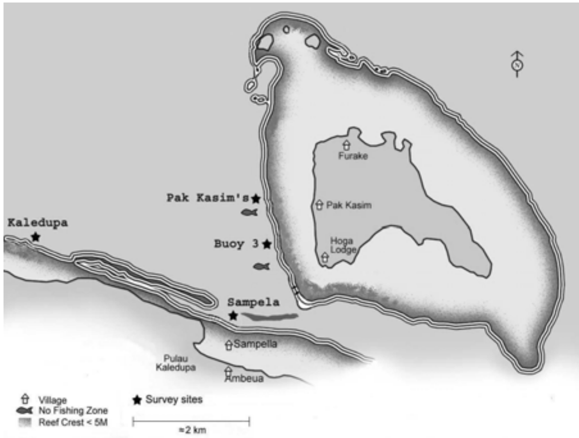


Figure 1: Location of the survey sites.

The number of coral colonies infested by coral associates was estimated along a 20 m long Line Intercept Transect (LIT) (English et al., 1997) at two different depths (6m and 12m). The number of macrobioeroders and coral predators found on each coral colony on the transect was recorded and corals were identified to the most precise level. To link the assemblages of coral associates observed with the characteristics of the benthic habitats, the cover of the major functional groups was estimated using a 0.5 m Point Intercept Transect (PIT) method (English et al. 1997) on the same 20 m-long transect as the macroinvertebrate survey.

	Kaledupa	Sampela	Pak Kasim's	Buoy 3
Latitude South	05°28'22''	05°29'01''	05°27'569''	05°28'40''
Longitude East	123°43'47''	123°45'08''	123°45'179''	123°45'45''
Rugosity	0.56 (0.08) N=25	0.73 (0.10)* N=15	0.58 (0.15) N=25	0.60 (0.19) N=23
Sedimentation rate (g d.wt.m^{-2}.d^{-1})	5.21 (1.01) N= 8	20.46 (2.12)* N= 9	7.25 (0.28) N= 6	
Light attenuation coefficient (K)	0.16 (0.01) N =5	0.24 (0.01) N = 4	0.12 (0.01) N = 5	0.13 (0.01) N = 5

Table 1: GPS position and characteristics of the different sites (* means that the difference with the other sites is signifiant, p<0.01).

Statistical analyses were performed with Minitab for parametrical and non-parametrical statistics. PRIMER v6 (Plymouth Marine Laboratory, Clarke & Warwick 2001) was used for analysis of community. Cochran tests were used to test for homogeneity of variances before ANOVA. Turkey's pairwise comparisons were used for post hoc comparisons. ANOSIM were performed to analyse similarities between sites after the ordinations (Multidimensional Scaling, MDS).

Results

A total of 831 scleractinian coral colonies belonging to 39 genera were recorded and analysed on 25 transects. Within live corals a total of 2815 associates were recorded infesting 376 coral colonies. The most conspicuous coral associates were lithophagid bivalves (2062 individuals infesting 242 coral colonies) making up for 73% of total coral infestations ; followed by dwelling hermit crabs of the genus *Paguritta* (306 individuals infesting 113 coral colonies) with 10.9% and the vermetid snail *Dendropoma maxima* (242 individuals infesting 116 coral colonies) with 8.6 % (Fig. 2 a and b). Other associates were less common and contributed little to total coral infestations (less than 3%).

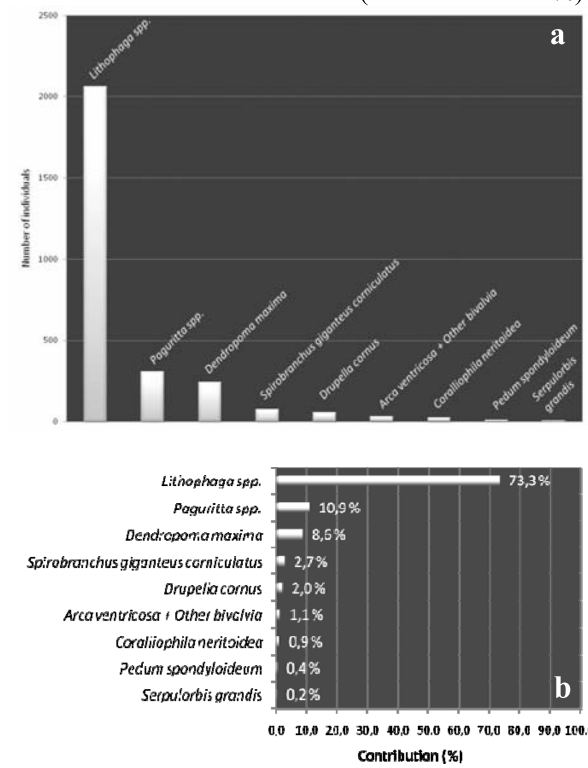


Figure 2: a. Number of bioeroder and coral predator organisms recorded during this study b. Repartition of the different bioeroder and coral predator species.

Infestation rate by scleractinian coral genus

The highest number of infested colonies on the transects was found for the genera *Montipora*, *Pavona* and *Porites* (Fig. 3a). They represented 33%, 23% and 18% of the total number of colonies infested respectively (Fig. 3b). These genera corresponded also with the most common taxonomic groups of scleractinian corals found on the transects (Fig. 3c).

The other genera were less common on the transects (Fig. 3c) and they represented less than 10% of the total number of infested colonies (Fig. 3b).

Infestation by site

At two sites, Pak Kasim's and Sampela, more than half of the coral colonies were infested (54% and 52% of the colonies for the two sites respectively). Only 32% of the coral colonies were infested in Kaledupa. Buoy 3 was in an intermediate state with 44% of the coral colonies being infested.

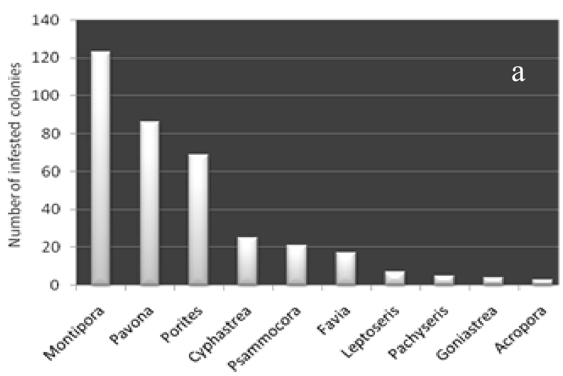
The majority of coral associates was found at all the sites excepted for *Drupella cornus* and *Serpulorbis grandis* which were absent at Buoy 3 and Sampela respectively. Within the same site, no significant difference was found between the two chosen depths (6 and 12 meters) in terms of the total number of infested colonies and the distribution of the studied organisms. A highly significant difference between locations (ANOVA One-Way, $F=18.42$, $p<0.01$) was noticed only for the lithophagid bivalves. The distributions of these organisms in Sampela and Pak Kasim's were significantly different from those in the other sites (Tukey's pairwise comparisons).

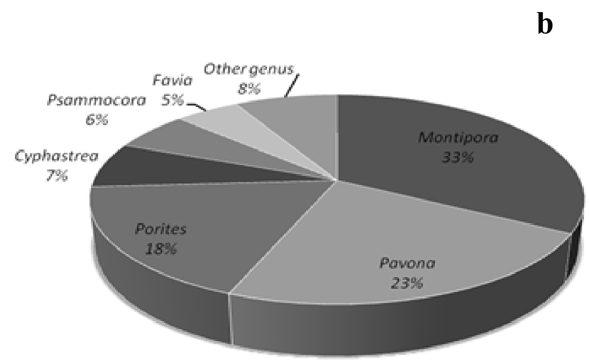
Community analysis.

Comparison of coral associates communities by Non-metric Multidimensional Scaling (MDS) and analysis of similarity (ANOSIM) indicated a significant difference among sites (ANOSIM One-way, Global $R = 0.691$, $p=0.001$)

Examination of the MDS plot (Fig. 4) showed a tendency of differentiation between the sites. Furthermore, pairwise comparisons of sites from ANOSIM resulted in R-values indicating important differences between Pak Kasim's / Kaledupa, Sampela / Kaledupa, Sampela / Buoy 3 (with R-values > 0.9) and between Pak Kasim's / Buoy 3 (R value > 0.8). No difference was found between the other paired sites. However, with regards to their positions on the MDS plot, the stations seem to be positioned along a gradient between two sites: Kaledupa and Sampela. Two groups were distinct on the MDS, the first one constituted by transects belonging to Sampela and Pak Kasim's, and the second one constituted by transects from Buoy 3 and Kaledupa.

Plotting the densities of the lithophagid bivalves on the MDS (Fig. 4), the global position of the replicates seems to be explained with regards to it. The site considered as the most "pristine", Kaledupa, has the lowest density of *Lithophaga* spp. (all densities < 1 ind.colony^{-1}). At the opposite, separated by the greatest distances on the MDS, are the replicates representing Sampela and Pak Kasim's. The Lithophagid'densities at these sites are the highest. The pattern observed, when the densities of this bivalve on the MDS are superposed, seems to be





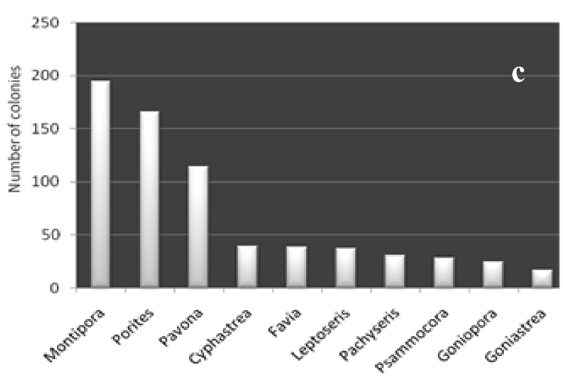


Figure 3: a. Number of scleractinian coral colonies infested for the ten most infected genera b. Ratio of the number of colonies infested corresponding to a given genus on the total number of infested colonies c. Number of colonies for the ten most common scleractinian coral genera.

coherent to the trend of the potential gradient between Sampela and Kaledupa.

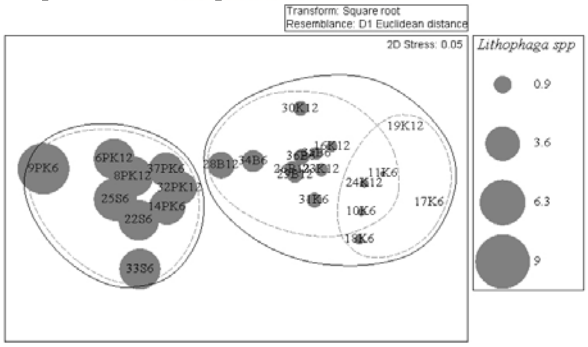


Figure 4: Bubble plot superposing the densities of *Lithophaga* spp. on the MDS (ind.coral colony^{-1}) (codes displayed on the MDS represent the name of transects and their characteristics: transect reference – localisation PK: Pak Kasim's, K: Kaledupa, S: Sampela, B: Buoy 3 – depth of the transect (6 or 12 meters)).

Link with coral reef status.

Significant differences between the studied sites were observed concerning the total benthic cover (multiple Kruskall Wallis tests on the different categories). Percent covers of abiotic and biotic categories in the four studied sites are illustrated in Fig. 5. For the same site, no significant difference concerning scleractinian coral cover was found between different depths. In contrary, for the same depth, significant differences were observed between the sites. The highest biotic (83%) and scleractinian coral cover (43%) was observed at Pak Kasim's. The same level of biotic cover was noticed at Kaledupa and Buoy 3 and no significant difference was observed between the three sites. However, the biotic cover was predominantly composed of soft corals at Kaledupa which explained a relatively low scleractinian coral cover in comparison with the other sites (20% and 26% at 6 and 12 meters respectively). Thus, the proportion of soft corals was significantly higher at this site. At 6 meter depth, the scleractinian coral cover at Kaledupa was significantly lower than that at Sampela (Kruskall Wallis test, $p<0.01$), despite the fact that Sampela was the site for which the biotic cover was the less dominant (only 39% of biotic cover). Abiotic cover at Sampela was thus significantly more important (Kruskall Wallis test, $p<0.01$). Moreover, concerning Sampela, the results of the LIT used for the infestation (126 colonies for three transects) put this site at the same level than Buoy 3 and Pak Kasim's (respectively 242 and 260 colonies for six transects) for the number of colonies recorded. The difference observed in the coral cover between Sampela and the other sites is attributable to the occurrence of a high numbers of small colonies at this place.

Regarding coral growth forms, multiple non parametric Kruskall Wallis tests showed that Kaledupa and Pak Kasim's had a higher proportion of branching corals. No significant difference was observed between the sites for the other categories of lifeforms taken into consideration (encrusting,

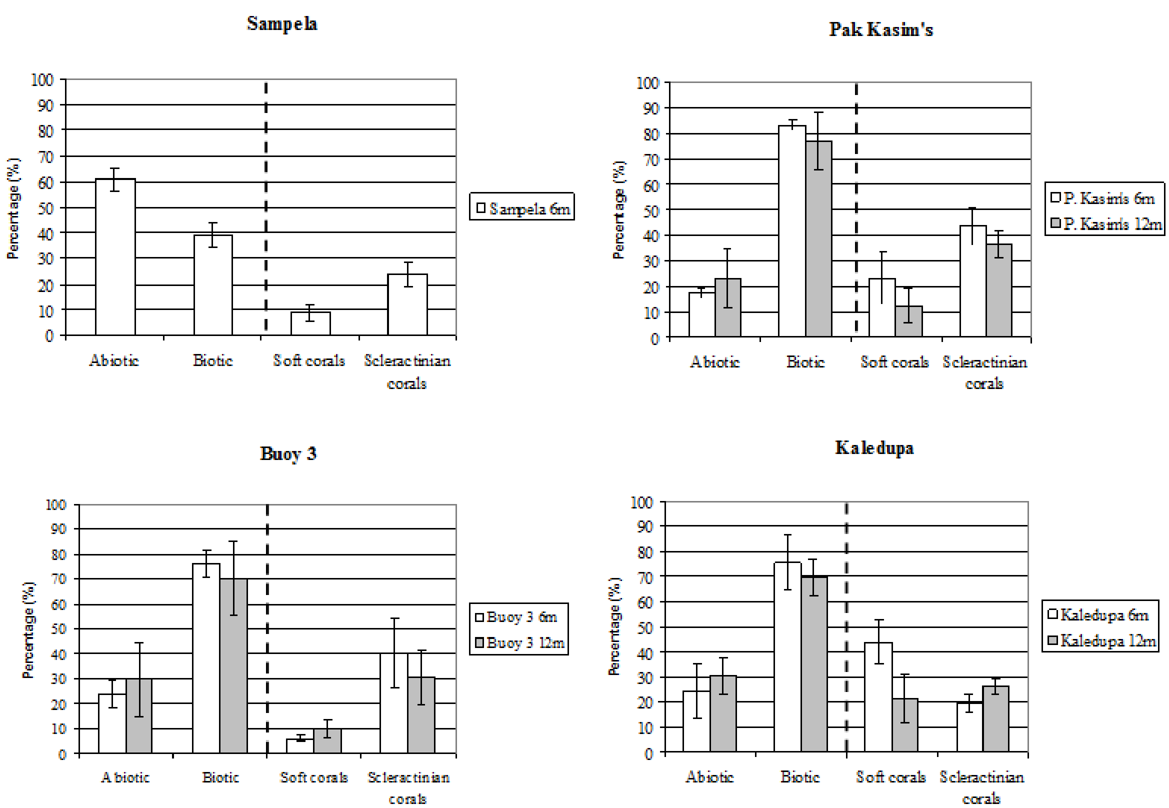


Figure 5: Summary of the benthic cover in the 4 studied sites (Sampela, Pak Kasim's, Buoy 3 and Kaledupa).

massive and foliose corals).

Discussion

When taking into account the environmental parameters measured such as sedimentation rate and rugosity, the obtained results suggest that Sampela can be considered as an impacted site, which agrees with the previous results of Crabbe and Smith (2002). In contrary, the sedimentation rate at Kaledupa was slighthy lower and reef complexity was higher than at the other sites. This site can be considered as a pristine one. The two other sites, Buoy 3 and Pak Kasim's, can be considered to be intermediately impacted.

Analysis of bioeroder and coral predator communities showed that despite the lack of any significant difference in biotic cover between the three sites Kaledupa, Buoy 3 and Pak Kasim's, a common gradient seems to emerge. The superposition of bioeroders' densities on the MDS plot showed the essential role played by the boring lithophagid bivalves, which probably contributes to the similarity between Sampela and Pak Kasim's. Although the biotic and coral cover of Pak Kasim's is high, this site also suffers from a similar level of infestation and perturbation as Sampela. However, unlike Sampela, visual observations and monitoring methods at Pak Kasim's did not reveal a substantial number of dead corals infested by bioeroders as in Sampela. It suggests that this site is going through the process of reef degradation previously experienced at Sampela.

The study of organisms associated with live scleractinian corals in the Wakatobi Marine National Park has shown that infestation rate of coral colonies by coral associates (essentially boring lithophagid bivalves) seems to be related to coral reef status (pristine, intermediate and impacted sites). The infestation rate by coral associates is more important in impacted site than in pristine site. Almost all coral associates are filter-feeding heterotrophs and hence, would be expected to increase in numbers in water with elevated nutrient concentrations (Risk et al. 2001; Floros et al. 2005). In consequence, as suggested by Risk et al. (2001) the health of a reef may be evaluated by scouring the density of coral associates on massive corals. This is base on the theory that coral associate numbers will increase with organic loading: stressed corals will be less able to protect themselves from settlement and overgrowth (Risk et al., 1993).

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