Substrate complexity and albedo preference of reef zooplankton

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Abstract. Coral reefs provide demersal zooplankton with a habitat divergent in structural complexity and colour from which to choose from. Most zooplankton are known to use light to guide orientation in the water column and many reef resident species are dependent on coral crevices or interstitial spaces to hide away from predators. By choosing the most suitable substrate, they would benefit from increased chances for survival and reproduction but little is known about whether substrate complexities and albedo contrasts are used in this context. In analyzing samples caught using emergence traps and experimental structures resembling *Acropora* in the coral reefs of Bidong Island, Malaysia, the results demonstrate a visual capability in a broad suite of zooplantkon taxa, and provide clues in demersal reef zooplankton that substrate albedo can influence behavior. However, species that are associated closely to the bottom substrate did not show a preference for higher complexities, as we predicted, and taxa with a pelagic lifestyle were also non-selective to structural complexity levels. Our results suggest that demersal zooplankton can respond to substrate albedo, emphasizing the potential implication of globally increasing bleaching and anthropogenic destruction of corals.

Key words: Reef zooplankton, substrate complexity, albedo, *Acropora* reef, emergence trap.

Introduction

Demersal zooplankton in coral reefs are provided with a habitat divergent in structural complexity and colour. Many zooplankton respond to underwater light intensities to orientate themselves in the water column (Forward, 1988) or to avoid visual predators. Similarly, many reef resident species reside in coral crevices and interstitial spaces to hide away from predators (Alldredge and King, 1977). Choosing the most suitable substrate would be beneficial to these zooplankton since it increases the chances for survival and reproduction. Whether substrate complexities and albedo contrasts influence substrate selection in demersal zooplankton is still relatively unknown.. Here we use emergence traps and experimental structures of varying complexity in the coral reefs of Bidong Island, Malaysia to test the responses to reef structure complexity of a broad suite of tropical zooplankton. We predict that taxa that are associated closely with the bottom substrate will, if they can differentiate complex structures of contrasting albedo, be attracted to higher complexities and low albedo. In contrast, we predict that both pelagic taxa (those that remain in the water column throughout their lives) and nocturnally emergent taxa (those that ascend into the water column at night, but spend the day hidden in benthic sediment) will show partial or non-selective response.

Material and Methods

The study was carried out in the fringing reef area of Bidong Island, Malaysia (Fig. 1) over six days in October 2010. The depth at the study site was 3.0-5.5 m depending on the tide. The reef consisted mainly of *Acropora* branching corals at near 100% coverage up to 20-30 m offshore, where the reef edge meets with sandy bottom.
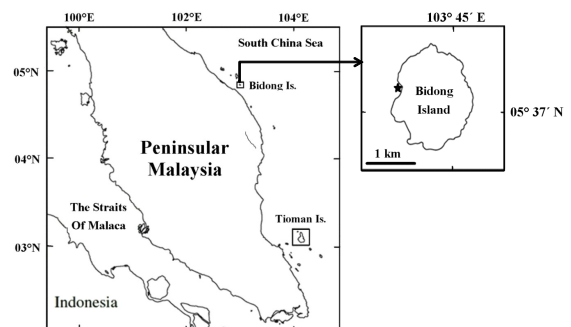

Figure 1: Location of sampling site at Bidong Island, Terengganu.

For structural complexity experiments, six units of 50 x 50 x 50 cm³ structures made of a combination of PVC pipes and flexible hoses (dia. ½ inch) were used to resemble the increasing complexity of *Acropora*

branching reefs (Fig. 2). Each structure is equipped with an emergence trap (Porter & Porter 1977) consisting of 1.5 m high cones of mesh size 140 µm. The structures were labeled C1, C2, C3 according to increasing complexity and duplicate structures were prepared for each complexity level. The surface area:volume ratio was also determined. These structures were placed randomly 0.5-1.0 m apart from each other on sandy bottom immediately adjacent to the edge of the fringing reef. The complexity experiment was carried out for three consecutive days.
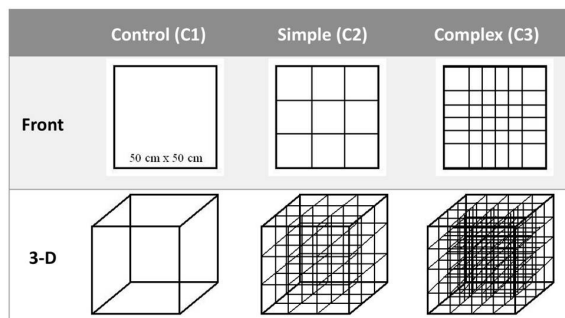

Figure 2: Experimental structures at three complexity levels.

For albedo experiments, black and white structures of the same complexity (C2) were used to test for albedo preference. Zooplankton samples were collected with the same emergence traps used in the structure complexity experiment and placed at 0.5-1.0 m apart from each other at the same site. For both experiments, sample cod-ends were collected at 1000 hr for and 1700 hr for 3 consecutive days. Thus, 1000-1700 hr represented day samples and 1700-1000 hr, night samples. Samples were concentrated and fixed immediately in 5% formalin seawater for taxonomic analysis and emergence rate estimations (inds. m^{-2} h^{-1}). Zooplankton were identified to the lowest taxonomic level possible. *In situ* water temperature, salinity and tide level were recorded at each collection.

Analysis of variance (ANOVA) was performed to test for differences in zooplankton emergence rates among the complexity levels. Student's t-test was used to analyze differences in emergence rates between the black and white structures.

Results

Mean temperature and salinity were 31.3 and 33.4 °C, respectively (Fig. 3). There was no significant difference in the two parameters between sampling days (one-way ANOVA: Temp p=0.22; Sal p=0.61). Tide levels varied less than 1 m throughout the study period.

Overall, 42 zooplankton taxa and 33 genera from 5 orders of copepod were identified. Emergence rates of zooplankton in the complexity experiment showed a significant difference between day and night (two-way ANOVA: n=16, p<0.001) but not among complexity levels (two-way ANOVA: p=0.823) (Fig. 4).

Copepods were dominant in the zooplantkon community especially at night when its numbers increased significantly (Fig. 5). *Appendicularia* and copepod nauplius was abundant in the day samples while the relative numbers of Chaetognath increased at night. *Microsetella* was the most dominant among the major copepod groups, followed by *Oithona*, *Oncaea* and *Corycaeus*. However, none of these dominant copepods showed a significant difference in emergence rates among the complexity levels tested.

For non-copepod taxa, only benthic ostracod and bivalve emergence rates showed a significant difference among the complexity levels (two-way ANOVA: p=0.03). A higher emergence rate of these taxa in the C1 structure caused this difference as revealed by a Tukey post hoc test.
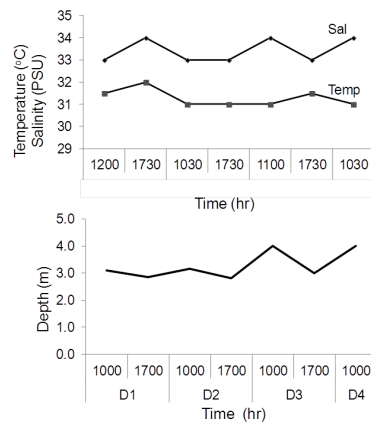

Figure 3: Environmental parameters during the sampling period.
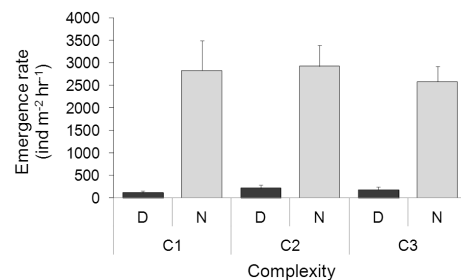

Figure 4: Average emergence rates of zooplankton between day (D) and night (N) among the complexity levels. (C1, 2, 3). Error bars indicate S.D.
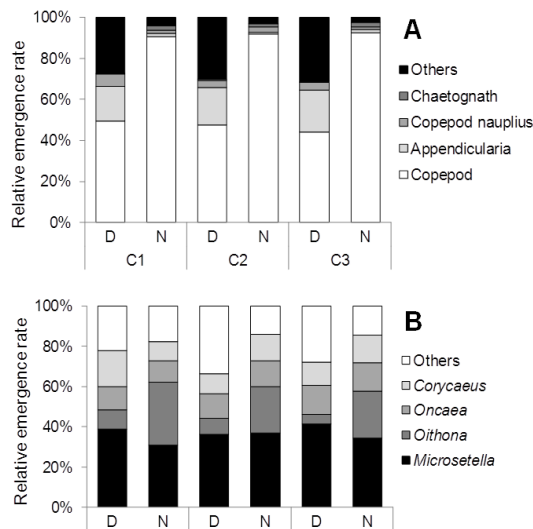
Figure 5: Relative emergence rates of the major zooplankton (A) and copepod (B) groups between day (D) and night (N) among the complexity levels (C1, 2, 3).
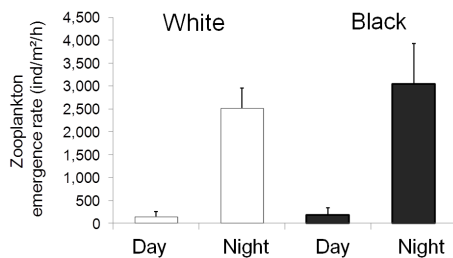

Figure 6: Average emergence rates of zooplankton between the white and black structures for day and night times. Error bars denote S.D.

Average zooplankton emergence rate showed a significant difference between day and night (two-way ANOVA: n=12, p<0.001) (Fig. 6); although it was relatively higher for the black structures in general, there was no significant difference (two-way ANOVA: n=12, p=0.355). However, some individual groups of zooplankton showed a significant preference to albedo (Table 1). Among these, all but two of the zooplankton showed preference for the black structure.

Taxon	Mean emergence rate (ind/m²/h)		Significance level (p)	Preferred Colour
	White	Black		
Appendicularia	36.4	81.6	<0.05	Black
Hyperiidae	1.2	2.7	<0.05	Black
Parvocalanus spp.	16.3	58.0	<0.05	Black
Unidentified calanoid*	7.2	29.2	<0.05	Black
Actinotrocha larvae	0.1	0.5	<0.05	Black
Bivalve	1.1	5.6	<0.01	Black
Gastropod	1.8	8.7	<0.05	Black
Hydromedusa	0.5	2.4	<0.01	Black
Mysid	1.0	1.8	<0.05	Black
Pilidium larvae	0.5	3.1	<0.001	Black
Polychaete larvae	0.4	1.8	<0.05	Black
Siphonophore	0.0	0.4	<0.001	Black
Acrocalanus spp.	0.4	0.0	<0.05	**White**
Euterpina sp.	0.4	1.2	<0.05	Black
Paracalanus spp.	5.1	14.7	<0.05	Black
Paracandacia spp.	1.8	0.2	<0.01	**White**
Temora spp.	0.6	2.5	<0.05	Black
Stephos spp.	1.1	1.6	<0.01	Black

Table 1: List of the zooplankton with a significant preference toward the tested colours.

Discussion

Our study demonstrates that some reef zooplankton are capable of detecting and responding to substrate albedo contrast. These taxa can potentially benefit from such behaviour because reefs are home to a wide variety of planktivores that feed there both day and night (Hamber et al 1988, Annese et al 2005). Risk of predation is dependent on visual detection and a darker environment greatly enhances the chances of survival (Alldredge & King 1977, Zaret & Suffern 1976). Thus, habitat albedo may be an important feature for determining residing preference.

Previous indication for substrate complexity preference is restricted to the zooplankton from various coral reef substrates of a natural reef habitat (Porter & Porter 1977) where the amount of zooplankton emerging from reef substrates was significantly related to the degree of three-dimensional structure of the substrates. However, only benthic ostracods and bivalves showed a significant difference in our study. For these taxa, the ability to exercise complexity preferences to determine and remain within a suitable habitat could be critical for recruitment success. For the majority of the zooplankton, the range of structural complexity levels tested in this study may have been too small to render any differences in emergence rates or that habitat structural complexity may not be a factor in determining substrate choice. Another possible explanation for this is that association with the seabed below the corals may be of greater importance for benthic associated zooplankters as many are known to reside within the interstitial spaces of reef sands.

The lightscape in shallow water environments is influenced by surface light conditions and incident irradiation underwater (Kirk 1983). These factors

combine to determine the level of light that produce responses to varying albedo contrasts. Although zooplankton photobiology is widely studied (Forward 1988, Ringelberg 1995), albedo detection in zooplankton is poorly understood, and a broad taxonomic investigation of visual mechanisms and thresholds is needed to enable predictions of the likely levels of detection of substrate albedo by zooplankton.

The recent trend in declining coral reef habitat due to rising sea temperatures (Glynn 1996) and anthropogenic influences (Brown 1987) is of great concern. In recently bleached reef environments, this can lead to increases in substrate albedo which, given our results, may mean that reef zooplankton abundances decrease as they steer away from these substrates to avoid potential predation risk. If this was the case, coral bleaching could lead to decreases in zooplankton diversity and biomass that underpin critical foodwebs and fisheries. While it appears the effect of substrate structural complexity could not be concluded from this study, the potential implications of physical destruction of reefs cannot be left unanswered. Our study, demonstrating ecologically relevant utilization of substrate albedo in a broad suite of tropical reef zooplankton, suggests that the influence of reef albedo for orientation is potentially important and widespread, and highlights the need for further research into the impact of bleaching and destruction throughout coral ecosystems.

Acknowledgement

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