Comparing the structure and function of the Antarctic and Tropic benthic communities following environmental changes

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Abstract. A comparative study was carried out to determine the impacts of environmental changes on the structure and function of benthic communities in polar and tropical regions. This study compared a new work in Tropical region with a previous study in Marian Cove, West Antarctic Peninsula. Samplings in Tropica region were done to determine the impacts of monsoon season on the benthic diversity in Bidong Island, Malaysia. Hand core (with the aid of SCUBA diving) was used to collect sediment samples containing benthic organisms at 3 stations during pre- and post-monsoon. Study found that both species number and functional diversity were low at stations with high environmental impacts, i.e. during post-monsoon season. However, the taxonomic diversity of the community was not different between seasons. These were found out to be in similar trend with the study in Polar region. The present study showed that the environmental variability had an effect on benthic communities both structurally and functionally. Although widely spatially separated, the responses of different benthic communities towards environmental changes were similar.
Key Words: benthic communities, functional diversity, Antarctic, Tropic.

Introduction. The marine system is perhaps the most complex among ecosystems and blessed with highly diverse communities and characterised with highly interrelated processes between biological and physical components (Dune et al 2004; Elliott 2002). Information on all aspects (e.g. structure and function) of this system is essential in managing its resources. The ecological structure and function are recognised as the main components to be maintained so that the system can provide its important services for the societal and economic benefits (Elliott 2002).

Effective environmental management requires biological indicators to assess the status of and/or trends in resources of interest. Benthic fauna have been one of the most common organisms used as indicators for assessing environmental quality in marine environments due to their diversity and known characteristics such as limited mobility (meaning they are unable to avoid the environmental changes as most pelagic fauna can) (Gray 1979) and long life spans of up to several years (Nilsson & Rossenberg 1997). Another factor that makes the benthic fauna suitable indicator organisms is their sensitive response to various environmental stressors due to their physiological tolerances, feeding mechanisms and trophic interactions (Pearson & Rosenberg 1978).

The impacts of environmental changes on the structure of benthic communities are well studied. Depending upon the latitudinal areas, the rise in seawater temperature may adversely affect the reproduction of some species while may increase the reproduction rate of other species. This in turn will change the composition and diversity of benthic faunal communities following the changes (Hiscock et al 2001). However, relatively less is known about the effect of climate and its dynamic on benthic ecosystem function and how the function varies under different climate-driven changes. Only recently, a growing interest on the benthic ecosystem function is evident. This is mainly based on the premise of 'functional redundancy' where the loss of a particular species doesn't affect ecosystem function since the function performed by that species is taken up by another species from the same functional group (Lévêque & Mounolou 2003; Walker 1992). In the context of the Antarctic environment, the changes of seawater temperature may change the diversity and composition of benthic communities seasonally. However, whether the change will affect the functional capacity (or health) of the ecosystem is unknown. Similarly, the same anticipation is also true for the Tropic ecosystem with regard to the impacts following environmental changes. Therefore, this study conducted to investigate the impacts of climate-driven environmental changes in both Polar and Tropic regions and to see how the impacts on benthic structure and function at both regions are compared.

Material and Method

Study area. Study in the Tropical region was conducted in Bidong Island (Figure 1). This island is located approximately 14 km off the mainland of Terengganu, in Peninsula Malaysia. It has no permanent inhabitant since the occupation of Viatnamese refugees which stopped in 1991. Due to its distance from the mainland, this island is influenced by the mainland in terms of current circulation (Daud & Akhir 2015). Bidong Island is also strongly influenced by the monsoon seasons which bring a frequent heavy raining from end of October to end of January (Ibrahim et al 2006). Meanwhile, Polar study by Moon et al 2015 was conducted in Marian Cove (Figure 2), in the West Antarctic peninsula.

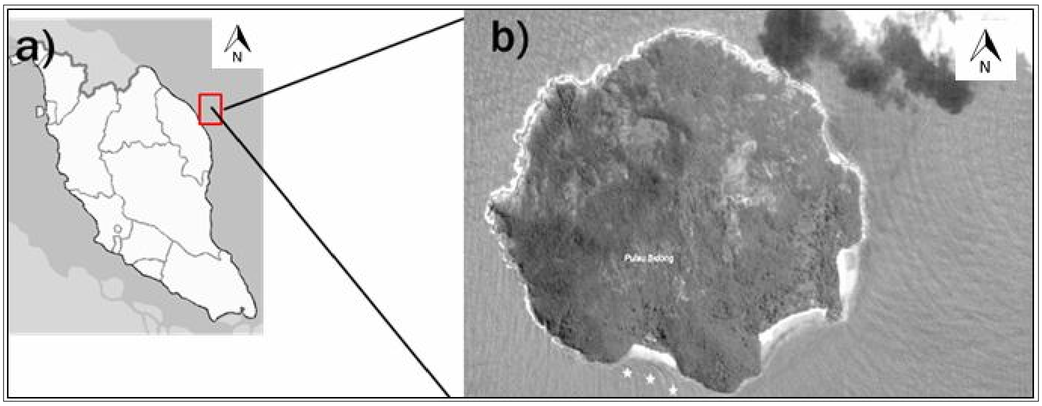

Figure 1. (a) Location of Bidong Island in the east coast of Peninsula Malaysia. (b) The Bidong Island and three sampling stations indicated near the shoreline (Google Maps 2016).

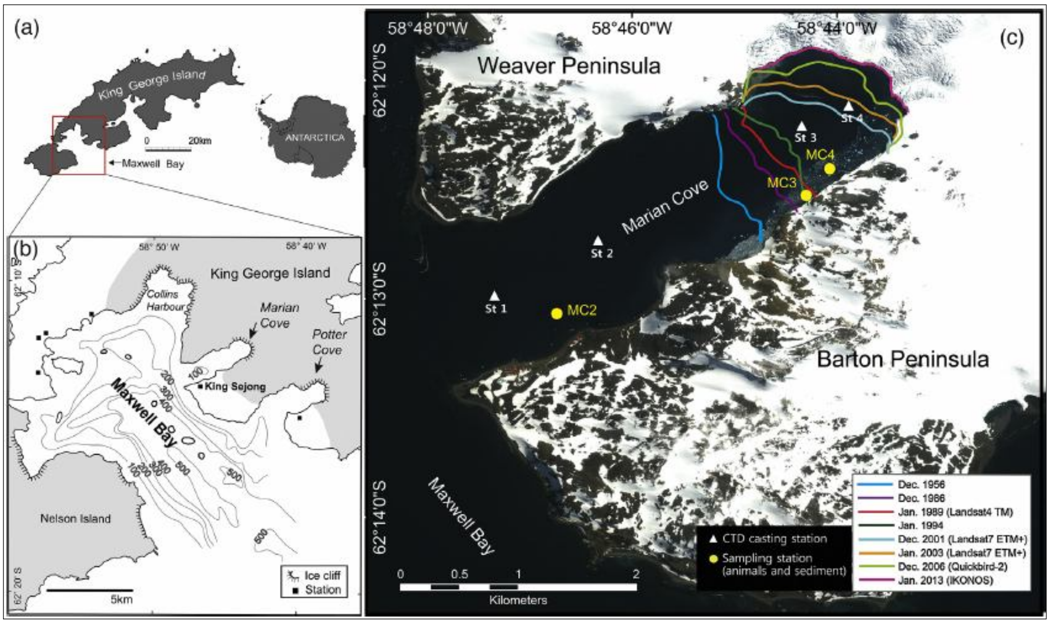

Figure 2. (a) Location of King George Island and Maxwell Bay; (b) Bathymetry of Maxwell Bay and its tributary embayment. The grey area denotes glacier cover; (c) Sampling sites in Marian Cove (MC). Source of all figures are from Moon et al (2015).

Sample collection. Study in tropical region was done to determine the impacts of rainy season. The pre-monsoon sampling was conducted in September 2013 while the post-monsoon sampling was conducted in March 2014. Samples were collected at three stations near the coastline of Pasir Cina beach in Bidong Island with three replications. Hand core (with the aid of SCUBA diving) was used to collect sediment samples containing benthic organisms. The collected specimens were transferred into a plastic bucket and fixed with 4-5% seawater-buffered formalin and preserved in 70% or 100% ethanol. All specimens were then identified to the lowest possible taxonomic levels. Study in the Polar region was carried out at stations with different degrees of impact from glacier melting (see Moon et al (2015) for details).

Structural and functional analyses. The benthic community structure was assessed based on species richness (S) and Taxonomic Distinctness (TD). S is simply the number of species recorded, while TD takes into account the taxonomic information of the community in its calculation. TD measures the average distance between species traced through the taxonomic classification (by mean of dendrogram) in an assemblage. This information is arranged in a species-by-sample data matrix with corresponding taxa and calculated by dividing the path length of every pair of species in the list by the total number of paths (Clarke & Warwick 2001). All calculations were done using the PRIMER 6 package (Clarke & Gorley 2006).

Analysis involving the functional traits of the organisms used in this study was Functional Diversity (FD). Based on the traits classification, a dendrogram is constructed and the total branch length of the dendrogram is measured to determine the functional diversity of a community (Petchy & Gaston 2007). In other word, FD measures how much some traits in one species are different to the traits in other species (i.e. complementarity between species). Complementarity between species increases as the difference between species traits values increases, which also increase the FD (Petchy & Gaston 2002). FD is influenced by the number of species, number of functional traits, community composition and species identity (Petchy & Gaston 2002, 2006). Determination of FD was based on different set of categories and traits depending on the regions. The Tropical benthic communities were classified into eight categories namely: size, larval type, relative adult mobility, body form, degree of attachment, adult life habit, feeding habit, and habitat. Similarly, each of these categories contained several different traits. For example, the category of adult life habit contained traits of 'sessile attachment', 'tube attachment', 'burrower' and 'crawler'. The classification of benthic traits in Polar region was as in Moon et al (2015). Species were assigned to each trait using a 'fuzzy coding' procedure in the range from 0 to 3; with 0 being no affinity and 3 being high affinity (Chevenet et al 1994). FD was then calculated using codes freely available from http://owenpetchey.staff.shef.ac.uk/Code/code.html (Petchy & Gaston 2002, 2006) and carried out using R version 3.0 software (R Development Core Team 2008). Both FD and TD use presence-absence data which give an advantage where these indices are less affected by variations in sampling effort or incomplete sampling (Clarke & Warwick 2001; Magurran 2004).

Statistical analysis. As data did not meet parametric data requirements, non-parametric tests were performed to measure the difference among stations and seasons. Kruskal-Wallis test was applied using the mean values for each of the above indices to verify the significant difference between stations.

Multivariate analyses were performed using PRIMER (Plymouth Routines in Multivariate Ecological Research) package version 6 (Clarke & Gorley 2006) to measure spatial and temporal differences in macrofaunal assemblages. Structural and functional (dis)similarities between stations and seasons were graphically presented on non-metric multidimensional scaling (MDS). This non-metric ordination gives no exact value but it is presented in terms or relative comparison. The distance between samples indicates the relative similarity of the multivariate data where samples that are clustered together are more similar than samples that are far apart. This ordination was further tested using analysis of similarity (ANOSIM) to test the significant difference between the samples.

Results and Discussion. The general comparison in Tropical study showed that the assemblages were significantly different. During pre-monsoon, the average number of species were 5.3 (±3.8), 6.7 (±0.6) and 2.7 (±0.6) for Station 1, 2 and 3 respectively. Meanwhile during post-monsoon season, the number was somewhat lower with 0.3 (±0.6), 2.3 (±1.5), and 3 (±1). The community in post-monsoon season was significantly lower in terms of species richness (Kruskal-Wallis test, $p < 0.05$). The higher number of benthic fauna during the pre-monsoon season seems to be related to the higher organic carbon content during this season compared to post-monsoon season as reported near Pahang coast, Peninsula Malaysia (Kamaruzzaman et al 2010). In terms of taxonomic diversity, communities from both seasons show no significant difference where samples from pre-monsoon season were as taxonomically distinct as the samples from post-monsoon season (Figure 3). Although the number of species during post-monsoon season was numerically lower than the pre-monsoon, however, the post-monsoon community contained almost similar taxa of higher level. This might reduce the degree of difference in terms of taxonomy between seasons. The findings on benthic community structure are comparable with the Polar study which also found that stations with higher degree of impact (depicted by the closer distance from glacier melting) recorded a lower number of species (Moon et al 2015). Similarly, the TD index also showed no difference between stations (Figure 4) (Moon et al 2015).

In terms of functional capacity, FD value was lower during post monsoon season (Kruskal-Wallis test, $p < 0.05$). The MDS plot shows that some samples from both seasons are dispersed away from each other, indicating a clear difference (Figure 5). This is in accord with findings in Moon et al (2015) where FD index values were lower at the inner cove (MC 4) than the MC 2 of the outer cover. Similarly, as shown in Figure 6, samples of MC 4 are dispersed away from samples of MC 2 and MC 3 which are clustered together, depicting that samples of MC 2 are more different than the MC 2 and other samples (Moon et al 2015). It was also recorded that traits diversity had a strong relationship with the number of species, where the increase number of species increase the FD value (Figure 7). This shows that the functions of one species of benthic fauna in Bidong Island were equally complementary to the functions of other species. This gives the meaning that when the FD increases due to the addition of any one species to the site, such increase would also occur when any other species are added (Sala et al 1996; Tilman et al 1997; D́iaz & Cabido 2001; Petchy & Gaston 2002).

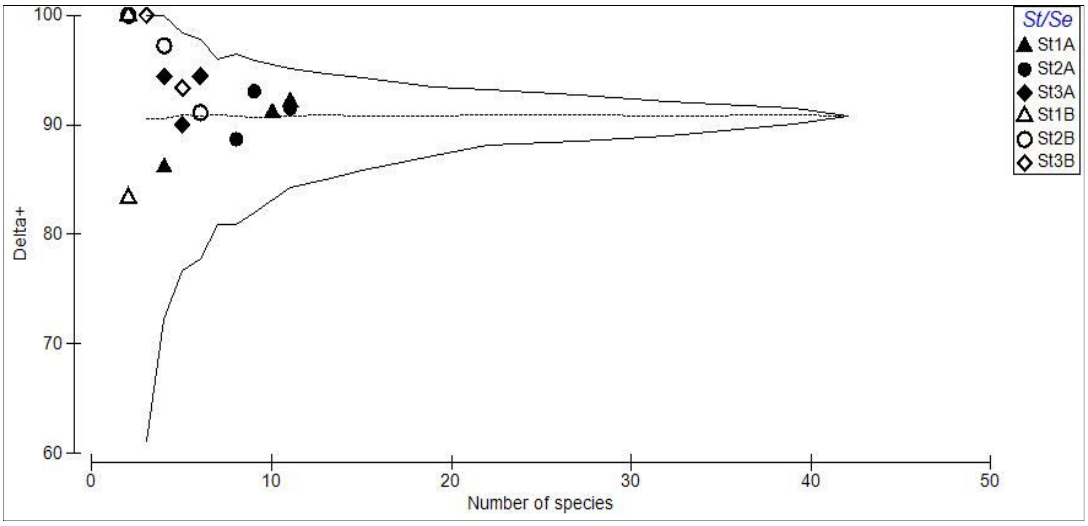

Figure 3. Comparison of taxonomic diversity among faunal assemblages collected from the three stations in Bidong Island at different station (St) and season (Se). The letter “A” after station codes depicts pre-monsoon season while the letter “B” depicts post-monsoon. The mean TD of the whole assemblage is represented by the dotted horizontal line, while the funnel lines indicate the 95% confidence limits. All values are within the funnel lines, indicating that all assemblages are taxonomically similar.

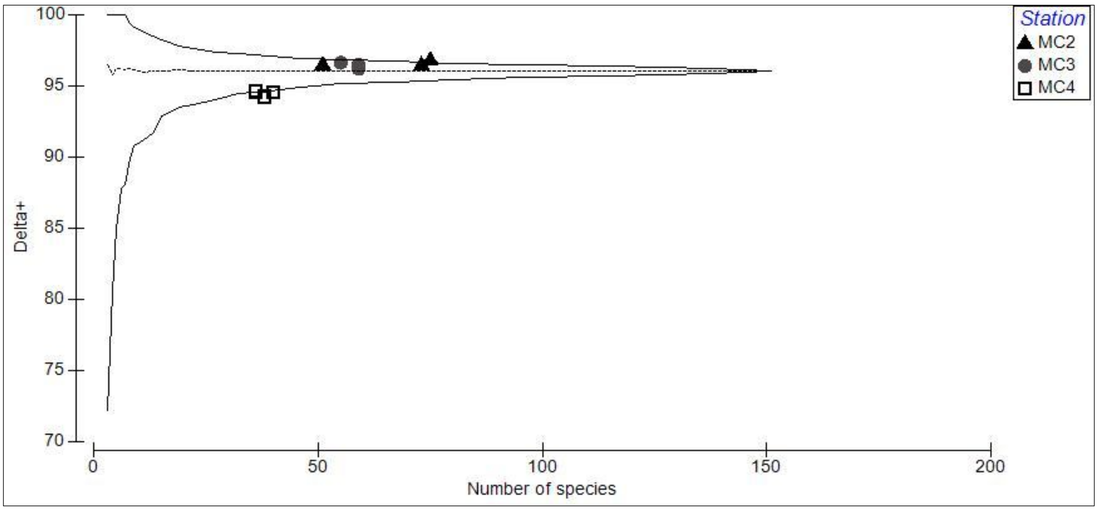

Figure 4. Comparison of taxonomic diversity among faunal assemblages collected from the three stations in Marian Cove (MC). All values are within the funnel lines, indicating that all assemblages are taxonomically similar. Figure is adopted from Moon et al (2015).

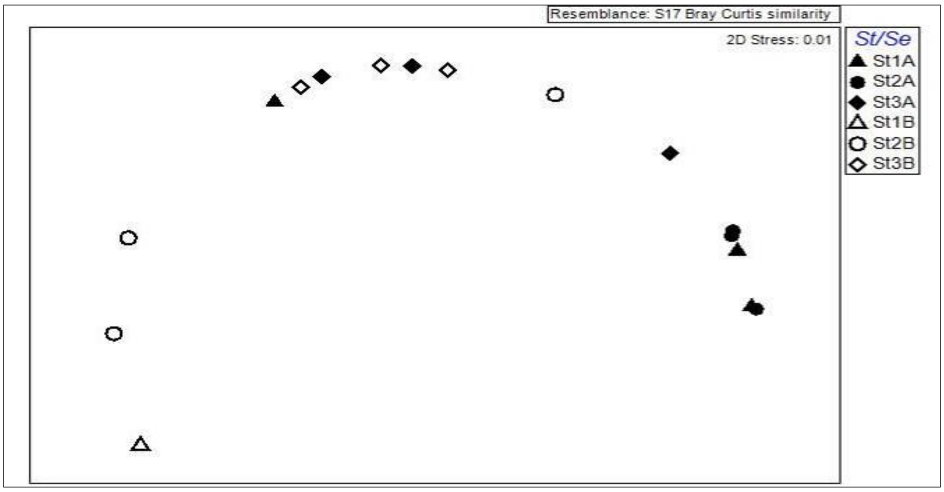

Figure 5. An MDS plot of Bray-Curtis similarity based on square root transformed data of the Functional Diversity index at Bidong Island at different station (St) and season (Se). The letter “A” after station codes depicts pre-monsoon while the letter “B” depicts post-monsoon.

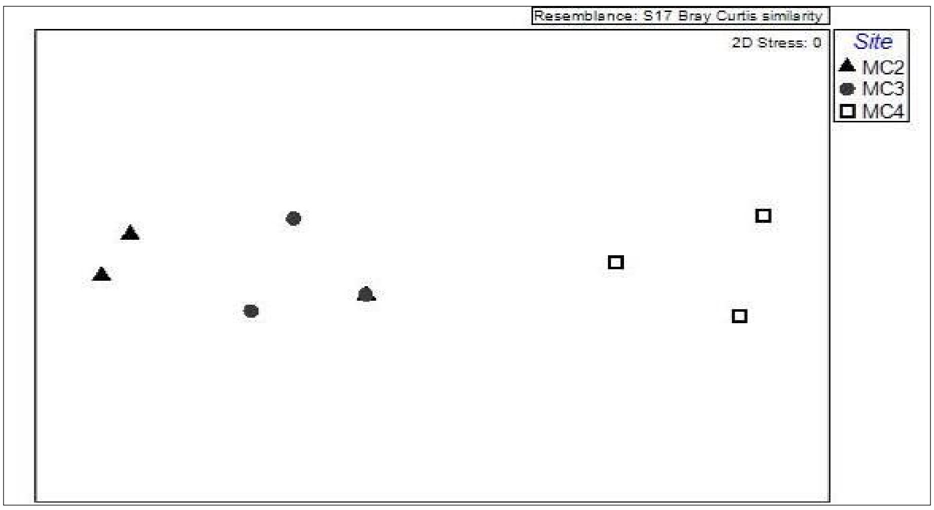

Figure 6. An MDS plot of Bray-Curtis similarity based on square root transformed data of the Functional Diversity index at stations MC 2, MC 3 and MC 4. Figure adopted from Moon et al (2015).

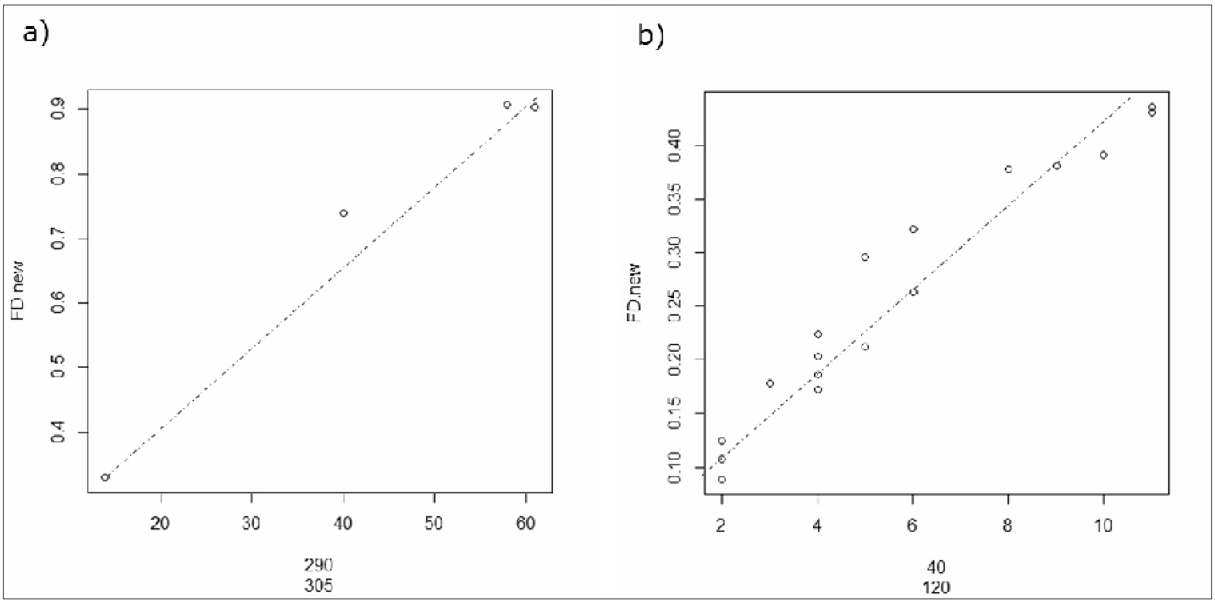

Figure 7. Graphs show the correlation between FD value and the number of species in a) Polar study and b) Tropical study. Both areas recorded that the increase number of species would increase the FD value.

Conclusions. This study showed that the environmental variability had an effect on benthic communities, both structurally and functionally. Although widely spatially separated, the responses of different benthic communities towards environmental changes were somewhat similar. The functional aspects of the Tropic benthic community seemed to be more sensitive to the physical change than the response of Polar benthic communities. This may be due to the removal of a few species with many functions that is recorded in Tropic study. However, a further study with a bigger spatial scale at both geographical regions is necessary to make a more justifiable conclusion with regard to the trend of change.

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