Community structure and taxonomic diversity of macrobenthic communities in Merchang lagoon, Malaysia

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Abstract. An estuarine area in the east coast of Peninsula Malaysia, namely Merchang lagoon was selected to conduct the present study on the structural and taxonomic diversities of macrobenthic communities. Samples were collected from 3 stations in four sampling occasions associated with different environmental conditions. Benthic community structures, in particular the abundance and species richness showed a significant difference between stations where station 1 which was characterized by clean sandy sediments recorded the lowest number of individuals and species. Likewise, a significant difference was also recorded between months where November (rainy season) comprised the lowest number of individuals and species. Such trend was however not evidence for the Simpson index and Pielou evenness index. In terms of taxonomic diversity, there was no clear difference recorded in taxonomic distinctness (TD) value between stations as well as between months. The dominance of certain species was the causative factor that contributed to the difference in community composition. In contrast, as the dominant species were not taxonomically different from the other common species recorded in the present study, the absence of these species in station 1 and November did not impose a significant impact on the taxonomic distinctness. A further study that measures the physical characteristics of the area is recommended for a better understanding on how the hydrodynamical changes following rainy season would directly affect the benthic organisms.

Key Words: macrobenthos, species composition, taxonomic distinctness, Peninsula Malaysia.

Introduction. Benthic macrofauna is very essential in marine ecosystem as it provides various functions to the health of the ecosystem. Soft-bottom macrobenthos is an important food source for fish as well as general marine food chain (Musale et al 2015; Li et al 2017). In estuarine ecosystems, macrobenthic communities are considered a critical component that help in maintaining the ecosystem functions through reworking, breaking down and incorporating organic matter into sediments (Heip et al 1995; Herman et al 1999). They have also been one of the most common organisms used as indicators for assessing aquatic ecosystems. They are very responsive to various environmental stressors due to their characteristics such as limited mobility (Gray 1979), long life spans of up to several years (Nilsson & Rossenberg 1997), and sensitive response to various environmental changes (Pearson & Rosenberg 1978; Rhoads et al 1978). In addition, their tolerance to environmental conditions while being sensitive to contamination makes them a suitable representative organism to reflect the environmental quality (Gao et al 2011). These bottom-dwelling organisms respond to the changes in environmental conditions through variations in abundance, biomass, diversity and species composition (Koperski 2010; Weliange et al 2017; Márquez et al 2017). Many studies showed that variation in environmental factors has led to the changes in macrobenthic community structure (e.g. Verissimo et al 2012; Carcedo et al 2015; Veiga et al 2017; Wang et al 2017).

There are 3 common categories of protocols that ecologists use in assessing benthic communities (Smith et al 2001; Borja et al 2008; Manusawai et al 2020) namely; 1) community structure-based measurement such as simple diversity index, 2) multimetric index measurements where a combination of multiple metrics into a single index is used (Nelson 1990; Engle et al 1994; Weisberg et al 1997), 3) multivariate analysis to describe the pattern of benthic community (Field et al 1982). Although the multivariate analysis is more sensitive to any community changes compared to the univariate methods (Norris 1995), however, transmitting of the findings from this analysis to the environmental managers could be difficult due to the complexity of multivariate analysis (Gerritsen 1995).

Although those protocols are useful in assessing the community structure, they however treat the species or taxa as equivalent entities (i.e. they do not discriminate between taxa). This is potentially problematic as different species perform various different functions in ecosystems. Intuitively, a faunal community in which a function is provided by only one taxon is considered less diverse than where that same function is provided by different taxa. Thus, the use of taxonomic diversity which incorporates the phylogenetic information is important in assessing the changes in benthic communities.

An estuarine area in the east coast of Peninsula Malaysia, namely Merchang lagoon was selected to conduct the present study on the structural and taxonomic diversities of macrobenthic communities. This estuarine ecosystem is understudied although it is important in terms of traditional fishing and small-scaled tourism activities. There is very limited number of researches in this lagoon with the only documented ecological work was on the fish communities in seagrass bed in 2005 (Aziz et al 2006). The present study was therefore conducted to provide a baseline information on the ecological process in Merchang lagoon with the emphasis on the structural and taxonomic diversities of macrobenthic communities.

Material and Method

Sampling design. This study was conducted in Merchang lagoon (5°0'49"N 103°18'16"E - 5° 2'16"N, 103°17'50"E) which is situated in the state of Terengganu in the east coast of Peninsula Malaysia. Merchang lagoon was characterized by oyster farming and dominant seagrass species of *Halodule pinifolia* and *Halophila ovalis* (Aziz et al 2006). However, a personal observation during the sampling period from November 2018 to October 2019 found out this lagoon was no longer inhabited by seagrass species. No oyster farming was also evidenced mainly due to topographical and hydrodynamical changes that imposed many problems to the farming industry. Samples were collected at three stations in November 2018 (monsoon), February 2019 (post-monsoon), June 2019 (non-monsoon) and October 2019 (pre-monsoon). Station 1 (St. 1) was located near jetty and characterized by clean sandy sediments. Station 2 (St. 2) was located in front of the river mouth and contained muddy sediments. Meanwhile, Station 3 (St. 3) was located near jetty and household area and characterized by sandy sediments (Figure 1). All samples were collected in triplications.

Sample collections. Sediment samples were collected using a mini ponar grab. Once the grab samples were taken on-board, sediments were then washed over 0.5 mm mesh sieves with seawater to remove the fine sediments. The sediments remain on the sieve were then back-washed into separate labelled containers and fixed in 4-6% buffered formaldehyde solution (diluted in seawater).

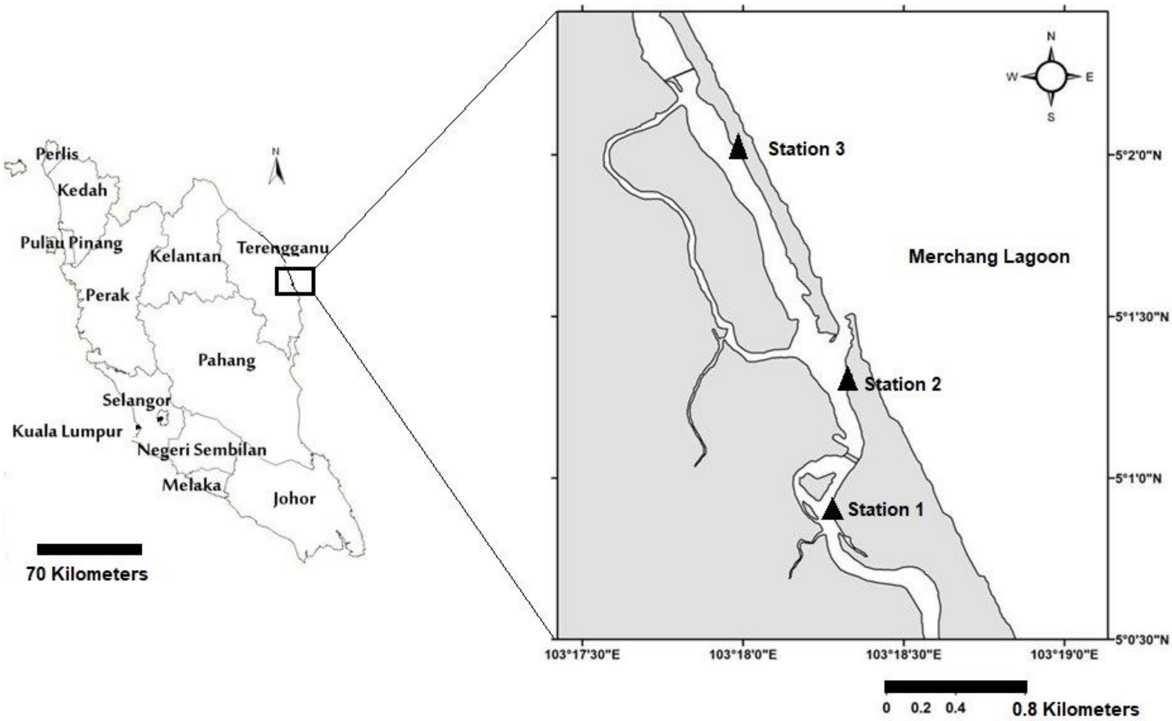


Figure 1. The location of three sampling stations (Station 1, 2, 3) in Merchang lagoon (Adapted from Alias et al 2014).

Macrofaunal sample analyses. Macrofaunal sample processing was carried out based on guidelines by Tagliapietra & Sigovini (2010) with some modifications. The sediments containing macrobenthos were washed with fresh water over a 0.5 mm sieve in fume cupboard to remove the formalin. The macrobenthos were then hand-picked and sorted according to major taxa in glass vials containing 70% ethanol. Specimens were identified to the lowest possible taxonomic level and counted for every individual.

Structural metrics including abundance (N), number of species (S), Margalef index (Dm), Simpson index (Ds) and Pielou index (J') were used to measure the macrobenthic community structure in this study. Margalef index was calculated by dividing the total number of species S, by the total number of individuals, N, in the sample (Magurran 2004):

$$\mathrm{Dm} = \frac{(S-1)}{\ln N}$$

Simpson index (Ds) was calculated based on the probability that if any two individuals are randomly picked from a large community, they are likely to be of the same species. This index is expressed as:

$$\mathrm{Ds} = \sum\left(\frac{ni[ni-1]}{N[N-1]}\right)$$

where *ni* is the number of individuals in the *ith* species; and *N* is the total number of individuals. The original Simpson index increases as diversity decreases. For an easier interpretation, Ds in the present study is expressed as 1 – D with the range of index value is from 0 to 1 (1 is maximum diversity) (Magurran 2004). Meanwhile, Pielou index measures the evenness of the community with formula:

$$J' = H/\log(S),$$

where H is the value of diversity derived from Shannon index and S is the number of species recorded in the sample (Magurran 2004).

In addition to these conventional metrics, an index that focuses on the taxonomical difference of a community (Magurran 2004), taxonomic distinctness (TD) was also applied. In measuring this, a taxonomic classification by mean of dendrogram is used by TD to measure the average distance between species. The TD value is measured by dividing the path length of every pair of species by the total number of paths in a dendrogram. This information is arranged in a species-by-sample data matrix with a corresponding taxonomic classification for calculation using the PRIMER 6 package (Clarke & Warwick 2001; Clarke & Gorley 2006).

Statistical analyses. Due to the non-conformity to the parametric characteristics, univariate analyses were performed using Kruskal-Wallis and Dunn's post hoc tests to measure the significant difference between samples. In addition, multivariate analyses were also carried out to measure the temporal and spatial differences in macrofaunal assemblages. All multivariate analyses were performed using PRIMER (Plymouth Routines in Multivariate Ecological Research) package version 6 (Clarke & Gorley 2006). Structural and taxonomic (dis)similarities between stations were graphically presented using non-metric multidimensional scaling (MDS). The distance between samples in the MDS plot indicates their relative similarity with samples that are grouped together being more similar than samples that are far apart.

Results

Community structure. Overall, there were 9,665 individuals of macrobenthos recorded in this study. Mollusca was found to be the most dominant phylum with 99% of composition. The other phylums contributed to a substantially small percentage of composition, where Annelida recorded only 65 individuals, followed by Nematoda (14 individuals) and Arthropoda (10 individuals). Within the Mollusca, class Gastropoda extremely dominant with more than six-fold number of individuals (8,181 ind.) compared to Bivalvia (1,338 ind.) (Figure 2). The four most dominant taxa were Pyramidellidae (family), followed by *Littoraria* sp., *Scaliola* sp., and Cardiidae (family).

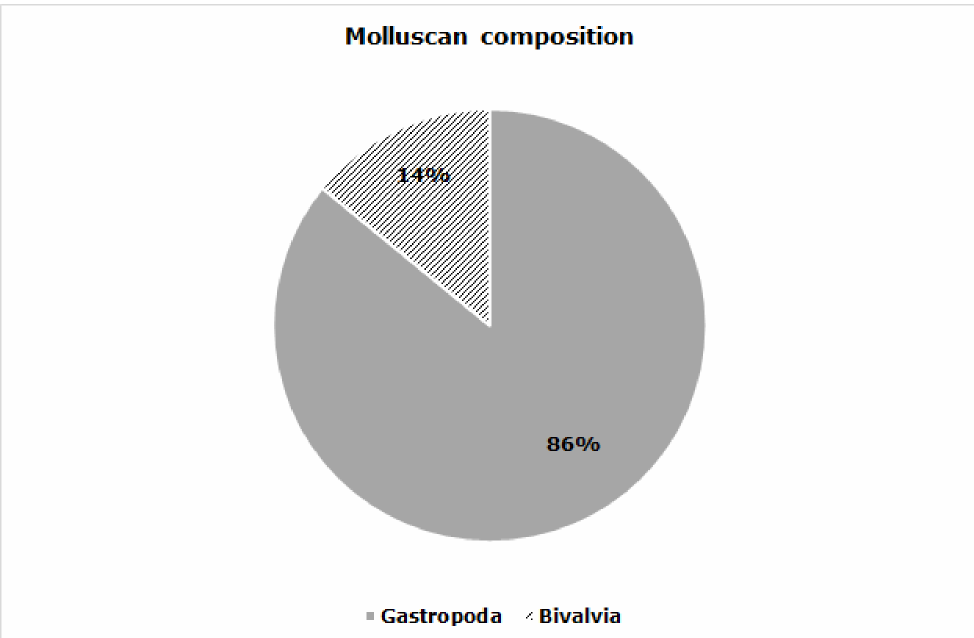


Figure 2. The class composition of phylum Mollusca in Merchang lagoon.

The most abundant macrobenthos was recorded at St. 2 with a total mean of 3,021.7 inds., while only 186.3 inds. and 14.0 inds. were recorded at St. 3 and St. 1 respectively (Figure 3). The temporal comparison of the macrobenthic abundance also recorded a substantial difference. The post-monsoon month (February 2019) recorded the highest total mean of the organisms (713.8 inds.) while the lowest was recorded in the pre-monsoon month (October 2019) with only only 13.9 inds. The difference between months was only significant at St. 2 (Kruskal-Wallis, $p < 0.05$).

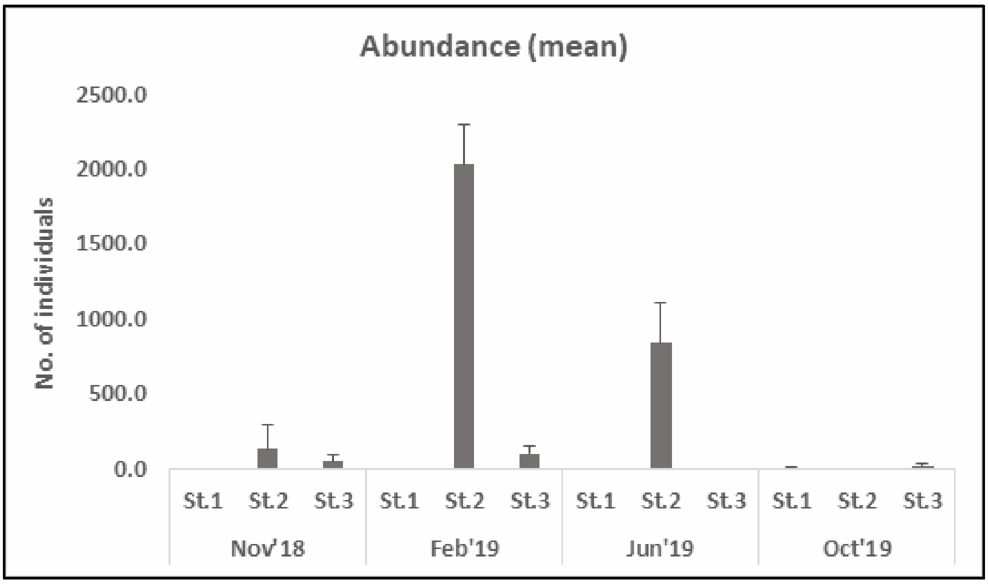


Figure 3. The mean abundance (with 95% confidence intervals) of macrobenthic communities in Merchang lagoon.

A multivariate analysis of the macrobenthic abundance is presented in a non-metric dimensional scaling (nMDS). In general, samples from St. 2 and St. 3 are clustered together which indicate that both St. 2 and St. 3 were more similar in terms of macrobenthic community composition compared to the composition of macrobenthos found in St. 1 (Figure 4a). This was in accordance to the univariate data of the macrobenthic abundance where St. 1 recorded the least number of individuals. Meanwhile, a counter intuitive trend was recorded in the macrobenthic temporal composition. Interestingly, samples from the low abundance months, November (monsoon) and October (pre-monsoon) are clustered together with samples from the highest abundance month, February (post-monsoon). This indicates that although the number of individuals was substantially low, macrobenthic communities in November and October were possibly comprised of the same taxa, as opposed to the taxa that were recorded in June (non-monsoon) (Figure 4b).

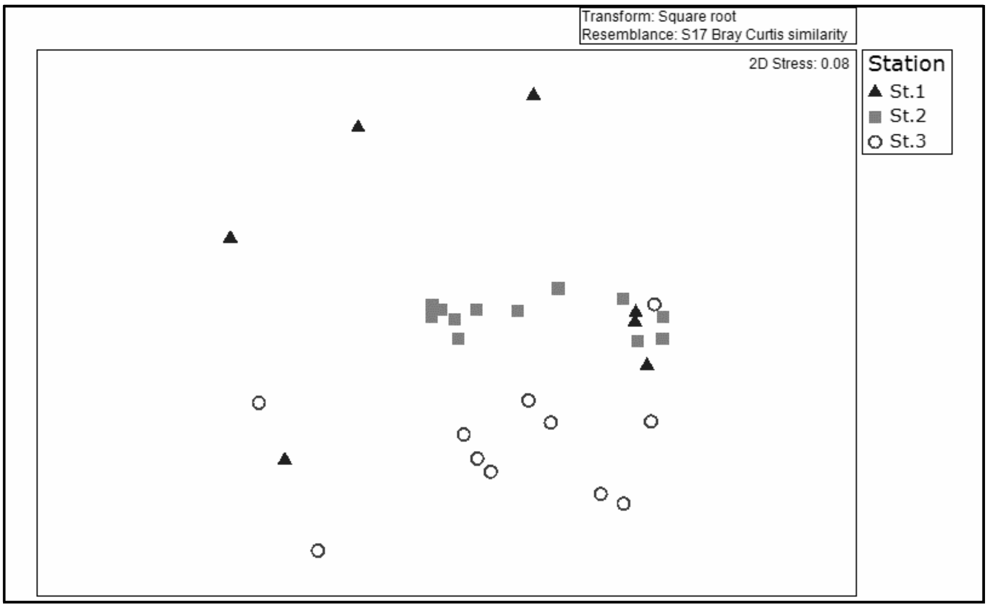


Figure 4a. An nMDS ordination of the distribution of samples of macrobenthic communities according to stations.

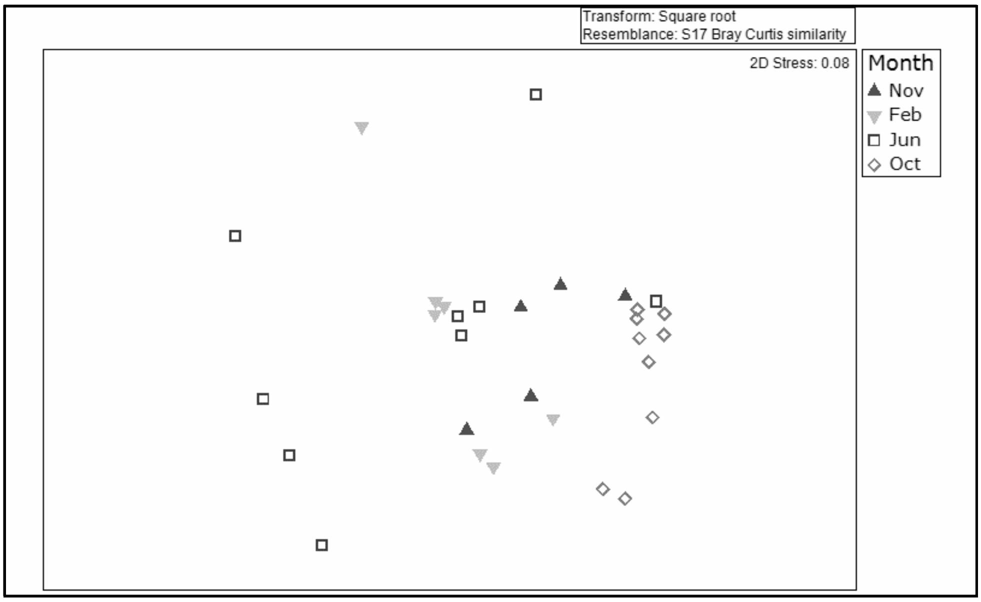
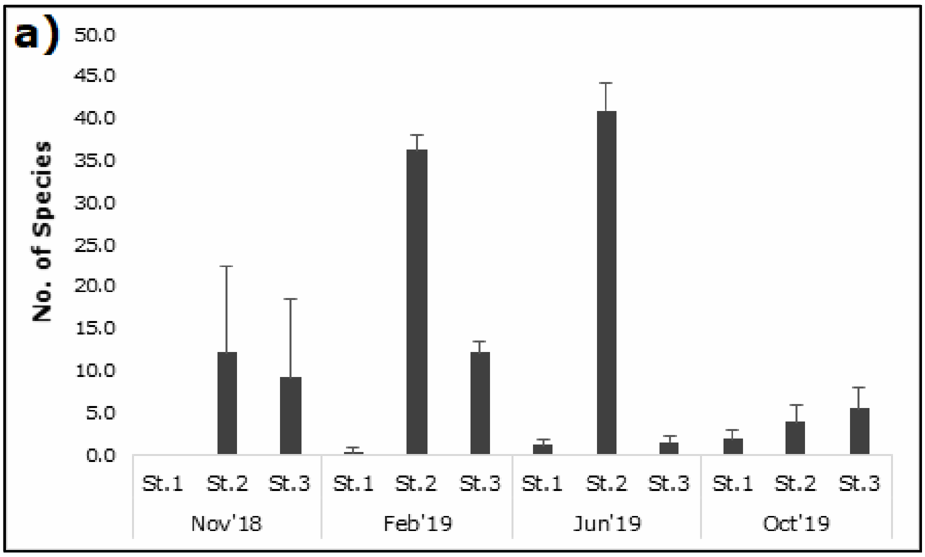


Figure 4b. An nMDS ordination of the distribution of samples of macrobenthic communities according to months.

Overall, there were a total of 103 species of macrobenthos collected in the study area in Merchang lagoon. The highest number of species was recorded at St. 2 in June with a mean of 44 species while the lowest number was at St. 1 in February with a mean of 0.7 number of species. There was however no macrobenthos recorded at St. 1 in November. In terms of temporal comparison, the non-monsoon and post-monsoon months, particularly at St. 2 recorded a higher number of species (Figure 5a). The number of species at St. 2 recorded a significant difference between months (Kruskal-Wallis, $p < 0.05$), in particular the samples in June 2019 comprised a significantly more species than the other stations (Dund's post hoc, $p < 0.05$). The similar trend was also evidence for a diversity metric, Margalef index (Dm) where macrobenthic communities in June (non-monsoon) and February (post-monsoon) recorded a significantly higher diversity compared to the monsoon and pre-monsoon months (Figure 5b) (Dunn's post hoc, $p < 0.05$). Analyses of the macrobenthic communities using dominance and evenness characteristics recorded no significant difference between the months and the stations (Figure 5c, 5d) (Kruskal-Wallis, $p > 0.05$).



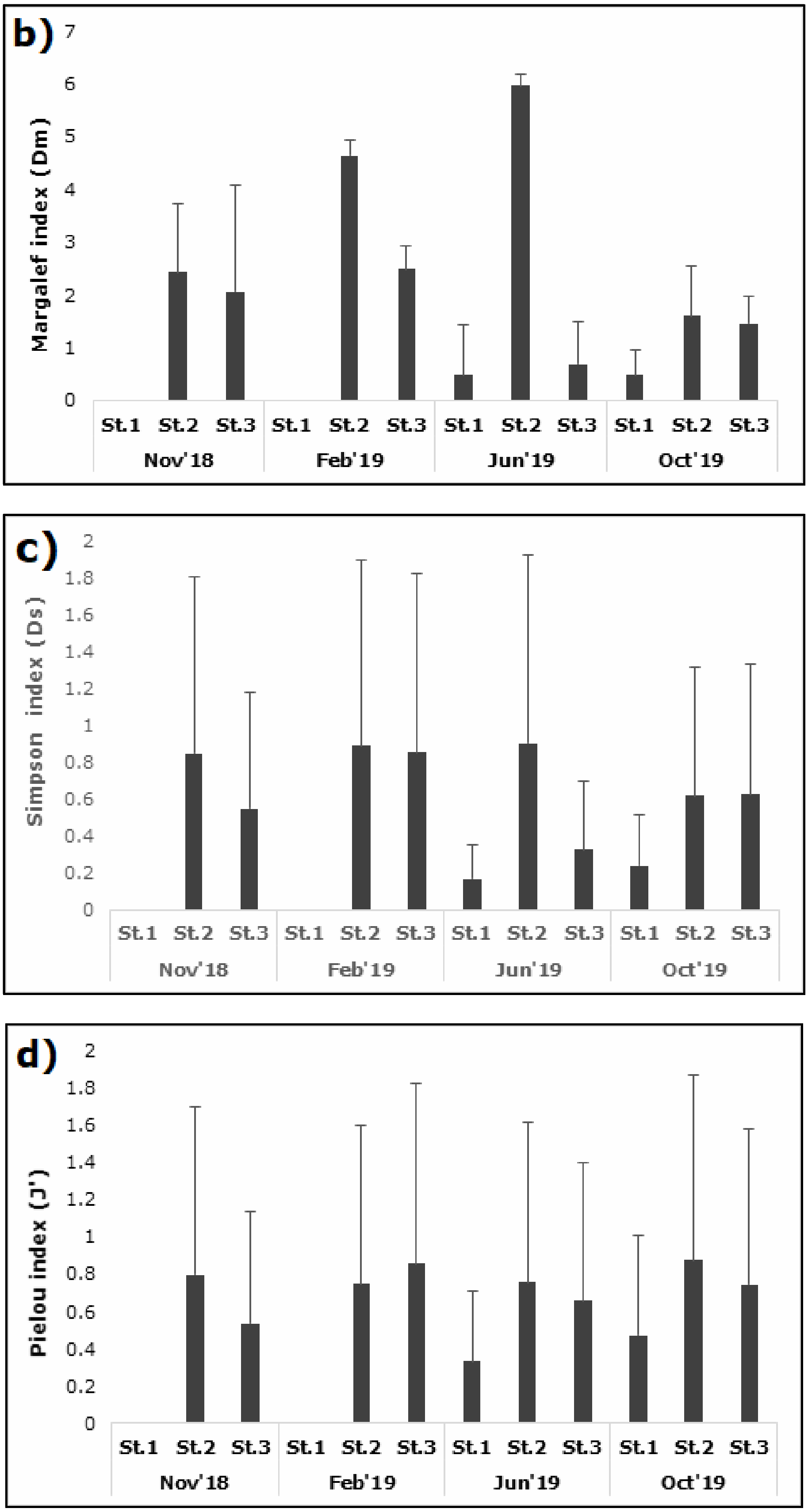


Figure 5. Bar charts show the comparison of macrobenthic communities in the study area based on a) Number of species, b) Margalef index, c) Simpson index, d) Pielous index.

Taxonomic diversity. The taxonomic diversity of the macrobenthic communities is measured by mean of TD. In general, St. 2 and St. 3 recorded a higher TD value compared to St. 1 (Figure 6). A temporal analysis of the TD values found out that the significant difference between months was only recorded at St. 2 (Kruskal-Wallis, $p < 0.05$). Specifically, the difference was recorded in comparisons between November and June and November and October (Dunn's post hoc, $p < 0.05$). A multivariate measurement of the TD values is displayed in a funnel plot where the x-axis represents the number of species and the y-axis represents the TD value (Figure 7). Generally, the funnel plots show that the number of species did not greatly influence the TD values. This can be seen where samples in February and June with higher number of species recorded fairly similar TD values with the samples in October. Interestingly, the highest TD value was recorded in October although with very low number of species. Meanwhile, since most of the samples are within the 2 funnel lines, it explains that the samples were taxonomically similar.

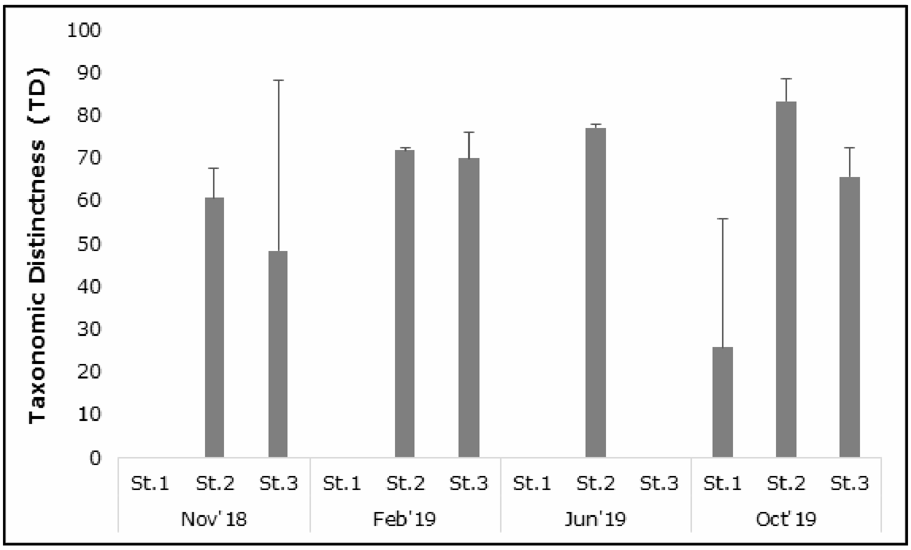


Figure 6. Comparison of TD values between stations and months in the study area.

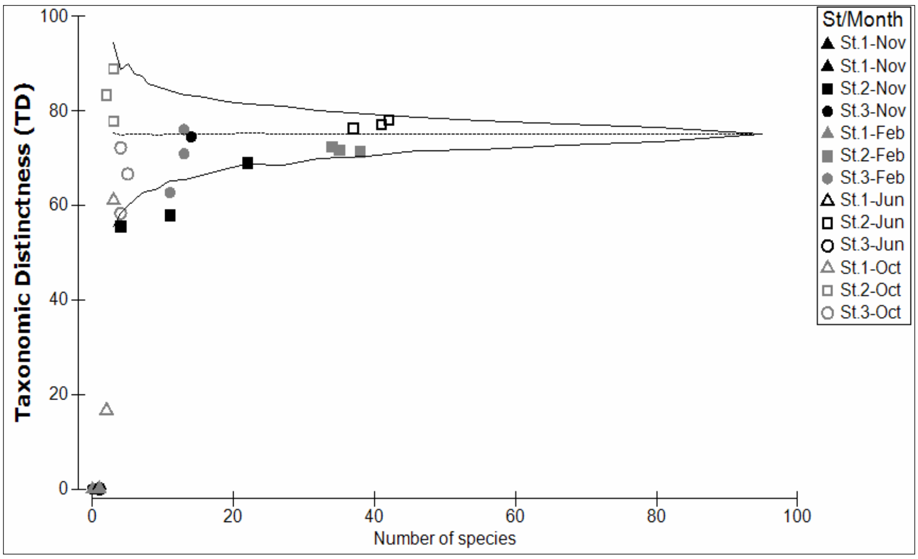


Figure 7. Comparison of taxonomic diversity among faunal assemblages. The mean TD of the whole assemblage is represented by the dotted horizontal line, while the funnel lines indicate the 95% confidence limits. Values within the funnel lines indicate the taxonomic similarity.

Discussion. The macrobenthic communities in the estuarine area of Merchang lagoon was dominated by Gastropoda and Bivalvia. The dominance of these taxa in the estuary in Malaysia was also recorded by John et al (2015). The abundance of Gastropoda in Merchang lagoon can be associated with the sediment characteristics in this area which was dominated by muddy particles (Sahidin et al 2019), especially at St. 2. Their feeding mechanism which relies mainly on the detritus makes this group to favor the muddy sediments (Kabir et al 2014; Mohanjaru 2015). In addition, Bivalvia might be benefited from the environmental conditions in the estuary area such as tidal fluxes which provide a perfect condition for filter feeding organisms (Pati et al 2008).

The dynamics of macrobenthic community distribution is influenced by the seasonal changes which contributed to a high variability of abundance following the seasons (Mistri et al 2001; Posey 1986). The macrobenthic community in Merchang lagoon showed a significant difference between stations and months (which associated with different seasons namely rain and dry). The present study showed that the number of macrobenthos was spatially and temporally different. According to Lamptey & Armah (2008), such differences could be due to dominant species that controlled the community structure and were spatially distributed. However, this was not entirely the case for the present study where the dominant species (e.g. *Littoraria* sp.) was only present at St. 2 and St. 3. The possible explanation is that St. 1 was in general lack of organism mainly due to its clean sand sediments that provide low amount of organic matter (Burone et al 2003; Hossain et al 2014). The significant temporal variation in macrobenthic community in the present study was largely due to the abundance of the dominant species. All dominant species and taxa were only abundant in February and June, indicating their importance in controlling the community structure in Merchang lagoon. In addition, the variability in environmental conditions may also influenced the difference in macrobenthic communities among different months (i.e. season). As stated by Posey et al (1998), variability in environmental conditions may lead to the changes in benthic recruitment, reproduction and survival. As in the present study, a significantly low number of individuals and species of organisms during monsoon season might be due to the hydrodynamic nature of the area that had been detrimental to the benthic organisms. It was unfortunate that due to the time and financial constrain, no measurement on the hydrodynamic characteristics of the area was taken. A classic literature by Newell (1970) suggested that certain species' have limited tolerance to the environmental changes. This could be related to the area in the present study that is subjected to torrential rain and high tidal wave during monsoon season, including in November where the number of organisms and species were the lowest. A multivariate analysis which takes into account the species composition showed that temporally, June was the month where the communities were the most different. Although February comprised the highest number of organisms, the difference was not as apparent as observed in June. This counter intuitive finding was possibly due to June recorded the highest number of species compared to other months. The different trends between univariate and multivariate metrics show that the number of individuals and the number of species are not the sole factors that measure the difference between macrobenthic communities. However, a multivariate approach should also be taken into consideration so that a different perspective can be offered in interpreting the changes in the communities.

The significant difference between stations and months in macrobenthos abundance and species richness was not also translated into taxonomic variability. The TD values in this present study were fairly similar spatially and temporally. Clarke & Warwick (2001) pointed out that TD's measurement is not greatly affected by sampling effort. This can be a good attribute as the more sampling effort resulting in the more individuals which in turn cause the more species to be recorded (Magurran 2004). However, this can be problematic too when this index might be less sensitive to the environmental changes (Clarke & Warwick 2001). The spatial and temporal similarity in the present study showed the influence of dominant species. St. 1 recorded a low number of individuals and species mainly due to the absence of dominant species that was only recorded in February and June at St. 2. However, such absence did not affect the taxonomic diversity as those dominant species were mainly from the same higher taxonomic levels. Therefore, did not impose much effect on the total path length between samples, contributing to the similar TD values.

Conclusions. The present study showed that the macrobenthos communities in Merchang lagoon were to some extent, spatially and temporally different. Such difference was mainly on the community structure with the main reasons were due to the dominance of certain species as well as the environmental conditions that have theoretically made the habitat unfavorable to be inhabited by the organisms. In contrast, a more complicated assessment namely based on taxonomic diversity did not find such difference. The communities remained the same taxonomic diversity mainly due to the dominant species were from the same higher taxonomic levels of the other species that present at all stations and in all months. However, this similarity should be carefully interpreted as the absence of dominant species may to some extent affect the entire benthic ecosystem functions. A further study that measures the physical characteristics of the area is recommended for a better understanding on how the hydrodynamical changes following rainy season would directly affect the benthic organisms.

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