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RESEARCH NOTE

Checklist of Molluscs (Gastropoda and Bivalvia) of Malaysia Exclusive Economic Zone (EEZ) in Sarawak Waters

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ABSTRACT

Most of the molluscs studies in Malaysia have focused only on their diversity and the knowledge on their relationship with the water depth are lacking. The hypothesis tested in this research was water depth influence the density of marine gastropods and bivalves of Malaysia Exclusive Economic Zone (EEZ) in Sarawak waters. The aim of the study was to determine the gastropod and bivalve species in Malaysia EEZ of Sarawak waters and the relationship of the species density with water depth. The sampling was conducted from 15th August 2015 until 9th October 2015. The gastropods and bivalves were collected from 32 stations of various depths using the Smith-McIntyre grab. The depth of the stations was from 20 m to 200 m. A total of 95 taxa (61 Gastropoda and 34 Bivalvia) were found in this study. The dominant molluscs species of Sarawak waters in Malaysia EEZ were *Limopsis* sp., *Turitella cingulifera*, *Pitar citrinus*, and *Cavolinia globulosa*. Species density was about 10 ind./m^2 to 610 ind./m^2 and the total density was between 250 ind./m^2 (Station 22) and 1,940 ind./m^2 (Station 2). The total density of gastropods and bivalves showed weak correlation and negative relationship with the depth of water. The findings of this study will aid future studies in Malaysia EEZ.

Keywords: Bivalves, gastropods, Malaysia EEZ, Sarawak waters

The South China Sea with a maximum depth of more than 5,000 m is the largest marginal sea in Southeast Asia (Hu *et al.,* 2000) located at the southwest corner of the North Pacific (Shaw, 1991). Countries that have a major influence on and claims to the sea include China, Malaysia, Philippines and Vietnam. East Malaysia (Sabah and Sarawak) is situated on the Sunda Shelf in relatively shallow water (Morton & Blackmore, 2001). According to the United Nations Convention on the Law of the Sea, 1982, the Exclusive Economic Zone (EEZ) is an area beyond and adjacent to the territorial sea. The EEZ shall not extend beyond 200 nautical miles from the baselines.

Molluscs are widely distributed in marine assemblages and may be extremely abundant in subtidal habitats (Zamprogno *et al*., 2013). This study focused only on two classes of molluscs that were Gastropoda and Bivalvia. The first fishery resources survey in the EEZ of Malaysia was conducted from 1985 to 1987 followed by the second survey from 1996 to 1997. A third survey was conducted from 2004 to 2005 off Sarawak with the objective of assessing the fishery resources in the area of 30 NM offshore (Jamil & Hadil, 2012). There was a survey on the community structure of benthic fauna in the South China Sea, which covered almost all parts of the Gulf of Thailand and the east coast of Peninsular Malaysia (Yasin & Razak, 1997), and along the coast of Sarawak, Brunei and Sabah (Piamthipmanus, 1998).

However, the South China Sea is poorly understood in terms of its marine biodiversity (Morton & Blackmore, 2001). Jamil and Hadil (2012) stated that the current knowledge of the biology of deep-water species in the Malaysian EEZ is still lacking. Furthermore, the distribution patterns of deep-sea benthic fauna in depth > 150 m of the Malaysia EEZ waters off Sabah and Sarawak coasts remained unknown (Jamil & Hadil, 2012). What is known is most often contained in reports, workshop and conference documents that are not available to the wider scientific community (Morton & Blackmore, 2001). Hence, the hypothesis is that the depth of water may influence the density of marine gastropod and bivalve of Sarawak waters in Malaysia EEZ. The objectives of this study were to (i) determine the marine gastropod and bivalve species in Sarawak waters of Malaysia EEZ and (ii) evaluate the relationship between the water depth and the density of gastropods and bivalves.

Study sites - The study area covered in this study, started from Kuching to Miri. A total of 32 stations of various depths were selected in this research and the coordinates of each station was recorded (Table S1). The samplings were conducted for 2 months, from 16th August to 9th October 2015 and the samplings were assisted by trained workers and researchers of SEAFDEC 2. The Training and Research Vessel, MV SEAFDEC 2 from SEAFDEC Training Department (TD), Bangkok, Thailand was deployed for this survey. Figure 1 shows the location of sampling stations in Sarawak waters of Malaysia EEZ.

Sampling technique - Marine gastropods and bivalves were collected from the bottom sediments using Smith McIntyre grab sampler. The area of the grab opening was 0.1 m^2. The collected materials were washed and sieved in the field with 500 µm mesh size sieve using seawater. All collected benthic specimens were placed in plastic bags and preserved in 70% ethanol. The specimens were labelled accordingly and stored in a cooler box. The samples were transferred to the laboratory for further analysis.

Laboratory analysis - Gastropods and bivalves were identified to the lowest level with the aid of a stereo microscope. The identifications were based on the key by Picardal and Dolorosa (2014); Hamli *et al*. (2012); Shabdin and Rosniza (2010); Bernard *et al*. (1993); and *The Mac*

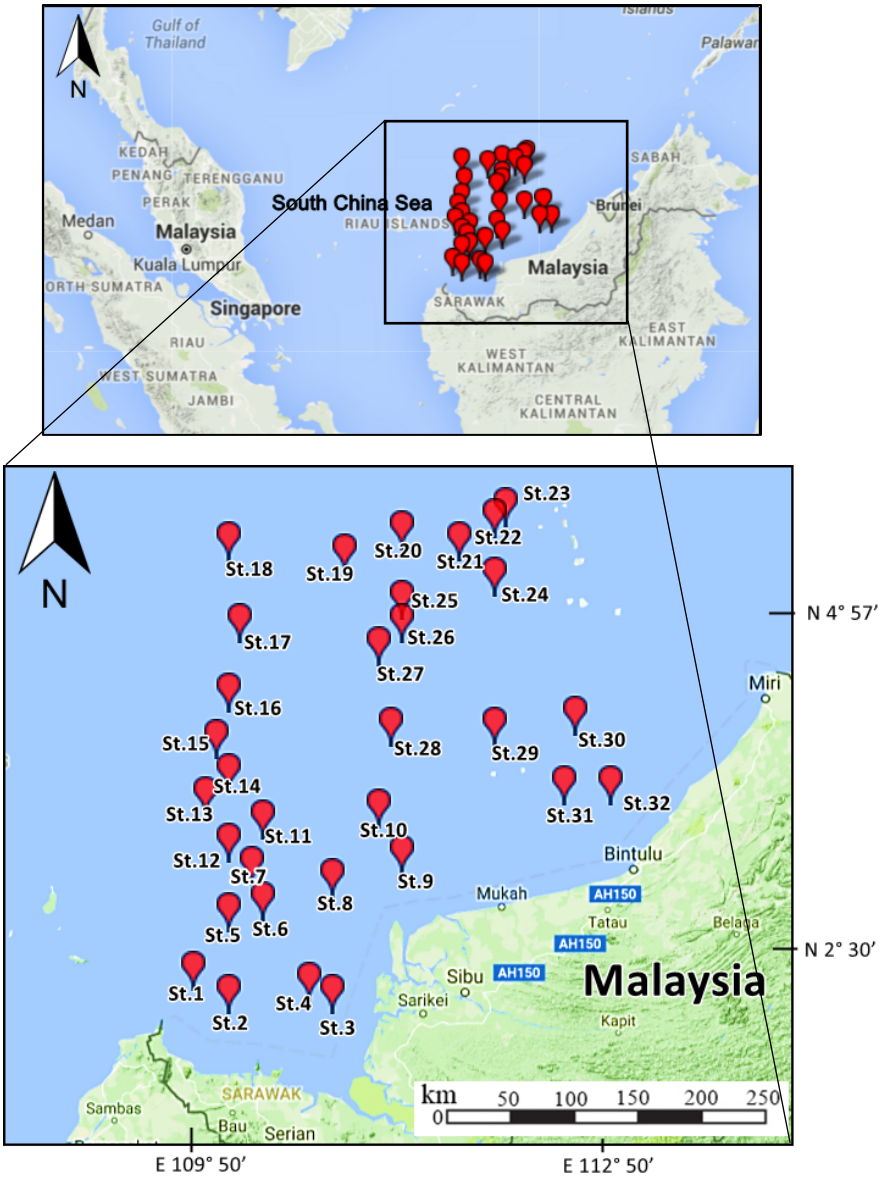

Figure 1. Map showing the location of sampling stations in Sarawak waters of Malaysia EEZ.

Donald Encyclopedia of Shell (1982). Shell characteristics in the adult stage, such as the shape of the shell, length and shape of the spire, mouth opening, opercular shape, color, ornamentation, umbo and type of hinge teeth were used for the species identification of gastropods and bivalves.

Data analysis - The data was analysed to find the density (number of individuals/ area of the grab) of gastropods and bivalves at the study area. Pearson-linear correlation was applied to determine the relationship between the water depth and the density of gastropods and bivalves. The correlation was performed by using Statistical Package for the Social Sciences (SPSS) software. Cluster analysis was performed using the Bray-Curtis similarity measure to investigate the similarities in the density of gastropods and bivalves between the stations. The relationship was based on the comparison of similarity matrices and was displayed using hierarchical agglomerative clustering technique (group average). Ordination using nonmetric multi-dimensional scaling (MDS) was performed to confirm the groups formed by the cluster. The cluster analysis was conducted using Plymouth Routines in Multivariate Ecological Research (PRIMER v7.0) software with the aid of Microsoft Excel 2010.

Gastropods and bivalves recorded - A total of 2,388 individuals of gastropods (1,158) and bivalves (1,230) were collected within all stations in Sarawak waters of Malaysia EEZ, representing 35 families of 61 gastropod species, and 18 families of 34 bivalve species. Overall, 53 families were identified with a total of 95 species. The most recorded species found were *Limopsis* sp. with a total of 365 individuals followed by *Turritella cingulifera* (282) and *Pitar citrinus* (228). The maximum density of gastropod and bivalve species in the study area was not more than 610 ind./m^2 and the minimum value was 10 ind./m^2 (Table S2). The highest density was recorded by *Limopsis* sp. at Station 2 followed by *P. citrinus* at Station 4 and *Cavolinia globulosa* at Station 1.

Some species were found to be very rare as they could only be seen at one station out of 32 stations. For example, *Calliostoma* sp. 1, *Vexillum gouldi, Latirus constrictus, dorsatus, Pyramidella* sp., *Rissoina otohimeae, Zebinella herosae, Dolomena* sp., and *V. scitulum* from the class Gastropoda and *Arca navicularis, Myadora* sp. 2 and *Acila divaricate* from the class Bivalvia. Meanwhile, some species were commonly found from more than 20 stations such as *Diacavolinia longirostris* and *T. cingulifera* from Gastropoda, and *Limopsis* sp. and *P. citrinus* from Bivalvia.

Correlation of total density with water depth - The relationship between the total density of gastropods and bivalves and the water depth was analysed using Pearson correlation. The total density was negatively related with the depth of water ($r = -0.371$; $p = 0.036$). The correlation was significantly weak ($p<0.05$). The strength of the correlation coefficient value is shown in Table S3.

Cluster analysis - Classification analysis using Bray-Curtis similarity with group average linking method followed by an ordination through MDS was conducted on the density of gastropods and bivalves. The groupings in cluster analysis are displayed in the dendogram (Figure 2). The result was also confirmed by the two-dimensional (2D) ordination of similarity matrices, which was displayed using the non-metric MDS (Figure 3). The cluster analysis grouped the sampling stations into 11 clusters at 50% similarity threshold. Station 1, 5, 15 and 17 were clearly separated from each other and formed four different clusters. Station 16, and 25 made up one cluster while, Station 12, 13 and 20 formed distinct group. Station 3 and 6 formed a cluster while Station 8 and 22 produced one cluster. Besides that, Station 2 and 4 generated a group, whereas Station 14, 19, 21, 24, 27, and 31 formed a group. Lastly, Station 7, 9, 10, 11, 18, 23, 26, 28, 29, 30 and 32 produced the biggest cluster consisting of nine stations.

Species density - The range of total density of gastropods and bivalves in Sarawak waters of Malaysia EEZ was between 250 to 1,940 ind./m^2. The highest was recorded at Station 2 whereas the lowest was recorded at Station 22. Their species density was about 10 to 610 ind./m^2. Yasin and Razak (1997) specified that molluscs were observed in smaller quantities in the East Coast of Peninsular Malaysia. Additionally, Piamthipmanus (1998) reported that the abundance of mollusc was only 1

Paradrillia sp., *P. inconstans, Subcancilla* sp., *Nassarius* ind./m^2 on average and ranged from 0 to 20 ind./m^2 during

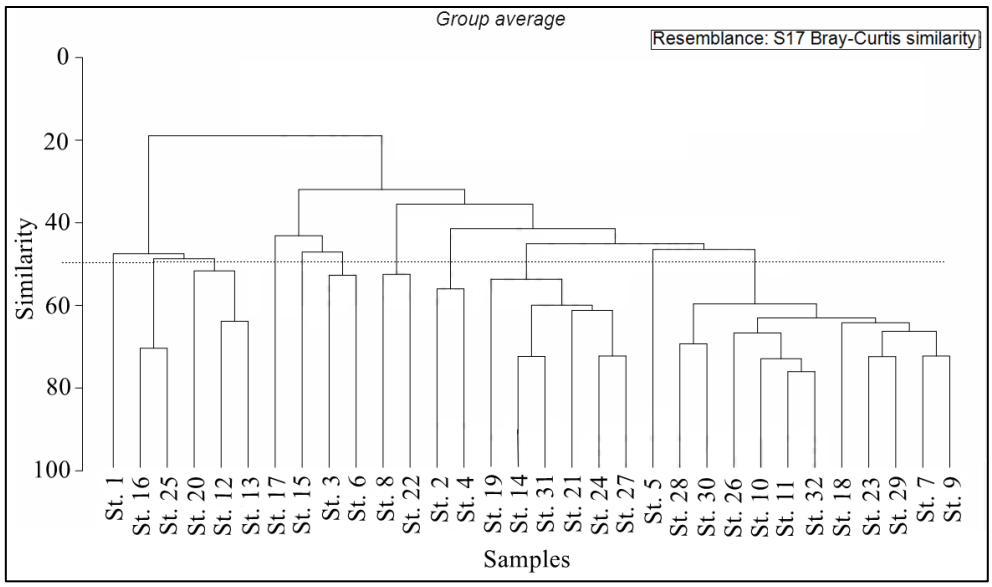

Figure 2. Dendogram produced by cluster analysis showing the percentage of similarity in density of gastropods and bivalves among all the stations in Sarawak waters of Malaysia EEZ based on Bray Curtis similarities.

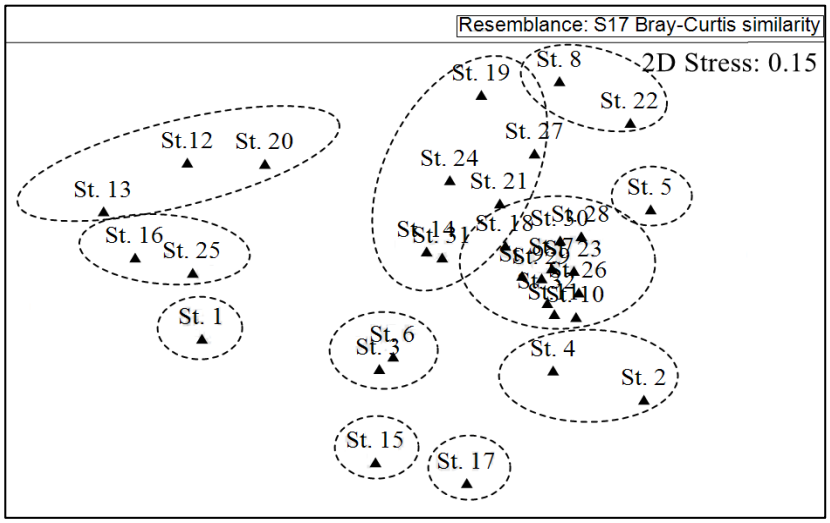

Figure 3. Multidimensional scaling (MDS) ordination (stress: 0.15) constructed based on the density of gastropods and bivalves among all the stations in Sarawak waters of Malaysia EEZ.

the previous macrobenthos study in South China Sea (Sarawak, Brunei and Sabah). This indicated that gastropods and bivalves occurred in low density during the previous surveys.

The total of 95 mollusc species found in this study was considered high as compared to previous studies (Aziz *et al*., 2017). Different number of mollusc species recorded in each study might be due to the different sampling methods employed. Sampling of mollusc have many methods such as, grab sampler, dredges, box-corers, hand nets (Tagliapietra & Sigovini, 2010). Different methods will have different sampling efficiency and thus will affect the results.

The highest density of molluscs was recorded by *Limopsis* sp. at Station 2 followed by *Pitar citrinus* at Station 4 and *Cavolinia globulosa* at Station 1. *Limopsis* is one of the most wide-spread bivalve genera and at least forty extant and more than thirty extinct species of *Limopsis* are known (Whittle *et al.,* 2011). Bivalves in this genus, which are epibenthic suspension feeders, have a particular affinity to deep-sea habitats. In the southern high latitudes, seventeen *Limopsis* species were recorded up to 600 m (Whittle *et al.,* 2011).

Its natural distribution at deep water promoted the high density of this species in Sarawak waters of Malaysia EEZ. Besides that, Munira (2011) found that 6% from the overall bivalve determined at Maluku, Indonesia was *P. citrinus*. Furthermore, in the previous study at South China Sea (Sarawak, Brunei and Sabah) by Piamthipmanus (1998), only two

In most ecosystems, community structure emerges as a result of complex interactions between biotic and environmental variable. Environmental factors such as nutrients and food availability are also important in structuring the macrofaunal community (Shabdin *et al.,* 2014). High density of molluscan in Sarawak waters of Malaysia EEZ can be probably because of sufficient food supply and stable environmental parameters. Furthermore, the sediment characteristics could also contribute to the higher density as the mean grain size, fine sand, very fine sand, silt, and clay contents could affect the mollusc's distribution and density (Santos & Vanin, 2004).

Arabian Sea showed the decline of the abundance of the macrofaunal from shallower to deeper stations along the west coast of India (Ingole *et al*., 2014). Degen *et al.* (2015) also stated the density of marine benthic macroinvertebrate generally decreases with increasing water depth and they proved it in their study in the Arctic deep sea where negative relationship between macroinvertebrate and water depth was observed. Besides that, Piamthimanus (1998) in the macrobenthos study at South China Sea, along coastal areas of Sarawak, Brunei and Sabah stated that the density of macrobenthic fauna tend to increase with the decrease of water depth. This study also confirmed the trends shown earlier where a significantly lower abundance was found in the deeper stations compared to the upper stations.

One of the driving forces behind this pattern is the decrease in food input, depending on the

bivalve species were obtained and one of those was *Pitar* sp. The high abundance of *Pitar* sp. in this study is applicable to its distribution earlier.

The gastropod, *C. globulosa* from the family Cavoliniidae is a tropical species inhabiting areas of 25°C (optimal temperature) and 34 PSU (optimal salinity) (Rottman, 1976). According to Bhattacharjee (2000), *C. globulosa* is generally confined to the tropical belt of the Indo-Pacific region. It is also recorded from Bay of Bengal, eastern part of Indian Ocean and Arabian Sea. A total of three species from this family were found in this study, which are *C. globulosa, Diacavolinia longirostris,* and *Diacria trispinosa.* Rottman (1976) stated that during an Expedition at The Gulf of Thailand and the South China Sea in 1959-1961, all these three species were collected. This indicated the abundance of this species in South China Sea since a long time before. Moreover, the temperature and salinity recorded in this study suit the optimum temperature and salinity needed for *C. globulosa* and trigger the species to be found in high density.

Relationship between the water depth and the density of gastropod and bivalve - The total density showed weak negative correlation with the depth of Sarawak waters of Malaysia EEZ. According to Naser (2011), depth affects the distribution of mollusc. Normally, in deep water environment, species and communities often change with increasing depth (Jamil & Hadil, 2012). For example, study at coastal water of
values found in the MDS configuration were low, indicating good representation of the interrelationship between the gastropods and bivalves of each station.

A total of 95 taxa obtained in this research from Sarawak waters of Malaysia EEZ shows that Malaysia is rich in molluscan distribution. The probability of obtaining higher species number in future studies is high. Many gastropod and bivalve species found have been recorded and published in previous studies in Sarawak. The highest density value of gastropod and bivalve species in the study areas was 610 ind./m^2. The highest density was recorded by *Limopsis* sp., *Pitar citrinus*, and *Cavolinia globulosa*. The total density of gastropod and bivalve in the study is weakly regionally varying surface production and the assimilation efficiency in the water column. The low food concentration in the deep sea leads to higher share of smaller organisms in the total community. This observation has been corroborated by more recent studies that found a decrease in mean body size with increasing water depth (Degen *et al.,* 2015). The high amount of sediment chlorophyll *a* can be found commonly near shore and shelf sediments due to its lower degradation in the water column. Conversely, high quality food will be consumed and elapsed before it reaches the deeper parts of the ocean floor and therefore less matter reaches the depths (Ingole *et al*., 2014). Therefore, less density in the deeper area in this study could be related to this possibility. Besides, food availability, substrate characteristics and hydrodynamic processes are also important factors for structuring benthic communities (Degen *et al.,* 2015). These factors are believed to affect the density of gastropod and bivalve in this study.

In the cluster analysis of similarity measure, where the most similar pairs of samples are first joined into clusters, high similarity in the abundance of gastropods and bivalves between stations was obtained. Similar habitat characteristics of the study areas within the EEZ of Sarawak waters of Malaysia EEZ caused the stations to be clustered together. Derived multidimensional scaling (MDS) ordination revealed the same grouping of stations as in the cluster analysis with 0.15 stress value. The stress

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influenced by the depth of water and this confirmed the hypothesis tested. Based on the groupings formed by cluster and non-metric MDS analysis, similar habitat characteristics among the study area is believed to be the reason of high similarity in gastropods and bivalves abundance. The data on the distribution of gastropods and bivalves in this study will aid to the next EEZ macrobenthos survey and future monitoring study.

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