*Phuket mar. biol. Cent. Res. Bull.***78:** 39–47 (2021)

DIVERSITY OF EPIBENTHIC INTERTIDAL MOLLUSCAN COMMUNITIES ON THE SEAGRASS BEDS OF MIDDLE BANK, PENANG, MALAYSIA

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ABSTRACT: The diversity of intertidal molluscan communities inhabiting the seagrass beds of Middle Bank, Penang, Malaysia was studied at four stations during the lowest tides, following the Natural Geography in Shore Areas (NaGISA) protocol. Fifteen 1m x 1m quadrats were placed at each station on the seagrass bed along the Middle Bank. The seagrass species reported in this study area are *Enhalus acoroides* (Linnaeus f.) Royle, 1839, *Halophila ovalis* (R. Brown) Hooker, 1858, and *Thalassia hemprichii* (Ehrenberg) Ascherson, 1871 with *E. acoroides* being the dominant seagrass species. A total of 12 species in eight families of Gastropoda and Bivalvia, namely Arcidae, Cerithiidae, Columbellidae, Melongenidae, Muricidae, Nassariidae, Neritidae, and Pinnidae were recorded. One-way ANOVA showed that p values of the substratum temperature (p=0.104) and salinity (p=0.866) had no significant difference among the stations, seagrass coverage and substratum particle size had a significant influence on the distribution of molluscs at Middle Bank. As a whole, molluscs can be found throughout the intertidal zone of the island. *Cerithium coralium* (Gastropoda: Cerithiidae) was the most dominant molluscan species inhabiting the seagrass beds.

Keywords: Diversity, mollusc communities, seagrass bed, Middle Bank, Penang Malaysia

INTRODUCTION

Malaysia being located in a hotspot area of the Indo-Pacific region is considered as one of the richest areas in terms of biodiversity (Briggs 1974). Seagrasses are usually found in shallow seawater of intertidal zones, where they form extensive beds or meadows underwater. Intertidal seagrass beds are rich in marine life such as macrozoobenthos, including many species of molluscs, as it provides habitat, breeding and feeding grounds for the animals (Ambo-Rappe *et al*. 2013). However, human exploitation and climate change have caused the density and diversity of seagrass as well as its associated species to decline since these benthic animals are immobile compared to fishes or other pelagic organisms (Short *et al*. 2011).

About 78 discrete seagrass beds are found scattered throughout Malaysia, with most of the seagrass areas located on the east coast of Peninsular Malaysia and in East Malaysia. Only two seagrass areas being reported in the west coast of Peninsular Malaysia, namely in Pulau Langkawi and Pulau Gazumbo along the Straits of Malacca (Bujang *et al.* 2006). These seagrass beds are also known to provide economic benefits to local fishermen, whilst encouraging tourism and serving as educational destinations for schoolchildren (Chee *et al.* 2017) and for the local environmental organisation.

Marine biologists from Centre for Marine and Coastal Studies (CEMACS), Universiti Sains Malaysia have been working on Pulau Gazumbo, an island adjacent to Middle Bank, since year 2001. Continuous monitoring of the abundance and biomass of seagrasses as well as their associated animal communities has provided invaluable information to assess the impact of coastal development within the vicinity of Pulau Gazumbo. While intensive studies have been conducted in Pulau Gazumbo, none has been carried out on the seagrass beds in Middle Bank. Hence, this current assessment examined the distribution on seagrass and diversity of molluscan communities in the seagrass bed of Middle Bank, Penang, where the data would be informative for conservation efforts.

MATERIAL AND METHODS

The sampling site was located at Middle Bank, Penang. Middle Bank is a low-lying sand bank situated between 5°36′N–5°40′N and 100°33′E –100°34′E. The area of this site is approximately 6.07 km^2 and near to Pulau Gazumbo (the adjacent island) which is about 1.5 km to the south of Middle Bank (Koh *et al*. 1997). Figure 1 shows the map of Penang (Malaysia) and the location of the Middle Bank, which is near to Georgetown in the South Channel.

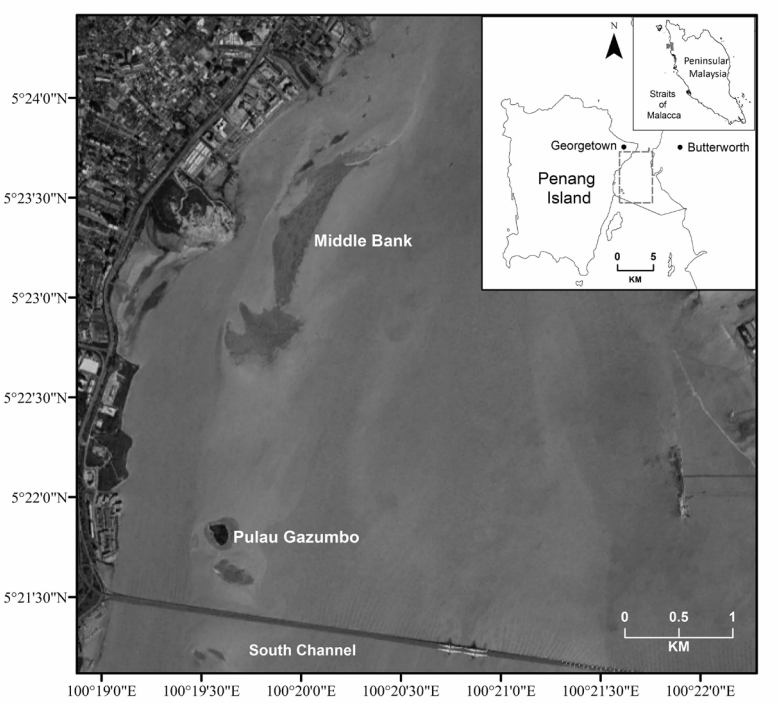

Figure 1. The map of Penang (Malaysia) showing the location of Middle Bank.

Middle Bank, which houses an extensive seagrass bed, lies in the small channel at a depth of approximately 5 m to 10 m (Chart Datum). It is also a habitat to diverse marine animals such as molluscs, arthropods, and echinoderms. This shallow, elongated sandbank is only exposed during low tides below 0.6 m and stretches for about 3 km. Little is known about the seagrass communities here as they are found submerged most of the time.

In this study, a total of four stations were surveyed at the Middle Bank. The sampling activities were carried out in October 2015 and January 2016 during the lowest spring tide of the month. The coordinates of the sampling stations were recorded and are shown in Table 1. Figure 2 shows the location of the sampling stations.

The Natural Geography in Shore Areas (NaGISA) (Rigby *et al*. 2007) protocol for seagrass bed was used in this study. A 30 m long transect line was laid parallel to the shore. Each station was further divided into three intertidal zones, which were upper, middle and lower. The delimitation of zones was determined based on the exposure of the seagrass bed and the bottom substratum. The intertidal zones exhibited different substratum characteristics, upper zone with higher percentage of sand, middle zone with mixture of sand and mud, and lower zone with higher percentage of mud. The distance between the zones were between 6 and 9 m. At every zone, five quadrats of 1 m x 1 m were laid along the transect line, with a fixed distance of five meters from each other as shown in Figure 3.

Table 1. The coordinates of the four stations at Middle Bank, Penang.

Station	Coordinates	Sampling Date	Tide level (m)
1	05.39438′N, 100.33671′E	30th October 2015	0.5
2	05.39419′N, 100.33693′E	30th October 2015	0.5
3	05.38720′N, 100.33217′E	25th January 2016	0.4
4	05.38811′N, 100.33226′E	25th January 2016	0.4

Figure 2. The sampling stations of Middle Bank.

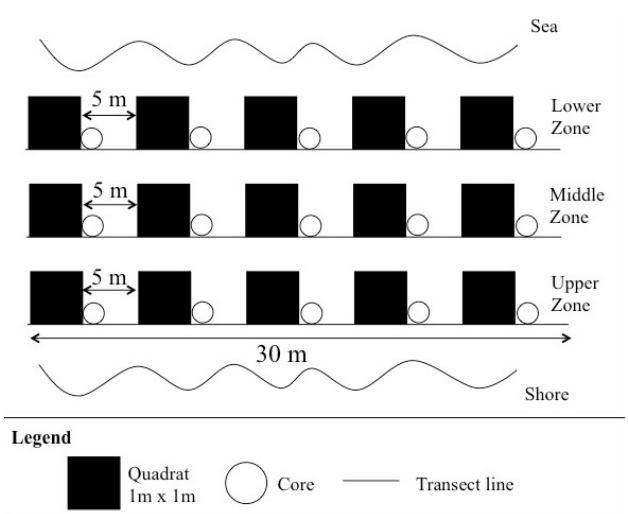

Figure 3. Placements of transect line, quadrat and core at each station.

All molluscs found within each quadrat were identified and counted. Voucher specimens were placed in labelled plastic bags. Further identification was done in the laboratory using identification keys from Arnold and Birtles (1989), Abbott (1974; 1991), Kotzian and Amaral (2013), Nateewathana (1995) and Tan and Woo (2010). The behaviour of the molluscs during the sampling was also noted.

To determine the percentage coverage of seagrass, the areal extent of seagrass in each quadrat from the sampling area was estimated by following the guide provided by Seagrass Net website (www.seagrassnet.org). Seagrass samples were collected in each quadrat by using a core with 8 cm diameter and 10 cm depth. The seagrass samples were separated from the sediment and placed into a labeled plastic bag. The seagrass was identified based on the exterior characteristics of the leaves, stems and roots, following the guide by Lanyon (1986).

For particle size analysis, a similar core was used for substratum collection. The core was placed outside each quadrat. Wet sieving was done and the particle size was classified following the Udden-Wentworth (Wentworth 1922) grain size classification. Physical parameters such as substratum temperature and salinity of seawater were recorded *in situ* at each station.

The variations in physical parameters between stations were tested using one-way analysis of variance (ANOVA). All physical datasets in this study passed the equal variance tests. The threshold value for the statistical significance was taken as $p<0.05$. The statistical analysis was done using SPSS Version 22 (IBM, USA).

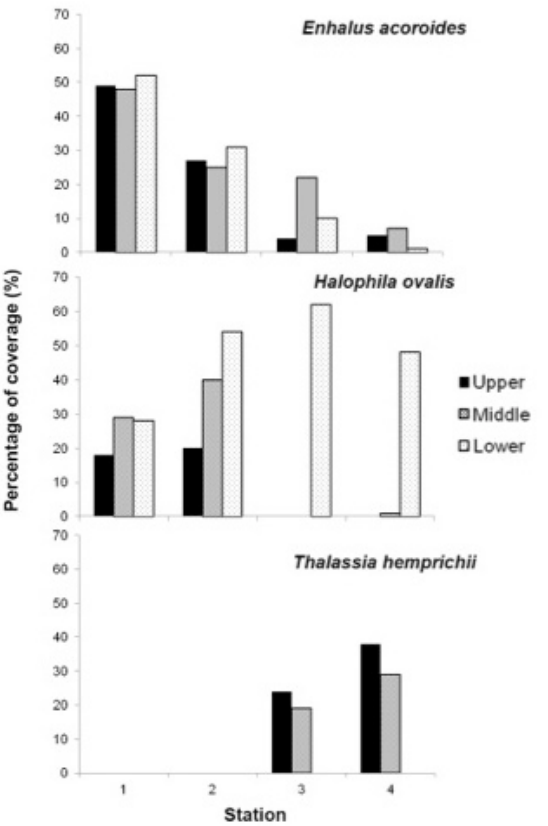

Figure 4. The percentage cover of different seagrass species at the intertidal zone of each sampling station of Middle Bank, Penang, Malaysia.

Table 2. Species composition of molluscs in seagrass bed of Middle Bank, Penang, Malaysia.

Class	Family	Species	Total number of individuals (15 m^2)
Gastropoda	Cerithiidae	*Cerithium coralium* Kiener, 1841	714
		Cerithium sp. Bruguière, 1789	1
	Columbellidae	*Pseudanachis basedowi* (Hedley,1918)	19
	Melongenidae	*Brunneifusus ternatanus* (Gmelin,1791)	1
	Muricidae	*Indothais gradata* (Jonas, 1846)	1
		Indothais javanica (Philippi, 1848)	3
	Nassariidae	*Nassarius livescens* (Philippi, 1849)	16
		Nassarius stolatus (Gmelin, 1791)	21
	Neritidae	*Nerita polita* Linnaeus, 1758	3
		Subtotal	**779**
Bivalvia	Arcidae	*Anadara antiquata* (Linnaeus, 1758)	1
	Pinnidae	*Atrina pectinata* (Linnaeus, 1767)	2
		Atrina serrata (G. B. Sowerby I, 1825)	1
		Subtotal	**4**
		TOTAL	**783**

RESULTS

Three species of seagrasses were identified at Middle Bank, Penang, Malaysia. They were *Enhalus acoroides* (Linnaeus f.) Royle, 1839, *Halophila ovalis* (R. Brown) Hooker, 1858, and *Thalassia hemprichii* (Ehrenberg) Ascherson, 1871. All these three species were found in waters of less than 1 m depth at low tide. The dominant species was *E. acoroides*, which was found at all the four stations at Middle Bank and at all the three zones (Figure 4). The percentage coverage of *E. acoroides* was the highest at Station 1 and Station 2, with an even distribution across different zones. *Halophila ovalis* was also reported in all the four stations but was more dominant at the lower zones, especially at Station 3 and Station 4. No *H. ovalis* was observed at the upper and middle zone at Station 3. For *T. hemprichii*, it was only recorded at Station 3 and Station 4 at the upper and middle zones and none was recorded at the lower zones at any stations.

A total of 12 species from eight genera and eight families of molluscs were found in the seagrass beds of Middle Bank, Penang. Gastropods dominated the study area with nine species, while only three species of bivalves were reported in this study. Table 2 shows the species composition of molluscs in the seagrass bed of Middle Bank. More than 99% of all the molluscs recorded were gastropods, and the family Cerithiidae dominated the assemblage with respect to abundance. Among the gastropods, *Cerithium coralium* predominated numerically; it comprised

Table 3. The species of molluscs found at the four stations surveyed at Middle Bank, Penang, Malaysia.

Class	Species	Total number of individuals per station				Total Station
		1	2	3	4	
Gastropoda	*Cerithium coralium*	215	201	136	162	4
	Cerithium sp.	-	-	1	-	1
	Pseudanachis basedowi	2	2	15	-	3
	Brunneifusus ternatanus	-	1	-	-	1
	Indothais gradata	-	1	-	-	1
	Indothais javanica	1	-	-	2	2
	Nassarius livescens	3	7	2	4	4
	Nassarius stolatus	7	6	8	-	3
	Nerita polita	2	-	1	-	2
Bivalvia	*Anadara antiquata*	1	-	-	-	1
	Atrina pectinata	-	1	1	-	2
	Atrina serrata	1	-	-	-	1
Total of species		**232**	**219**	**164**	**168**	

Note: '-' = not present

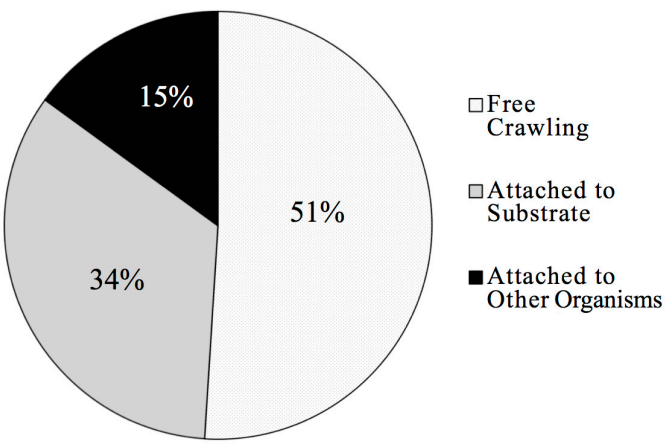

Figure 5. The percentage of molluscs behaviours found in the seagrass in Middle Bank, Penang, Malaysia.

nearly 91% of all molluscs in the quantitative samples. The families Cerithiidae, Muricidae and Nassariidae were represented by two species each. Bivalves were represented by only three species, which comprised only 0.5% of the molluscan specimens.

The density of living molluscs in the seagrass bed in Middle Bank was 783 individuals in 15 m^2. *Cerithium coralium* was the most abundant species in the seagrass bed (714 individuals in 15 m^2), followed by *Nassarius stolatus* (21 individuals in 15 m^2) and *Pseudanachis basedowi* (19 individuals in 15 m^2).

Cerithium coralium and *Nassarius livescens* were found at all the stations. *Anadara antiquata* and *Atrina serrat*a were only found at Station 1, while *Brunneifusus ternatanus* and *Indothais gradata* were only found at Station 2 (Table 3). Station 1 has the most diverse species of molluscs with eight species, followed by Station 2 and 3 with seven species, while Station 4 exhibited the lowest diversity of molluscs with only three species.

Most of the molluscs especially the gastropods were found crawling freely (51%) on the seagrass bed searching for food during low tide. Among the species that were crawling freely were *Cerithium coralium*, *Nassarius livescens*, *N. stolatus*, *Indothais javanica* and *Nerita polita*. Some of the molluscs were observed to be attached to substrata (34%) such as rocks or the seagrass leaves, which served as their food. Some 15% of the molluscs were attached to other organisms such as other molluscs or crustaceans. Figure 5 shows the percentage of the molluscs occurring on different substrata at the seagrass beds in Middle Bank.

Most of the molluscs found in the seagrass bed at Middle Bank were able to tolerate air exposure up to one hour during the low tide. When exposed, some gastropods were seen to be crawling towards submerged areas, while the bivalves were seen hiding or burrowing into the substratum for protection against air exposure. Due to the intolerance towards air exposure for a long period of time, most of the molluscs were found in depth of 0.2 m in the substratum.

The particle size analysis showed that, there were slight differences between each intertidal zone. Size range of particles varied from $\geq$ 2.00 mm to < 63 μm, which is from gravel to silt. The percentage of silt was the highest in the lower zone, meanwhile gravel was the highest in the upper zone. In comparison, Station 3 and 4 had a higher percentage of coarser sand particles than Station 1 and 2.

Neither substratum temperature nor salinity showed significant differences among the stations, p=0.104 and p=0.886 respectively. Generally, the substratum temperature did not show high variation at each station. Highest temperature, 30.0 ± 0.3 °C, was recorded at Station 1 in the month of October 2015. Meanwhile the lowest temperature, 28.0 ± 0.6 °C, was recorded at Station 4 in the month of January 2016. Salinity varied from 25 to 29 ppt. The physical parameter values were found to be within the normal range for coastal environment.

DISCUSSION

The benthic fauna assemblage of molluscs occupying the extensive seagrass beds may be very rich with respect to both diversity and abundance. The 12 transects sampled in this study on a seagrass meadow of Middle Bank, Penang, Malaysia, harboured 12 species representing two molluscan classes (Gastropoda and Bivalvia), and a density of 783 individuals in 15 m^2. Comparatively, Middle Bank shows less species diversity compared to Pulau Gazumbo, the adjacent island in Penang. A total of 22 species was reported in Pulau Gazumbo by Nur-Najmi (2001). The species found at Middle Bank are similar to those found at Pulau Gazumbo. The number of species may have decreased from year 2001 to 2016, and this may be related to anthropogenic activities such as land reclamation around the seagrass meadows.

The coverage of seagrass has positive correlation with the distribution and abundance of mollusc species. *Halophila ovalis* was found to be the highest in percentage at lower zone of Station 2 (55%) and the lowest on the upper zone (22%). This is correlated to the highest numbers of *C. coralium* found at the lower zone compared to uper zone. In addition, *E. acoroides*, which was the dominant seagrass species found in Middle Bank, plays an important role as providing areas for egg deposition of molluscs. Besides being a feeding ground for molluscs, the seagrass bed also served as a hiding site for the benthic organisms. According to Edgar and Robertson (1992), seagrass bed acts as a hiding place for molluscs to escape from predators (i.e. molluscivore gastropods, crabs and fish) during the day, where the molluscs are able to hide beneath the seagrass leaves.

Some of the molluscs, such as *N. livescens*, were found attached on seagrass blades, which are wider and have larger surface area compared to other seagrass species. In contrast, *T. hemprichii* showed the highest percentage coverage at Station 4 but the diversity and abundance of molluscs was low. This is an indication that *T. hemprichii* may not be favoured by molluscs as a place for hiding or for food.

Cerithium coralium is the most dominant gastropod found in all the sampling sites in Middle Bank, followed by *Nassarius stolatus* and *Pseudanachis basedowi*. The dominant position of *Cerithium coralium* in Middle Bank is due to its ability to tolerate air exposure during the low tide. This species was reported in the upper zone where the area was exposed the longest during the low tide. Most of the other molluscs were not found in the upper zone, which was dryer. *Cerithium coralium* has a broad Indo-West Pacific distribution, occurring from southern Japan and the Ryukyu Islands south through the Philippines, Gulf of Thailand, and Indonesia to Australia and New Guinea, and the east of Micronesia and the Marshall Islands (Palomares and Pauly 2009). The high density of *C. coralium* may be due to the abundance of food found in the seagrass meadows, given that this cerithiid is an algal-detritus feeder (Houbrick 1974).

The distribution of the molluscs at the intertidal areas is strongly affected by the variation of physico-chemical conditions such as sediment stability. Studies have demonstrated that the abundance and diversity of molluscs associated with the seagrass meadows are higher than in sediments without seagrass. Seagrasses provide physical structure on otherwise often largely featureless sediment bottoms, enhancing community diversity, biomass as well as primary and secondary production (Duffy 2006; Marbà *et al*. 2006; Creed and Kinupp 2011; Leopardas *et al*. 2014; Barnes 2017).

This study has reported that most of the molluscs seemed to be crawling freely (51%) during low tide. The remaining molluscs were found to be attached to either the substratum or to other organisms. Most of the free crawling molluscs were seen to be moving among the seagrass rhizomes, namely *C. coralium*, *N. livescens*, *N. stolatus* and *I. javanica*.

This study is the first record of the diversity of seagrass and molluscs at Middle Bank, Penang, Malaysia. The information gathered in this preliminary study has increased our knowledge on biodiversity, which is prerequisite to improving the conservation effort in this area. However, this study has not been able to demonstrate a direct link between the low species diversity related to the destruction of nature and Middle Bank being located nearby a reclamation area, which is experiencing heavy load of sedimentation. We have to conclude that a better understanding of the relationship between habitat type and molluscs species is required.

ACKNOWLEDGEMENTS

We thank the Universiti Sains Malaysia Reef Research Group for their kind assistance and support in the field studies. This study was supported by Jabatan Taman Laut Malaysia (JTLM) grant 304/PPantai/650969/J122 .We would like to thank the researchers at the Universiti Sains Malaysia Marine Science Laboratory for their kind assistance and support in the field studies and our special thanks to the late Prof. Jørgen Hylleberg for his guidance and encouragement to all young scientists working on molluscs.

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Manuscript received: 6 October 2020
Accepted: 8 January 2021

Across the equator in Sulawesi, Indonesia.
Excursion trip of the 5th TMMP Workshop, 1994

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