Ecological study of macrozoobenthos in the mudflat zone of Sembilang National Park, South Sumatra

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Abstract. Macrozoobenthos is related to certain substrates in accordance with its adaptability and ecological function. The existence of macrozoobenthos on the coast of Sembilang National Park needs to be studied ecologically. The study purpose was to study the ecology and biodiversity of macrozoobenthos and its relationship with the environment in the mudflat zone. Macrozoobenthos sampling used the stratified sampling method at four stations. Each station consisted of three substations based on the supratidal zone, the intertidal zone, and the subtidal zone. Macrozoobenthos was taken from the surface to a depth of 20 cm on quadrant transects. The macrozoobenthos found consisted of 3 classes, 16 species, and 442 individuals. The highest macrozoobenthos composition was the Gastropoda class, with a total of 60%. The highest abundance of individuals was found at station 1 of the subtidal zone with a total of 222 Ind./m^2, which is the species *Cerithidea cingulata* in the Gastropoda class. Based on the study results, we were able to conclude that the macrozoobenthos community biodiversity index was closely related to the higher availability of dissolved oxygen and higher sand concentrations along the mudflat zone. This system would affect the macrozoobenthos existence found in the environment, especially in Sembilang National Park.

1 Introduction

Macrozoobenthos are key ecological components, particularly in coastal regions. They establish crucial communities within benthic ecosystems, essential to the study of both biotic and abiotic relationships in coastal and marine benthic environments [1, 2]. Playing a dynamic role in the food chain [3, 4], their presence is bolstered by a diverse array of benthic groups. These groups include detritivores, primary predators, and apex predators, adapting to specific ecosystem conditions. The ecological significance of macrozoobenthos as central figures in the food chain has been further highlighted [5, 6], marking their status as critical biotic factors within coastal ecosystems.

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South Sumatra is distinguished by its extensive coastal regions, largely managed within Sembilang National Park [4, 7]. This conservation area prioritizes using rehabilitating, and protecting coastal wetland forests, primarily composed of mangrove plant communities. Its landscape features vast mudflat beaches [4], shaped by sedimentation from the Musi and Banyuasin Rivers [8, 9]. The characteristics and biodiversity of macrozoobenthos in these mudflat areas can be revealed through the study of the vast muddy beaches of Sembilang National Park [10, 11]. It is hypothesized that specific macrozoobenthos groups inhabit submerged coastal zones, while others prefer drier areas [12, 14].

Ecological study has become a crucial approach in assessing ecosystem conditions [15, 17]. The ecosystems within the mudflat beaches of Sembilang National Park serve as a vital link in the food chain for migratory bird species [4]. These birds rely on the area as a stopover during their biannual migration. Therefore, monitoring through abiotic element approach is favored for its accurate depiction of biodiversity interrelations within habitats. Furthermore, the study of macrozoobenthos, acting as filter feeders with limited mobility, can provide insights into environmental interactions with external factors, including pollution, human activity, and other phenomena. This research aims to elucidate the biodiversity levels across different zones of the mudflat gradient of Sembilang National Park.

2 Method

2.1 Study area

Sembilang National Park had extensive muddy beaches. The average mud depth was 30–60 cm. The sampling locations were in areas where migratory birds were often found; there were a total of 4 stations. The station points were spread across several small rivers, namely station 1 was Barong Kecil river, station 2 was Barong Besar river, station 3 was Siput river, and station 4 was Dinding river. Each station was sampled using quadratic transects at three sampling points (substations) with three replications, each 300 m apart and perpendicular to the shoreline. The station location is presented in Figure 1.

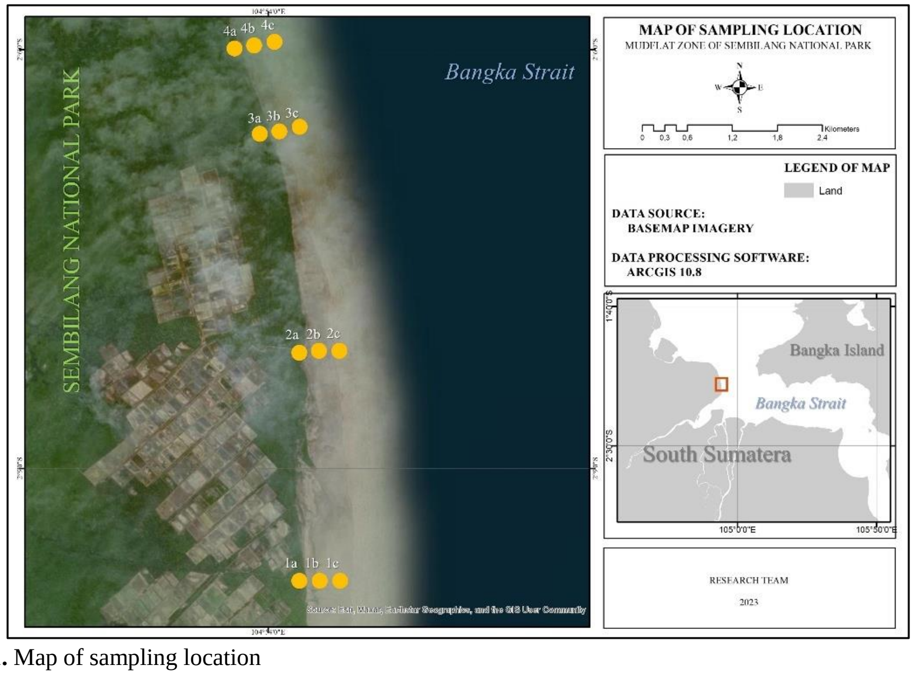

Fig. 1. Map of sampling location

2.2 Sample collections

Sampling was conducted in October 2022. Sampling at each station consisted of 3 substations, each 300 m away from the beach to the sea at low tide. The samples taken were macrozoobenthos samples and sediment samples. Sampling was carried out in quadratic transect lines using a PVC core sampler (Ø = 15 cm, h = 30 cm). The macrozoobenthos taken was on the surface of the sediment to a depth of 30 cm [1, 2, 3]. The sample was put into a filter with a mesh size of 1 cm, then the sample was cleaned with seawater. The samples were put into zip-lock bags, labeled, and stored in a coolbox.

2.3 Environmental parameters

Each substation measured water parameters in situ using portable water quality equipment when macrobenthos sampling was carried out and sediment samples were taken for sediment grain size measurements. The water parameters measured were pH, dissolved oxygen, temperature measured using a multiparameter, and salinity measured using a hand refractometer [4, 5]. Meanwhile, sediment samples were taken using a PVC core sampler, weighing as much as ±500 g. Environmental parameter data, namely pH, DO, salinity, temperature, and sediment grain size, were processed using Microsoft Excel 2019.

Sediment grain measurement used dry and wet sieving methods [6]. Sediment type was determined based on the gravel, sand, silt, and clay fraction percentage. This sediment fraction data processing using Microsoft Excel 2019 is referred to the Shepard method [7].

2.4 Macrozoobenthos identification

Samples were identified in the laboratory based on morphological observations of each individual macrozoobenthos found. Gastropods, malacostraca, and bivalves were some of the largest classes. Some points that were considered in identifying gastropods included shell style and color, shell spiral line shape, shell tower shape, and shell mouth shape. Malacostraca identification included the style, color, and shape of the carapace and the shape, color, and texture of the claws (propodus, carpus, and merus). Bivalves identification included the shell's size, shape, color pattern, pattern, and texture. In total, the identification of macrozoobenthos referred to the identification book [8, 9, 10].

2.5 Data analysis

Water quality data was processed and presented in tabular form using Microsoft Excel 2019. Biodiversity index data, including diversity index (H'), evenness index (E), and dominance index (C) [11, 12, 13], were processed using Microsoft Excel 2019. Then, the data were analyzed using PCA (Principal Component Analysis) in the XLSTAT 2023 program to explain the relationship between biodiversity and environmental variables [1, 14].

3 Results and Discussion

3.1 Presence and composition of macrozoobenthos in the mudflat zone

The research location in the mudflat zone of Sembilang National Park was very supportive of macrozoobenthos life. Based on the sampling results, 3 classes of macrozoobenthos were found, namely gastropods, bivalves, and malacostraca, with 16 macrozoobenthos species. The 16 species came from 9 species of gastropods, 4 species of malacostraca, and 3 species of bivalves. The picture of macrozoobenthos found is presented in Figure 2. The presence of macrozoobenthos in each station is presented in Table 1.

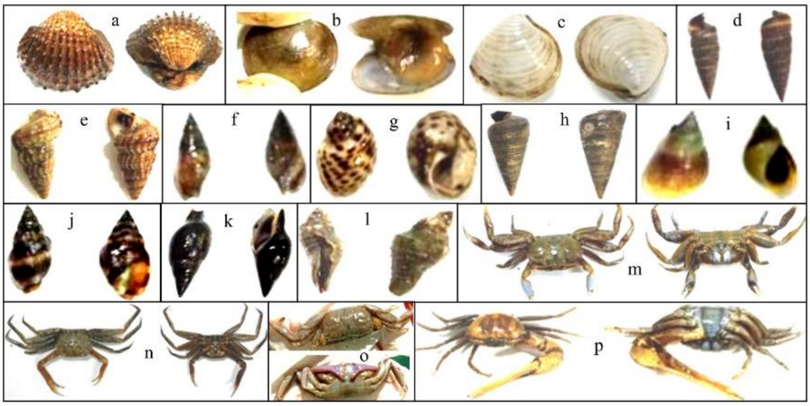

Fig. 2. Picture of macrozoobenthos species found from the mudflat zone of Sembilang National Park, (a) *Anadara granosa*; (b) *Pilsbryconcha Exilis*; (c) *Spisula solidissima*; (d) *Cerithidea Cingulata*; (e) *Cerithidea quadrata*; (f) *Nassarius olivaceus*; (g) *Babylonia spirata*; (h) *T. telescopium*; (i) *Littoraria angulifera*; (j) *Nassariius limatus*; (k) *Scaphella swainson*; (l) *Peringia ulvae*; (m) *Thalamita crenata*; (n) *Chiromantes haematocheir*; (o) *Macropthalmus telescopicus*; (p) *Uca* sp.

Table 1. The presence of macrozoobenthos at each station

Class	**Species**	**Presence of macrozoobenthos**											
		St. 1			**St. 2**			**St. 3**			**St. 4**		
		a	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**
Bivalvia	*Anadara granosa*	+	-	+	+	+	+	+	+	+	-	+	+
	Pilsbryconcha exilis	-	-	-	+	-	-	-	-	-	-	-	-
	Spisula solidissima	-	-	-	+	+	-	+	-	+	-	-	-
Gastropoda	*Babylonia spirata*	+	-	-	+	-	-	+	+	-	-	-	-
	Cerithidea cingulata	+	+	+	-	-	-	-	-	+	+	+	+
	Cerithidea quadrata	-	+	-	-	-	-	-	-	-	-	-	-
	Littoraria angulifera	+	-	-	-	-	-	-	-	-	+	-	-
	Nassariius limatus	-	-	-	+	+	-	-	-	+	-	-	-
	Nassarius olivaceus	-	-	-	+	+	+	+	+	-	-	-	-
	Peringia ulvae	-	+	-	-	-	-	+	-	-	+	-	+
	Scaphella swainson	-	+	-	-	-	-	-	-	-	+	+	-
	T. telescopium	-	+	+	+	-	-	+	-	-	-	-	+
Malacostraca	*C. haematocheir*	+	-	-	-	-	-	-	-	-	-	-	+
	M. telescopicus	+	-	-	+	-	+	+	-	+	+	-	-
	Thalamita crenata	-	-	-	+	-	-	+	-	-	-	-	-
	Uca sp.	+	-	-	-	-	-	+	-	+	-	-	-

Note: (+) Present, (-) Absent, (a) High intertidal zone, (b) Middle intertidal zone, (c) Low intertidal zone, (St.) Station

At station 1, the bivalve class found was only *A. granosa*, the gastropod class consisted of 9 species, and the malacostraca class consisted of 4 species. At station 2, the bivalve class consisted of 3 species, the gastropod class consisted of 4 species, and the malacostraca class consisted of 2 species. At station 3, the bivalve class consisted of 2 species, the gastropod class consisted of 6 species, and the malacostraca class consisted of 2 species. At station 4, the bivalve class consisted of 1 species, the gastropod class consisted of 5 species, and the malacostraca class consisted of 2 species.

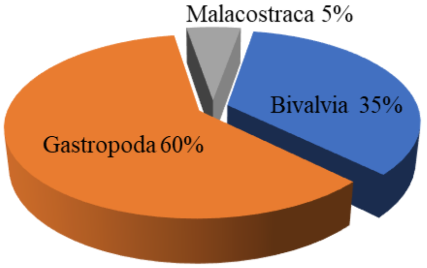

Fig. 3. Percentage of macrozoobenthos class composition

The gastropod class is more dominant because it has the capacity to adapt quite well to habitat conditions in the mudflat zone [23, 24, 25] stated that the mudflat zone is abundant in organic elements that benthic organisms need. The gastropod class likes to eat the remains of mangrove leaves or mangrove litter that dominates the coastal area of the Sembilang National Park area [26]. While bivalves were relatively few in the sampling sites, the presence of bivalves in the intertidal zone was less when compared to the subtidal zone due to environmental dynamics [27, 28, 29]. The intertidal zone is more influenced by water dynamics, especially coastal waves, while bivalves tend to have a limited tolerance for instability in their habitat compared to the gastropod class [30, 31]. Based on the composition of only 5%, Malacostraca indicates a mismatch between habitat conditions at the sampling site and its natural habitat. Malacostraca, consisting of mud crabs *Uca* sp., will favor harder mud conditions [32, 33]. This is certainly not the case at the sampling sites, which generally comprise more than 90% wet clay. Malacostraca species closely identified with the mudflat zone are *Uca* sp. [34, 35], but its presence is less common in this study. However, it is more likely to be found in the high intertidal zone than in the supratidal zone.

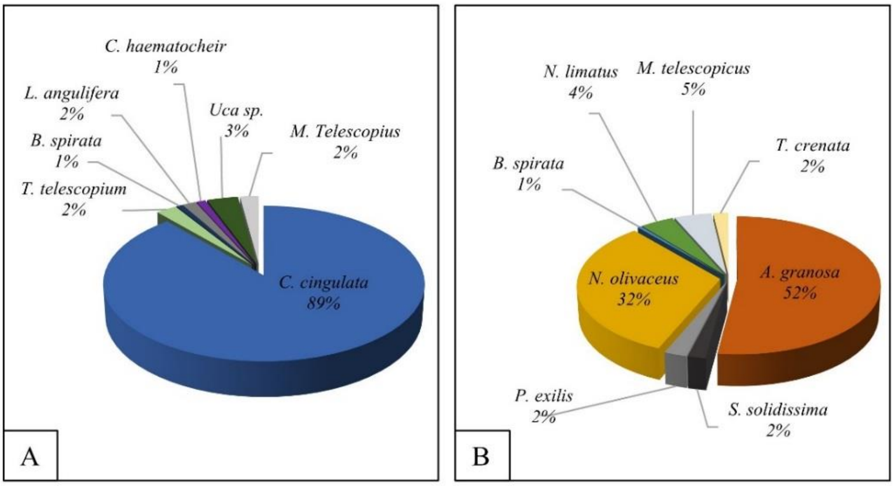

Fig. 4. Percentage of macrozoobenthos species composition at each station, (A) Station 1; (B) Station 2

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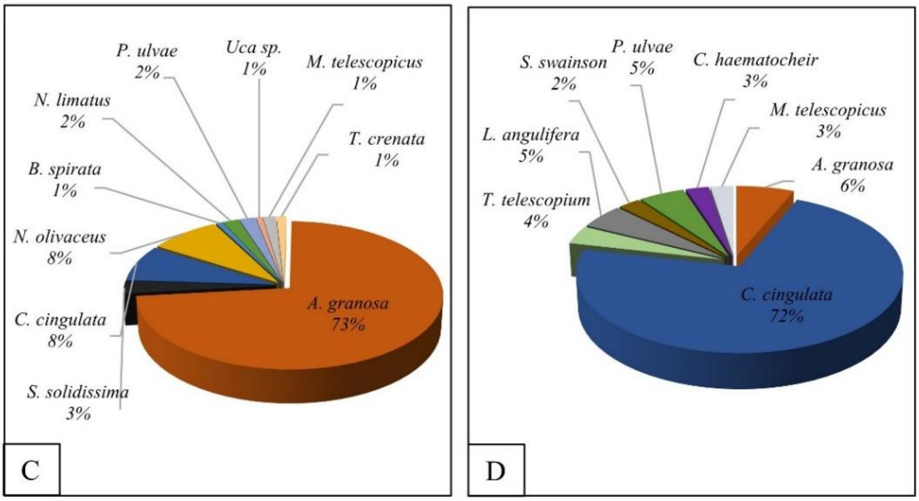

Fig. 5. Percentage of macrozoobenthos species composition at each station, (C) Station 3; (D) Station 4

Station 1 had *C. cingulata* as the dominant species with 89%, station 2 had *A. granosa* as the dominant species with 52%, and *N. olivaceus* with 32%. Station 3 had *A. granosa* as the dominant species with 73%, and station 4 had *C. cingulata* as the dominant species with 72%. Habitat condition factors and the level of competition are thought to affect the species with a high percentage in each research location [36].

3.2 Macrozoobenthos biodiversity in the mudflat zone

The abundance of macrozoobenthos, based on the study's results in the mudflat zone of Sembilang National Park, varied greatly between substations, ranging from 2 to 222 Ind./m^2. The results of macrozoobenthos abundance are presented in Table 2.

Table 2. The abundance of macrozoobenthos species found in the mudflat zone

Class	Species	Abundance of individuals (Ind./m^2)											
		St. 1			St. 2			St. 3			St. 4		
		a	b	c	a	b	c	a	b	c	a	b	c
Bivalvia	*Anadara granosa*	0	0	0	17	15	5	20	16	27	0	1	1
	Pilsbryconcha exilis	0	0	0	2	0	0	0	0	0	0	0	0
	Spisula solidissima	0	0	0	1	0	0	1	0	1	0	0	0
Gastropoda	*Babylonia spirata*	2	0	0	0	0	0	0	0	0	0	0	0
	Cerithidea cingulata	1	5	219	0	0	0	0	0	7	1	1	17
	Cerithidea quadrata	0	1	0	0	0	0	0	0	0	0	0	0
	Littoraria angulifera	4	0	0	0	0	0	0	0	0	1	0	0
	Nassariius limatus	0	0	0	2	1	0	0	0	2	0	0	0
	Nassarius olivaceus	0	0	0	13	8	2	2	6	0	0	0	0
	Peringia ulvae	0	1	0	0	0	0	2	0	0	1	0	0

Class	Species	Abundance of individuals (Ind./m²)											
		St. 1			St. 2			St. 3			St. 4		
		a	b	c	a	b	c	a	b	c	a	b	c
	Scaphella swainson	0	1	0	0	0	0	0	0	0	0	0	0
	Telescopium telescopium	0	3	3	0	0	0	0	0	0	0	0	1
Malacostraca	*Chiromantes haematocheir*	3	0	0	0	0	0	0	0	0	0	0	1
	Macropthalmus telescopicus	5	0	0	3	0	0	0	0	1	1	0	0
	Thalamita crenata	0	0	0	1	0	0	1	0	0	0	0	0
	Uca sp.	9	0	0	0	0	0	0	0	0	0	0	0
Total		24	11	222	39	25	7	27	22	38	4	2	20

Note: (a) High intertidal zone, (b) Middle intertidal zone, (c) Low intertidal zone

Based on Table 4, station 1 had the highest abundance of macrozoobenthos, with 222 Ind./m^2, located in the low intertidal zone (1c). The high abundance is likely due to abundant food availability in the form of rich organic matter, which is then supported by a very fine clay substrate. As a result, no other species could compete in this habitat condition.

Several studies have revealed that some gastropods favor habitats rich in organic matter, especially near mangrove areas [14, 37]. Some species are also reported to have been found in very high abundance, namely *C. cingulata* in the intertidal zone of Betong Island and *Umbonium vestiarium* in the intertidal zone of Aling Bay [38]. In addition, the area's proximity to the mangrove community significantly increased the organic matter in the substrate [39, 40]. Substrates rich in organic matter are usually indicated by the presence of detritus organisms such as snails [41].

Based on Table 3, the highest diversity index value was station 1 at the high intertidal zone, while the lowest diversity index was station 1 at the low intertidal zone with an index value of 0.1. The highest evenness was station 4 at the high intertidal zone (4a) with an index value of 0.95. In contrast, the lowest evenness index was station 1 at the low intertidal zone (1c) with an index value of 0.07 with 3 different species and a very large difference in individuals per species. The dominance index obtained from the research results was highest at station 1 low intertidal zone (1c) with an index value of 1.0, while the lowest dominance index was at station 1 high intertidal zone (1a) and station 4 high intertidal zone (4a) with an index value of 0.2.

Table 3. Community structure of macrozoobenthos in mudflat zone

Stations		Diversity (H')		Evenness (E)		Dominance (C)	
		Value	Category	Value	Category	Value	Category
1	a	1.6	mid	0.83	high	0.2	low
	b	1.3	mid	0.80	high	0.3	low
	c	0.1	low	0.07	low	1.0	high
2	a	1.5	mid	0.71	high	0.3	low
	b	0.8	low	0.59	mid	0.5	low
	c	0.7	low	0.66	high	0.6	high
3	a	1.0	mid	0.48	mid	0.6	high
	b	0.6	low	0.58	mid	0.6	high
	c	0.9	low	0.51	mid	0.5	high
4	a	1.5	mid	0.95	high	0.2	low
	b	1.0	mid	0.91	high	0.4	low
	c	0.6	low	0.36	low	0.8	high

Note: (a) High intertidal zone, (b) Middle intertidal zone, (c) Low intertidal zone

3.3 Water and sediment quality in mudflat areas

The results of water quality measurements at the location point showed relatively normal conditions for muddy waters except pH. These environmental parameters could support the life of macrozoobenthos organisms, namely gastropods, malacostraca, and bivalves. Water quality at the sampling location is presented in Table 4, and sediment grain measurement is presented in Table 5.

Based on Table 4, measurements of water quality parameters in the study area were temperature 25.5 °C–32 °C, pH 6.1–8.5, DO 6.7–11.9 mg/L, and salinity 4.8–21.6 psu. The measurement results of water quality parameters at all stations varied, but they were still in the good range for biota life in the sea waters except pH. The water temperature range was influenced by the intensity of the sun in the morning when sampling was carried out. Measured pH levels had a fairly wide range, more acidic water conditions measured at stations 1 and 2 were thought to be due to the influence of river water containing quite a lot of organic matter especially in mangrove waters. Some studies stated that organic content in river and mangrove waters can significantly reduce pH levels from natural conditions [15, 16]. Oxygen levels are in a good range for the habitat of macrozoobenthos organisms. The salinity at this location tended to be brackish because the sampling point was at the estuary, and the measurements were taken at low tide. In Table 5, the sediment type was only in the clay category. The percentage value indicated a very fine and soft sediment condition. This habitat is likely to support benthic life well [17, 18].

Table 4. Water quality measurements at sampling stations

Stations		Parameters			
		Temperature (°C)	**pH**	**DO (mg/L)**	**Salinity (psu)**
1	a	25.5	6.3	11.9	4.8
	b	26.5	7.1	11.5	5.3
	c	26	6.1	11.7	4.9
2	a	27.9	6.2	10.1	9.8
	b	30.2	7.4	8.9	1.2
	c	28	6.5	9.5	10
3	a	29.2	8	7.2	20.5
	b	32	8.5	6.7	21.6
	c	30.9	8.1	7.1	20.9
4	a	28.9	7.3	10.3	20.1
	b	30.1	7.9	9.4	20.4
	c	29.8	7.6	9.7	19.5
Quality standard for biota in sea waters		28-32	7-8.5	>5	0-34

Note: (a) High intertidal zone, (b) Middle intertidal zone, (c) Low intertidal zone, government regulation number 22 of 2021 appendix VIII (Quality standard for biota in sea waters for mangrove waters ecosystem)

In general, the physico-chemical conditions of the waters in the estuary region are influenced by tidal events [19]. Some water parameters, such as pH and salinity, are quite heavily influenced by tides [20]. The dominance of saltwater masses during high tide will enter slowly while being able to push back the river current [21]. The difference in salinity range in the estuary is also quite influenced by the position of the observation location in the estuary. Associated salinity taken from several areas of the estuary shows the same relationship. Salinity measurements in the estuary in the inner part of the river show lower values when compared to the outer part of the estuary [22].

Table 5. Sediment grain size at sampling stations

Stations		Percentage of sediment fraction (%)			Type of substrate
		Sand	Mud	Clay	
1	a	7.59	1.28	91.13	Clay
	b	4.00	1.61	94.39	Clay
	c	7.76	1.65	90.59	Clay
2	a	1.83	3.88	94.29	Clay
	b	1.58	3.81	94.62	Clay
	c	0.62	4.62	94.75	Clay
3	a	2.54	2.98	94.48	Clay
	b	2.85	5.30	91.85	Clay
	c	1.78	2.56	95.66	Clay
4	a	1.07	3.79	95.14	Clay
	b	1.33	4.16	94.51	Clay
	c	4.61	3.28	92.10	Clay

Note: (a) High intertidal zone, (b) Middle intertidal zone, (c) Low intertidal zone

3.4 Relationship between macrozoobenthos community structure and water quality conditions

The relationship between macrozoobenthos community structure and water quality conditions was presented in Figure 6 in the form of PCA ordination. The results of the relationship between water quality parameters pH, DO, temperature, grain size, and salinity and abundance, diversity, evenness, and dominance obtained cumulative Eigenvalues F1 and F2 of 77.91% (Figure 6). The eigenvalue variability of each axes was F1 (45.85%) and F2 (32.06%). The F1 group consisted of DO, macrozoobenthos abundance variables, sand substrate, temperature, pH, salinity, mud substrate, and clay substrate, while the F2 group consisted of diversity, evenness, and dominance indices.

PCA ordination obtained on the F1 axis consisting of stations 3a, 3c, and 4b has main variables that are positively correlated with temperature, pH, salinity, mud substrate, clay substrate, but negatively correlated with DO, macrozoobenthos abundance, and sand substrate (Figure 6). At station 1c, the variables DO, macrozoobenthos abundance, and sand substrate are positively correlated, meaning that at station 1c, the value of the three variables tends to be higher among other stations. Station 1c has the highest abundance of 222 individuals with DO concentration of 11.7 mg/L and sand composition of 7.76%. These results suggest that sites with high macrozoobenthos abundance provide good DO quality [44]. This means oxygen concentration is crucial to support gastropod life at station 1c.

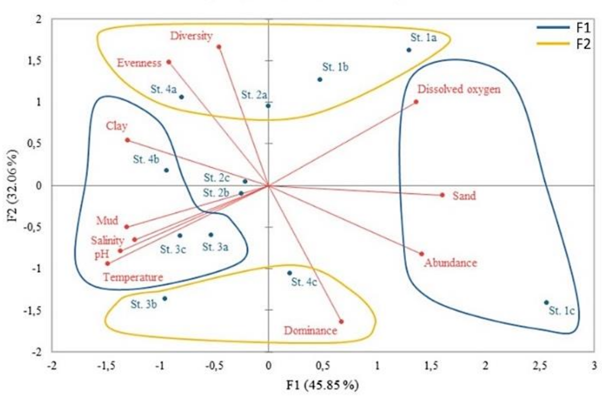

Fig. 6. Results of PCA ordination of biodiversity and water quality variables

4 Conclusion

This study found three classes of macrozoobenthos that play an ecologically important role in the mudflat zone of Sembilang National Park, namely gastropods, bivalves, and Malacostraca, with a total of 16 species, consisting of 9 species of gastropods, four species of Malacostraca, and three species of bivalves. The highest composition was gastropods at 60%, bivalves at 35%, and malacostraca at 5%. The highest species abundance was at station 1 of the low intertidal zone with 222 Ind./m^2 from the Gastropoda class, *C. cingulata* species, while the lowest abundance was at station 4 of the medium intertidal zone with two Ind./m^2. The relationship between biodiversity and water quality suggests that sites with high macrozoobenthos abundance provide good DO quality, and these conditions will also support the availability of food for migratory birds in the coastal area of Sembilang National Park.

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