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MOLLUSKS DIVERSITY IN THE PROTECTED COASTLINE OF BERBAK-SEMBILANG NATIONAL PARK INDONESIA

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Abstract

Mollusk has a role as a food source in benthic ecosystems. Presumably, there has been a decrease in its diversity on the protected coastline of Berbak-Sembilang National Park (BSNP) due to fluctuations in water quality parameters that threaten the sustainability of another biota in the web food system. The purpose of this study was to describe the diversity of mollusks and their correlation with water quality in the protected coastline area. The research methodology was carried out, namely: water quality data collection, mollusk sampling, diversity analysis, and correlation analysis. Principal component analysis and similarity analysis were used. The results showed that there were 28 species of mollusks, which were classified into two classes: Bivalvia (79%), and Gatropoda (49%), with 21 species. The mollusk abundance means 263.25 ind.m^{-2}, and the diversity is categorized as low H'<1 except stations 2 and 4. It is supported by the dominant species, namely Anadara granosa (36.61%), and Nutricola sp. (35.47%. There are two clusters of mollusks: open coastal areas are characterized by higher temperatures, nutrients, salinity, pH, currents, and brightness, and estuary clusters are characterized by higher dissolved oxygen and mollusk abundance.

Keywords*: Bivalvia; Gatropoda; Macrobenthos; Mollusks diversity; Protected coastline*

Introduction

Mollusks are a group of aquatic benthics that are infauna and epifauna with limited movement. Its existence makes it very vulnerable to being influenced by various changes in environmental quality. Aquatic sediments such as mud, sand, and rocks are reported to have many differences in the diversity of these biota. Diversity mollusks are very easy to find at the benthic with a substrate of mud and sand [1, 2]. Although also found on rock substrates [3], mollusks on mud substrates were found to be more diverse due to the nature of their filter feeders, especially in mangrove ecosystems [4–6]. On the other hand, the mollusks were a major food source for demersal fish and seabirds [7]. Several species of shorebirds, storks, and seabirds were found to prey on mollusks [8, 9]. Various threats will reduce the diversity of mollusks in various habitats. Most of the larval stages of macrofauna were planktonophagous,

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providing food for large zooplankton and fish, which significantly affected the number and species composition of macrofauna [10, 11].

Berbak-Sembilang National Park (BSNP) is an estuary area located on the coast of Sumatra Island with a long coastline covered by a wide mangrove forest. They are supported by a thick and nutrient-rich mud substrate, which has an impact on increasing the abundance and diversity of biota, especially benthic organisms. There are 32 mangrove species in BSNP, with an area of 70,263 hectares [12]. Nevertheless, this area has decreased from year to year due to many factors, such as forest fires, coastal abrasion, forest encroachment by residents, and the creation of pond shrimp farming [13]. The destruction of mangrove forests has a very significant impact on decreasing the abundance and diversity of benthic organisms, especially the mollusk phylum, where their limited movement causes them to adapt to the fluctuation's environmental changes [14]. Furthermore, the linkage of mollusks with mangrove ecosystems is very high because mangroves are the main food source, and thick silt is a very suitable habitat for their growth [15, 16].

The dynamics of changing water quality have an impact on decreasing the mollusk community structure in an area, which will be exacerbated by an increase in anthropogenic waste [17, 18]. However, a decrease in mollusk diversity can also occur in protected areas such as the BSNP, especially in coastal areas, which are vulnerable to environmental changes. This has a significant impact on the diversity of mollusks as a sessile biota with very limited movement [4]. In addition, the discharge of water masses from land carrying suspended substances and organic matter has an impact on increasing the distribution of abundance and diversity of mollusks [19]. This occurs naturally and continuously over time [20].

This study aims to examine the diversity of mollusks along the protected coastline of BSNP. In addition, it is also to update data on mollusks, the largest group of benthic organisms reported in the tropical coastal area of the eastern part of Sumatra Island.

Experimental part

Study Area

The Berbak-Sembilang National Park (BSNP) is a mangrove forest conservation area of about 2,051km² [13, 21]. This area has a thick mud subtract, sourced from some rivers around it, such as the Sembilang River, Barong River, and Banyuasin River. In addition, this coastal area has endemic biota such as the Sembilang fish (*Plotusus canius*), the giant freshwater turtle (*Chitra indica),* and the saltwater crocodile (*Crocodylus porosus*), and it makes a habitat for several types of shorebirds, storks, and migratory birds [8]. Macrobenthos in this area is the main food for these birds.

The protected coastline of the BSNP was specifically targeted for this study (Fig. 1). BSNP is located on the western coast of the Bangka Strait, South Sumatra, which is an estuary area formed from a mixture of freshwater masses from the mainland of Sumatra with seawater masses from the Melaka Strait and the South China Sea [22]. The BSNP coastline has dynamic water quality parameters, which are during the rainy season and the dry season. In the rainy season, freshwater discharge from the mainland will increase, which results in a decrease in salinity and brightness and an increase in nutrients. In addition, high mangrove waste will increase water fertility. In contrast, in the dry season, there are clearer waters and an increase in salinity due to the dominant influence of seawater masses. Overall, the BSNP estuary shows a

dynamic environment where water quality parameters are directly or indirectly influenced by different seasons and/or episodic events of freshwater input to the offshore [12].

This research was conducted on October 24–26, 2020, at eight observation stations along the protected coastline of BSNP waters, with a length of about 60km. Stations 1 and 2 represent the bay area and the open coast. Stations 3, 4, and 5 represent river estuary areas, while Stations 6, 7, and 8 represent open shore areas and migratory bird habitats (Fig. 1).

Fig. 1. Map of sampling stations in Berbak-Sembilang National Park

Methods

Data collection and sampling processing

Data on the water's physical parameters (i.e., pH, salinity, dissolved oxygen, temperature, brightness, and current speed) are carried out *in situ* with three repetitions at the observation station, respectively. Measurements were used for the water pH with a pH metre, salinity with a hand refractometer, dissolved oxygen (DO) with a DO metre, temperature with a digital thermometer, brightness with a Secchi disc, and current speed with a current meter. Nitrate and phosphate measurements used a spectrophotometer [23].

Mollusk samples were collected from the surface of the substrate to a depth of 20cm in a 1×1m transect. A sampling at the station was carried out three times, respectively. Then, at each station, the samples were put in labelled sample boxes for analysis in the laboratory. The mollusk sample obtained was separated from sediment, washed with clean water, and preserved with 8% formalin [24] and samples identified by refer to [25-27].

Statistical analysis

Data analysis on water quality parameters was described using MS Excel software. The mollusk abundance data were analysed in terms of total percentage and total individuals per species. The species diversity data were analysed by the Shannon-Winner index (H') and the Dominance Index by Simpson (C). Principle component analysis (PCA) was used to analyse the correlation between water quality parameters and the abundance and diversity of mollusks, and the similarity of stations was analysed by Bray-Curtis dissimilarity analysis using XLSTAT 2021.

Results and discussion

Water quality parameters of Berbak-Sembilang National Park

The results of the measurement of the quality of the waters in the coastal area of BSNP showed that the conditions were relatively stable or normal for the growth of mollusks. The average pH value of the waters was obtained under normal conditions of 7.29 ± 0.59, as well as a salinity of 30.38 ± 1.30 PSU. Although there was a slight decrease at station 8 (28 PSU), this salinity was normal in the estuary area.

Dissolved oxygen (DO) and temperature in all observation stations were categorized as in good condition, with mean values of 7.78±0.78mg·L^{-1} and 29.49±0.14ºC, but brightness showed a low mean value of 15.45±6.18%, especially in the estuary area rivers, namely: stations 3, 4, and 5. The flow velocity was found to be decreasing in the bay or estuary area with an average value of 0.18±0.12m·s^{-1}, while the distribution of nitrate and phosphate concentrations was shown to be relatively even with a mean of 6.08±0.48mg·L^{-1} and 0.18±0.01mg·L^{-1} (Table 1).

Table 1. Water quality parameters of Berbak-Sembilang National Park

No	Water quality	Stations							
		1	2	3	4	5	6	7	8
1	pH	7.41	7.46	7.51	7.46	7.01	7.17	8.20	6.08
2	Salinity (PSU)	30.00	32.00	30.00	30.00	30.00	31.00	32.00	28.00
3	DO (mg.L^{-1})	8.63	8.37	8.50	8.03	7.48	6.30	7.60	7.30
4	Temperature (ºC)	29.65	29.63	29.42	29.40	29.35	29.36	29.43	29.69
5	Brightness (%)	17.56	20.89	10.87	6.52	8.70	24.36	17.72	16.98
6	Current Speed (m.s^{-1})	0.08	0.19	0.08	0.13	0.16	0.47	0.15	0.18
7	NO_3 (mg.L^{-1})	6.67	6.20	5.45	6.24	5.53	5.66	6.23	6.69
8	PO_4 (mg.L^{-1})	0.20	0.19	0.16	0.19	0.17	0.17	0.19	0.20
9	Pyhtoplankton abundance (cell.L^{-1})	68,206	100,451	108,148	3,715	17,383	11,952	46,757	26,278

The fluctuation of water quality parameters in all observation stations of the Berbak-Sembilang National Park (BSNP) was found to be slightly different, and this is a good condition for the growth of aquatic biota, especially mollusks. There are several parameters found to decrease in the estuary area, such as brightness and speed of currents. This is due to the impact of the stirring of the water mass from the land with the seawater mass formed in the mixing area. This characteristic was also reported in many publications [17, 28-31].

Mollusks species of community structure

A total of 28 species of mollusks were identified in BSNP, nominated by the Gastropoda with 21 species and the Bivalvia with 7 species. However, the abundance of Bivalvia was greater than the abundance of Gatropoda. The distribution of the abundance and diversity of species was found to be uneven, such as *Anadara granosa*, which was found in almost all observation stations, but more species were found in only one or two at the station (Table 2).

The composition of mollusks in all observation stations was found to comprise only two classes, which were dominated by Bivalvia (79%), and Gatropoda (21%).

Table 2. Mollusks species of Berbak-Sembilang National Park

No	Class	Species	Stations							
			S1	S2	S3	S4	S5	S6	S7	S8
1	Gatropoda	*Colpospira* sp.	-	+	-	-	-	-	-	-
2	Gatropoda	*Nassarius crenoliratus*	-	+	-	-	+	-	-	-
3	Gatropoda	*Tonna oleria*	-	+	-	-	-	-	-	-
4	Gatropoda	*Tomlinia rapulum*	-	+	-	-	-	-	-	-
5	Gatropoda	*Turbinella* sp.	-	+	-	-	-	-	-	-
6	Gatropoda	*Oliva* sp.	-	+	-	-	-	-	-	-
7	Gatropoda	*Melanopsis frustulum*	-	-	+	-	-	-	-	-
8	Gatropoda	*Telescopium telescopium*	-	-	+	+	-	-	-	-
9	Gatropoda	*Nerita balteata*	-	-	+	+	-	-	-	-
10	Gatropoda	*Pirenella conica*	-	-	+	-	-	-	-	-
11	Gatropoda	*Ellobium gassiesi*	-	-	-	+	-	-	-	-
12	Gatropoda	*Euspira napus*	-	-	-	+	+	-	-	-
13	Gatropoda	*Natica marchadi*	-	-	-	+	-	-	-	-
14	Gatropoda	*Naticarius hebraeus*	-	-	-	+	-	-	-	-
15	Gatropoda	*Septaria psittacea*	-	-	-	+	-	-	-	-
16	Gatropoda	*Pterygia dactylus*	-	-	-	+++	-	-	-	-
17	Gatropoda	*Busycotypus canaliculatus*	-	-	-	+	-	-	-	-
18	Gatropoda	*Cerithidea pliculosa*	-	-	-	+	-	-	-	-
19	Gatropoda	*Thais* sp.	-	-	-	+	-	-	-	-
20	Gatropoda	*Volema pyrum*	-	-	-	+	-	-	-	-
21	Gatropoda	*Euspira strebeli*	-	-	-	-	-	-	+	-
22	Bivalvia	*Anadara granosa*	+	+++	+++	+++	+	+	-	-
23	Bivalvia	*Leukoma* sp.	-	++	-	-	-	-	-	-
24	Bivalvia	*Mactra chinesis*	-	-	+	-	-	-	-	-
25	Bivalvia	*Humilaria kennerleyi*	-	-	-	+	-	-	-	-
26	Bivalvia	*Tellina* sp.	-	-	-	-	+	-	-	-
27	Bivalvia	*Nutricola* sp.	-	-	-	-	+++	+++	-	+++
28	Bivalvia	*Macoma* sp.	-	-	-	-	-	-	+	-

There were 28 species of mollusks found on the protected coastline of the BSNP, grouped into two classes, namely Bivalvia (79%), with 7 species, and Gatropoda (21%), with 27 species. The individual composition of Bivalvia was more dominant than that of Gatropoda, although the number of species was lower. Bivalvia have a high tolerance for changes in environmental parameters [32]. This composition has also been reported on the west coast of India [33], in the estuary of the Gharehsou River [34], in a mangrove plantation, and in two natural associations in Khanh Hoa, Vietnam [35]. In contrast to the report, Polychaeta is more dominant in the Yangtze River Estuary and Batam Island, Indonesia [36], Gatropoda is found to be dominant in the Estuary Musi [2], Gatropoda is also dominant in the Great Lake District Pasuruan East Jawa [37], and Gatropoda dominates Mumbai, west coast of India [38]. This indicates that the individual distribution of the two classes of mollusks is highly dependent on their habitat.

Mollusks abundance and diversity

The overall mean value of individual mollusks at the study sites was 263ind·m^{-2}. The highest abundance found at station 4 is 531ind·m^{-2}, station 3 is 495ind·m^{-2}, station 6 is 333ind·m^{-2} and station 5 is 297ind·m^{-2}, while others are taken as the average found. Two species of mollusks were found to dominate, namely *Anadara granosa* (36.61%) and *Nutricola* sp. (35.47%), both of which are from the Bivalvia, in contrast to the abundance of the

Gatropoda, which was dominated by *Pterygia dactylus (5.56%)* and *Volema pyrum (2.14%)*. In addition, the distribution of Bivalvia was found to be more even than that of Gatropoda (Fig. 2).

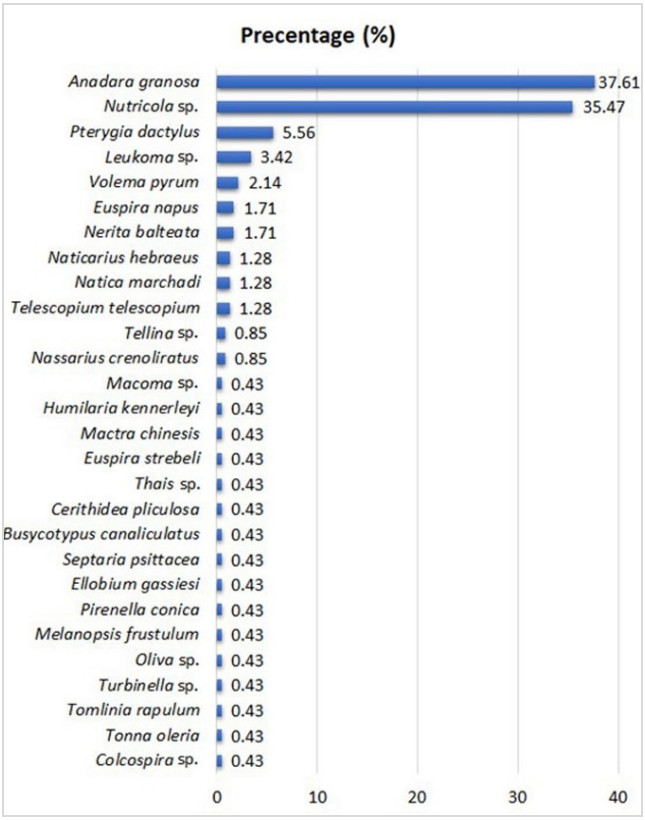

Fig. 2. Percentage of mollusks species of Berbak-Sembilang National Park

Given the diversity of species, the Shannon-Wiener index (H') all decreased significantly at almost all low-category observation stations (Station 1, 3, 5, 6, 7, and 8), unless there were two stations in the moderate category (Station 2 and 4). This was also supported by the Simpson index value (C), where species dominance occurs in almost all locations (Fig. 3).

The abundance of mollusks was found to be quite high, which increased significantly in the estuary area compared to the open coastal area. This is thought to be influenced by the discharge of water masses from the land, which carry more suspended material and nutrients. Besides that, the meeting of water masses creates a mixing area, which has an impact on increasing the fertility of the waters. This condition is very suitable for the growth and reproduction of the mollusk community as an aquatic sessile biota. This total abundance was higher than that reported by [20, 39-48].

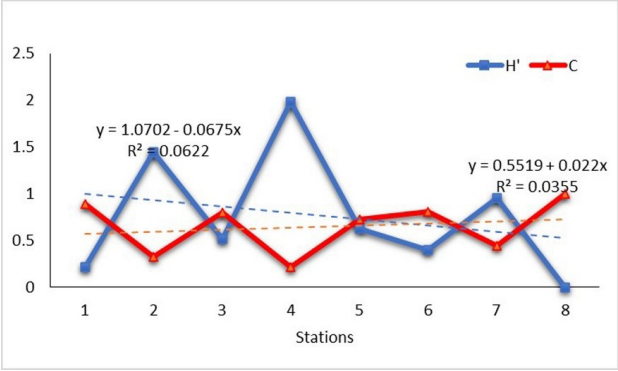

Fig. 3. Diversity index of mollusks of Berbak-Sembilang National Park

There are two species found to dominate in BSNP, namely *Anadara granosa* (36.61%) and *Nutricola* sp. (35.47%), classified in the Bivalvia [49–51]. Gatropoda abundance was shown by *Pterygia dactylus* at 5.56% and *Volema pyrum* at 2.14% [37, 52, 53]. The distribution of *A. granosa* and *Nutricola* sp. species was found to be more even than other species. This species is reported to have stronger survival abilities [32, 54, 55]. In contrast to what was reported by [56], the identified Bivalvia of *Mactra veneriformis* and *Cyclina sinensis* were more resistant to the organic matter in the Geum River estuary.

Correlation between water quality parameters with mollusks abundance and diversity of Berbak-Sembilang National Park

The results of the relationship between water quality parameters and mollusk abundance and diversity at the study location obtained Eigenvalues Cumulative 82.61%; five groups were formed, namely: four groups formed on the F1 and F2 axes, while the others were formed on the F3 axis. Besides that, the similarity between the observation stations was formed by two clusters coded MB1 and MB2 (Fig. 4).

Based on Figs. 4a and b, *the first group* contributing from the positive F1 axis illustrated that stations 1 and 8 were characterized by higher temperatures and concentrations of nitrate and phosphate, which were thought to be influenced by a larger supply of land.

The MB2 cluster was formed by station, and *the second group* was formed on the negative F1 axis by showing that stations 3 and 5 were characterized by a higher abundance of mollusks, where they were located just around the mouth of the Sembilang river. *The three group*s were formed on the positive F2 axis, which illustrated that Station 6, with a stronger characteristic of current velocity and water brightness, assumed that the location was directly facing the open sea. *The fourth group* was formed on the negative F2 axis, where station 4 was characterized by higher oxygen; presumably, there was an influence of the mixing area between the water mass of the river and the sea. *The fifth group* was formed on the positive F3 axis. It was found that stations 2 and 7 were characterized by more stable salinity and pH, which was thought to reduce the influence of the freshwater mass from the river.

The results of the similarity analysis calculated by the Bray-Curtis dissimilarity index (Fig. 4c) showed that the distribution of mollusk abundance and diversity was significantly

similar and formed two clusters (MB1 and MB2). An average similarity value of 83.74%. MB1 clusters are formed at stations 1, 2, 6, 7 and 8, which are on the open coast.

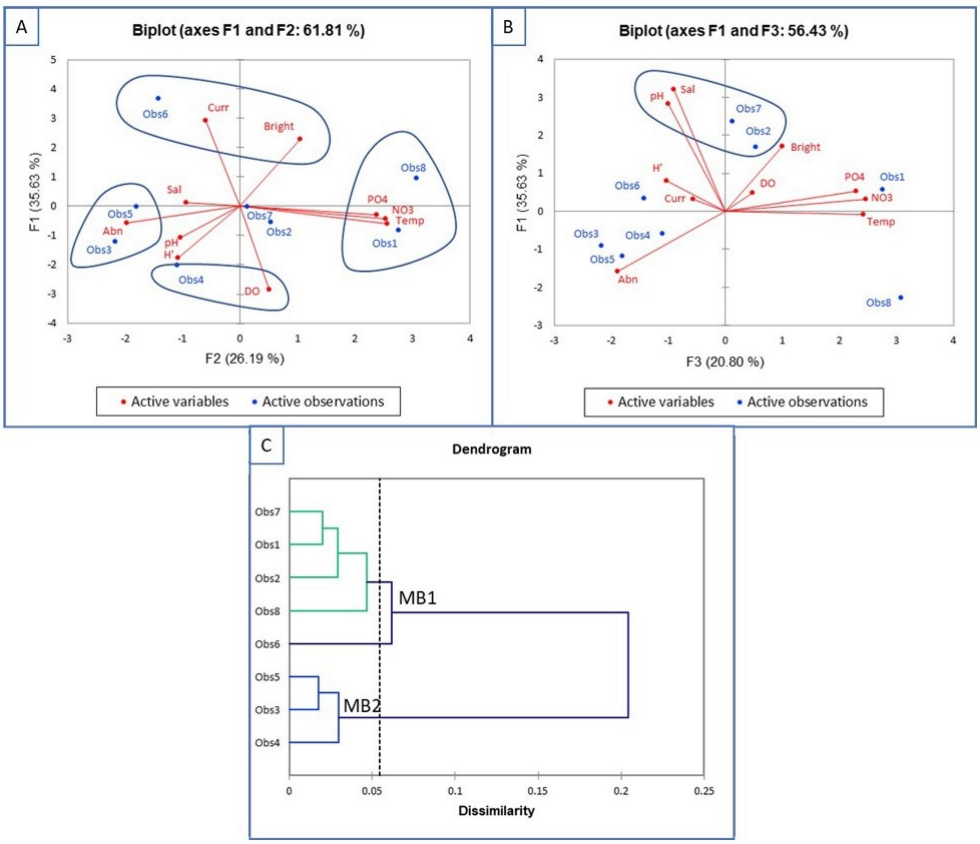

Fig. 4. Correlation between water quality parameters with mollusks abundance and diversity: (a) F1 and F2 axes; (b) F3 axes; (c) Dendrogram dissimilarity

These clusters are characterized by higher temperatures, salinity, pH, nutrient brightness, and water currents. This is thought to be due to the strong influence of the seawater mass area of the Melaka Strait and the South China Sea (3, 4, and 5), located at the mouth of the river mouth, characterized by dissolved oxygen and a higher abundance of mollusks compared to other locations. Continuous fluctuations in water quality parameters were thought to have an impact on the dominance of several species at each station. The two clusters illustrated that the abundance and diversity of mollusks on the protected coastline of BSNP were significantly affected by changes in water quality parameters.

The relationship between water quality parameters and the abundance and diversity of mollusks along the protected coastline in BSNP is characterized by higher temperatures and nutrients in the river mouth area, while brightness and flow velocity are lower. The discharge of inland water masses through rivers is affected because it brings temperature, nutrients, and suspended materials to a higher level, and there is a mixing of freshwater and seawater, which makes the current slowdown. The number of individual mollusks in the estuary area is higher and more diverse than others. This was also reported by [40], that the benthic community

responded to oxygen concentrations, salinity, and particle size. The BSNP open coastal areas are characterized by higher temperature, nutrient, salinity, pH, current, and brightness parameters. It is assumed that the influence of seawater masses from the Malacca Strait and the South China Sea is more dominant; it has an impact on the decline in mollusk diversity.

Y. Xingzhong et al. [57] pointed out that macrofauna was sensitive to changes in the pelagic environment. *Y. Xingzhong et al.* [57] found that along the estuary gradient, benthic species numbers increased with the increase in salinity. The salinity gradient was the dominant factor determining the distribution pattern of mollusks in protecting the coastline of BSNP, and currents play a role in the water mass distribution and diversity of mollusks with limited movement, especially on juvenile faces [58].

There are two clusters for mollusk habitat in BSNP, namely: the open coastal cluster and the estuary water cluster. The open coastal cluster found the diversity of mollusks slightly lower than the estuary cluster dominated by Bivalvia. It is shown that the freshwater mass of the river is more suitable for the growth and reproduction of mollusks than the open coast. Variation in macrobenthic diversity may be primarily attributed to changes in stem density and salinity [29]. As estuaries are complex, diverse ecosystems, benthic communities are controlled by a combination of factors, such as salinity, pH, tidal fluctuation, dissolved oxygen, sediment composition, and organic matter, and no single factor could be considered an ecological master factor [59,60].

Conclusions

There are 28 species of mollusks found on the protected coastline of Berbak-Sembilang National Park, classified into two classes: Bivalvia (79%), with 7 species, and Gatropoda (49%), with 21 species. Water quality parameters were found under normal conditions and supported mollusk growth. The abundance was found to be uneven, both in the estuary area and on the open seacoast. The diversity of species is categorized as low; this is supported by the species that dominate, namely *Anadara granosa (37.61%)* and *Nutricola* sp. (35.47%). Based on PCA, it shows that the observation stations in open coastal areas are characterized by higher nutrients, salinity, pH, currents, and temperatures, while the estuary areas are characterized by higher dissolved oxygen and mollusk abundance. Similarity analysis has revealed that the two clusters of distribution of mollusk diversity in BSNP, namely open coastal areas and river estuaries, are both significantly different and influenced by water quality fluctuations.

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References

[1] A.A. Abdelhady, M.M. Khalil, E. Ismail, J. Fan, S. Zhang, J. Xiao, *Water chemistry and substrate type as major determinants of molluscan feeding habit and life–mode in lagoon sediments*, **Estuarine, Coastal and Shelf Science**, **220**, 2019, pp. 120-130,

https://doi.org/10.1016/j.ecss.2019.02.019.

[2] Rozirwan, Melki, R. Apri, Fauziyah, A. Agussalim, Hartoni, I. Iskandar, *Assessment the macrobenthic diversity and community structure in the Musi Estuary, South Sumatra, Indonesia*, **Acta Ecologica Sinica**, **41**(4), 2021, pp. 346-350, https://doi.org/10.1016/j.chnaes.2021.02.015.

[3] A. Sahidin, Z. Zahidah, H. Hamdani, I. Riyantini, R. Sewiko, *The Biodiversity of Gastropods in Karapyak Rocky Shores, Pangandaran Region, West Java Province, Indonesia*, **Omni-Akuatika**, **14**(2), 2018, pp. 79-85.

[4] S. Almaniar, Rozirwan, Herpandi, *Abundance and diversity of macrobenthos at Tanjung Api-Api waters, South Sumatra, Indonesia*, **AACL Bioflux**, **14**, 2021, pp. 1486-1497.

[5] Rozirwan, Fauziyah, R.Y. Nugroho, Melki, T.Z. Ulqodry, F. Agustriani, E.N. Ningsih, W.A. E. Putri, A. Absori, M. Iqbal, *An ecological assessment of crab's diversity among habitats of migratory birds at berbak-sembilang National Park Indonesia*, **International Journal of Conservation Science**, **13**(3), 2022, pp. 961-972.

[6] Rozirwan, Nanda, R.Y. Nugroho, G. Diansyah, Muhtadi, Fauziyah, W.A.E. Putri, A. Agussalim, *Phytochemical composition, total phenolic content and antioxidant activity of Anadara granosa (Linnaeus, 1758) collected from the east coast of South Sumatra, Indonesia*, **Baghdad Science Journal**, **20**(4), 2023, pp. 1258-1265, https://doi.org/10.21123/bsj.2023.6941

[7] J.A. Crooks, *Predators of the invasive mussel Musculista senhousia (Mollusca: Mytilidae)*, **Pacific Science**, **56**(1), 2002, pp. 49-56.

[8] M. Iqbal, D. Mulyana, H. Martini, A. Setiawan, I. Yustian, H. Zulkifli, *Updating recent checklist of shorebirds in Banyuasin Delta (Sembilang), South Sumatra, Indonesia*, **Stilt The Journal for the East Asian-Australasian Flyway**, **73**, 2020, pp. 69-71.

[9] M.N. Janra, A. Mursyid, I.G. Aadrean, M. Ringga, M. Ikhsan, *Shorebird surveys at the Coast of West Sumatra Province, Indonesia: 2017-2018*, **Stilt**, **72**, 2018, pp. 27-32.

[10] K. Liu, H. Lin, X. He, Y. Huang, Z. Li, J. Lin, J. Mou, S. Zhang, L. Lin, J. Wang, J. Sun, *Functional trait composition and diversity patterns of marine macrobenthos across the Arctic Bering Sea*, **Ecological Indicators**, **102**, 2019, pp. 673-685, https://doi.org/10.1016/j.ecolind.2019.03.029

[11] Rozirwan, Melki, R. Apri, R.Y. Nugroho, Fauziyah, A. Agussalim, I. Iskandar, *Assessment of phytoplankton community structure in Musi Estuary, South Sumatra, Indonesia*, **AACL Bioflux**, **14**(3), 2021, pp. 1451-1463.

[12] I.A. Ratmoko, D. Budianta, R. Ridho, E. Wildayana, Z. Idrus, N. Nuryamsasni, *Analytic hierarchy process for zonation review of Sembilang National Park, Banyuasin Regency, South Sumatera Province, Indonesia*, **IOP Conference Series: Earth and Environmental Science**, **737**(1), 2021, Article number 12019, doi:10.1088/1755-1315/737/1/012019.

[13] R.A. Sarno, Z. Suwignyo, M. Dahlan, M. Munandar, M.R. Ridho, *Reproductive phenology of Bruguiera sexangula (Lour.) Poir. in Berbak and Sembilang National Park, South Sumatra*, **Berkala Penelitian Hayati Journal of Biological Researches**, **23**(2), 2018, pp. 62-69, https://doi.org/10.23869/43.

[14] N. Wu, F. Li, D.D. Rousseau, *Terrestrial mollusk records from Chinese loess sequences and changes in the East Asian monsoonal environment*, **Journal of Asian Earth Sciences**, **155**, 2018, pp. 35-48, https://doi.org/10.1016/j.jseaes.2017.11.003.

[15] J. Feng, Q. Huang, H. Chen, J. Guo, G. Lin, *Restoration of native mangrove wetlands can reverse diet shifts of benthic macrofauna caused by invasive cordgrass*, **Journal of Applied Ecology**, **55**(2), 2018, pp. 905-916, https://doi.org/10.1111/1365-2664.12987.

[16] Rozirwan, R.Y. Nugroho, M. Hendri, Fauziyah, W.A.E. Putri, A. Agussalim, *Phytochemical profile and toxicity of extracts from the leaf of Avicennia marina (Forssk.) Vierh. collected in mangrove areas affected by port activities*, **South African Journal of Botany**, **150**, 2022, pp. 903-919, https://doi.org/10.1016/j.sajb.2022.08.037.

[17] Rozirwan, Fauziyah, P.I. Wulandari, R.Y. Nugroho, F. Agutriani, A. Agussalim, F. Supriyadi, I. Iskandar, *Assessment distribution of the phytoplankton community structure at the fishing ground, Banyuasin estuary, Indonesia*, **Acta Ecologica Sinica**, **42(**6), 2022, pp. 670-678, https://doi.org/10.1016/j.chnaes.2022.02.006.

[18] M.R.M. Zaki, S.H.M. Zaid, A.H. Zainuddin, A.Z. Aris, *Microplastic pollution in tropical estuary gastropods: Abundance, distribution and potential sources of Klang River estuary, Malaysia*, **Marine Pollution Bulletin**, **162**, 2021, Article number 111866, https://doi.org/10.1016/j.marpolbul.2020.111866.

[19] E.M. Fonseca, J.R. Fernandes, L.S. Lima, et al., *Effects of dredged sediment dumping on trace metals concentrations and macro benthic assemblage at the continental shelf adjacent to a tropical urbanized estuary*, **Ocean & Coastal Management**, **196**, 2020, Article number 105299.

[20] J. Yan, Y. Xu, J. Sui, X. Li, H. Wang, B. Zhang, *Long-term variation of the macrobenthic community and its relationship with environmental factors in the Yangtze River estuary and its adjacent area*, **Marine Pollution Bulletin**, **123**(1-2), 2017, pp. 339-348, https://doi.org/10.1016/j.marpolbul.2017.09.023.

[21] S. Sarno, R.A. Suwignyo, Z. Dahlan, M. Munandar, M.R. Ridho, N. Aminasih, H. Harmida H, M.E. Armanto, E. Wildayana, *The phenology of Sonneratia alba J. Smith in Berbak and Sembilang National Park, South Sumatra, Indonesia*, **Biodiversitas Journal of Biological Diversity**, **18**(3), 2017, pp. 909-915, https://doi.org/10.13057/biodiv/d180307

[22] Rozirwan, I. Iskandar, M. Hendri, R. Apri, Supardi, N. Azhar, W. Mardiansyah, *Distribution of phytoplankton diversity and abundance in Maspari island waters, South Sumatera, Indonesia*, **Journal of Physics: Conference Series**, **1282**(1), 2019, Article number 012105, doi: 10.1088/1742-6596/1282/1/012105.

[23] Rozirwan, A.P. Saputri, R.Y. Nugroho, N.N. Khotimah, W.A.E. Putri, Fauziyah, A.I. Sunaryo, *An Assessment of Pb and Cu in Waters, Sediments, and Mud Crabs (Scylla serrata) from Mangrove Ecosystem Near Tanjung Api-Api Port Area, South Sumatra, Indonesia*, **Science and Technology Indonesia**, **8**(4), 2023, pp. 675-683, https://doi.org/10.26554/sti.2023.8.4.675-683.

[24] E.J. Weerman, P.M.J. Herman, J. Van de Koppel, *Macrobenthos abundance and distribution on a spatially patterned intertidal flat*, **Marine Ecology Progress Series**, **440**, 2011, pp. 95-103, https://doi.org/10.3354/meps09332.

[25] T. Hibberd, *Field identification guide to Heard Island and McDonald Islands benthic invertebrates*, **Deep-Sea Research Part II-Topical Studies in Oceanography**, **53**(8–10), 2009, pp. 985-1008.

[26] R.D. Purchon, **The biology of the Mollusca**, Elsevier, 2013.

[27] C.F. Sturm, T.A. Pearce, Á. Valdés, **The Mollusks: A Guide to Their Study, Collection,**

and Preservation, Universal-Publishers, 2006.

[28] J.M. Guerra-García, C. Navarro-Barranco, M. Ros, F. Sedano, R. Espinar, A. Fernández-Romero, G. Martínez-Laiz, J.A. Cuesta, I. Giráldez, E. Morales, M. Florido M., *Ecological quality assessement of marinas: An integrative approach combining biological and environmental data*, **Journal of Environmental Management**, **286**, 2021, Article number 112237, https://doi.org/10.1016/j.jenvman.2021.112237.

[29] W. Lv, W. Zhou, Y. Zhao, *Effect of freshwater inflow on self-restoration of macrobenthic diversity in seaward intertidal wetlands influenced by reclamation projects in the Yangtze estuary, China*, **Marine Pollution Bulletin**, **138**, 2019, pp. 177-186, https://doi.org/10.1016/j.marpolbul.2018.11.044.

[30] M. Pelletier, D. Cobb, K. Rocha, K.T. Ho, M.G. Cantwell, M. Perron, M.A. Charpentier, H.W. Buffum, S.S. Hale, R.M. Burgess, *Benthic macroinvertebrate community response to environmental changes over seven decades in an urbanized estuary in the northeastern United States*, **Marine Environmental Research**, **169**, 2021, Article number 105323, https://doi.org/10.1016/j.marenvres.2021.105323.

[31] A. Saputra, R.Y. Nugroho, R. Isnaini, Rozirwan, *A review: The potential of microalgae as a marine food alternative in Banyuasin Estuary, South Sumatra, Indonesia*, **Egyptian Journal of Aquatic Biology and Fisheries**, **59**, 2021, pp. 1053-1065.

[32] G. Bramwell, A.G. Schultz, C.D.H. Sherman, M. Giraudeau, F. Thomas, B. Ujvari, A.M. Dujon, *A review of the potential effects of climate change on disseminated neoplasia with an emphasis on efficient detection in marine bivalve populations*, **Science of the Total Environment**, **775**, 2021, Article number: 145134, https://doi.org/10.1016/j.scitotenv.2021.145134.

[33] R. Subramanian, J. Retnamma, A. Nagarathinam, J. Loganathan, P. Singaram, V. Chandrababu, *Seasonality of macrobenthic assemblages and the biotic environmental quality of the largest monsoonal estuary along the west coast of India*, **Environmental Science and Pollution Research**, **28**(28), 2021, pp. 37262-37278.

[34] S. Jamani, M. Gholizadeh, R. Patimar, A. Fathabadi, *Identification and Abundance of Macrobenthic in Estuary of the Gharehsou River*, **Journal of Fisheries**, **74**(1), 2021, pp. 31-43, DOI: 10.22059/JFISHERIES.2021.300109.1216.

[35] S.S. Zvonareva, Y.I. Kantor, T.T.H. Nguyen, T.A. Britayev, *Diversity and Long-Term Dynamics of the Macrobenthos in a Mangrove Plantation and Two Natural Associations of Khanh Hoa Province, Vietnam*, **Biology Bulletin**, **47**(9), 2020, pp. 1115-1125.

[36] A. Fitrah, *Diversity and abundance of polychaetes in the west coast waters of Batam Island, Kepulauan Riau Province-Indonesia*, **AACL Bioflux**, **13**(1), 2020, pp. 381-391.

[37] V.E. Susilo, M.I.P. Dewi, N. Mujiono, W. Subchan, J. Prihatin, *The diversity of Gastropoda in grati lake district pasuruan east java*, **Journal of Physics: Conference Series**, IOP Publishing (2021), Artilce number 12008, DOI:10.1088/1742-6596/1832/1/012008

[38] G. Kantharajan, P.K. Pandey, P. Krishnan, V.D. Samuel, V.S. Bharti, R. Purvaja, *Molluscan diversity in the mangrove ecosystem of Mumbai, west coast of India*, **Regional Studies in Marine Science**, **14**, 2017, pp. 102-111, https://doi.org/10.1016/j.rsma.2017.06.002.

[39] R. Abdollahi, S.E. Darzi, H. Rahimian, R. Naderloo, *Biodiversity of intertidal and shallow subtidal habitats in Abu Musa Island, Persian Gulf, Iran, with an updated species*

checklist, **Regional Studies in Marine Science**, **33**, 2020, Article number 100975, https://doi.org/10.1016/j.rsma.2019.100975

[40] R.M. Amorim, J. de F. Delgado, J.A.B. Neto, M.A. Crapez, C.S. Fernandez, O.A. e Negrello Filho, E.M. Fonseca, *The benthic macrofauna along the estuarine gradient of the Paranaguá estuary*, **Regional Studies in Marine Science**, **39**, 2020, Artilce number: 101459, https://doi.org/10.1016/j.rsma.2020.101459.

[41] Q. Guan, J. Liu, D.P. Batzer, X. Lu, H. Wu, *Snails (Mollusca: Gastropoda) as potential surrogates of overall aquatic invertebrate assemblage in wetlands of Northeastern China*, **Ecological Indicators**, **90**, 2018, pp. 193-200, https://doi.org/10.1016/j.ecolind.2018.01.069.

[42] M.B. Hossain, *Trophic functioning of macrobenthic fauna in a tropical acidified Bornean estuary (Southeast Asia)*, **International Journal of Sediment Research**, **34**(1), 2019, pp. 48-57, https://doi.org/10.1016/j.ijsrc.2018.08.002.

[43] P.R. Jayachandran, S.B. Nandan, M. Jima, P. Joseph, N.D. Xavier, O.K. Sreedevi, M.P. Prabhakaran, K.J. Joseph, *Macrobenthic functional feeding groups in a microtidal monsoonal estuary (Kodungallur–Azhikode estuary, India)*, **Regional Studies in Marine Science**, **25**, 2019, Article number 100444, https://doi.org/10.1016/j.rsma.2018.100444.

[44] T.J. Joshua, R. Toefy, C. Sparks, S.P. Kirkman, T. Samaai, *Macro-benthic invertebrate assemblages in the Betty's Bay marine protected area (Kogelberg region South Africa)*, **Regional Studies in Marine Science**, **22**, 2018, pp. 1–8, https://doi.org/10.1016/j.rsma.2018.04.001.

[45] J.M. Park, S.-H. Huh, *Epibenthic invertebrate fauna in the southern coast of the East Sea, Korea*, **Journal of Asia-Pacific Biodiversity**, **11**(2), 2018, pp. 217-222, https://doi.org/10.1016/j.japb.2018.03.006

[46] T.V. Rehitha, N. Ullas, G. Vineetha, P.Y. Benny, N. V Madhu, C. Revichandran, *Impact of maintenance dredging on macrobenthic community structure of a tropical estuary*, **Ocean & coastal management**, **144**, 2017, pp. 71-82, https://doi.org/10.1016/j.ocecoaman.2017.04.020.

[47] D.M. Suratissa, U. Rathnayake, *Effect of pollution on diversity of marine gastropods and its role in trophic structure at Nasese Shore, Suva, Fiji Islands*, **Journal of Asia-Pacific Biodiversity**, **10**(2), 2017, pp. 192-198, https://doi.org/10.1016/j.japb.2017.02.001.

[48] M. Youssef, H. Madkour, A. Mansour, W. Alharbi, A. El-Taher, *Invertebrate shells (mollusca, foraminifera) as pollution indicators, Red Sea Coast, Egypt*, **Journal of African Earth Sciences**, **133**, 2017, pp. 74-85, https://doi.org/10.1016/j.jafrearsci.2017.05.013.

[49] E.T. Opa, R.C. Kepel, R. Lasabuda, J.D. Kusen, C.P. Paruntu, R. Djamaluddin, F.B. Boneka, D.M. Mantiri, *Ecological suitability of mangrove tourism in Mantehage Island as the outermost small island in North Sulawesi, Indonesia*, **Aquaculture, Aquarium, Conservation & Legislation**, **14**(1), 2021, pp. 120-129.

[50] N.S. Saffian, C.T.C. Peng, N. Ilias, A.T.S. Hwai, *Overview and challenges of blood cockle culture in Malaysia*, **IOP Conference Series: Earth and Environmental Science, 414,** 2020, Article number 012020, doi:10.1088/1755-1315/414/1/012020.

[51] F.E. Wells, K. Sanpanich, S.K. Tan, T. Duangdee, *The Marine and Estuarine Molluscs of Thailand*, **Lee Kong Chian Natural History Museum,** National University of Singapore, Singapore, 195, 2021.

[52] A.A.T.N. Amarasinghe, T. Eswaramohan, R. Gnaneswaran, *Gastropods Diversity in Thondaimanaru Lagoon (Class: Gastropoda), Northern Province, Sri Lanka*, **Journal of Geoscience and Environment Protection**, **9**(3), 2021, pp. 21-30, DOI: 10.4236/gep.2021.93002.

[53] K. Rekha, S. Anbalagan, S. Dinakaran, *Distributional ecology of snails (Gastropoda: Mollusca) in seasonal ponds of Tamil Nadu, South India*, **Acta Ecologica Sinica**, **41**(5), 2021, pp. 410-415, https://doi.org/10.1016/j.chnaes.2020.10.004.

[54] Q. Li, G. Wang, H. Wang, S. Shrestha, B. Xue, W. Sun, J. Yu, *Macrozoobenthos variations in shallow connected lakes under the influence of intense hydrologic pulse changes*, **Journal of Hydrology**, **584**, 2020, Article number: 124755, https://doi.org/10.1016/j.jhydrol.2020.124755

[55] I.D. Marsden, N. Baharuddin, *Gastropod growth and survival as bioindicators of stress associated with high nutrients in the intertidal of a shallow temperate estuary*, **Estuarine, Coastal and Shelf Science**, **156**, 2015, pp. 175-185, https://doi.org/10.1016/j.ecss.2014.05.032.

[56] J. Noh, S.J. Yoon, H. Kim, C. Lee, B.O. Kwon, Y. Lee, S. Hong, J. Kim, J. Ryu, J.S. Khim, *Anthropogenic influences on benthic food web dynamics by interrupted freshwater discharge in a closed Geum River estuary, Korea*, **Environment International**, **131**, 2019, Article number: 104981, https://doi.org/10.1016/j.envint.2019.104981

[57] Y. Xingzhong, L. Jianjian, L. Hong, *Distribution pattern and variation in the functional groups of zoobenthos in the Changjiang Estuary*, **Acta Ecologica Sinica**, **22**(12), 2002, pp. 2054-2062.

[58] A. Reis, A.T. Alves, A. Dórea, T.M. Beneli, T.S. Santos Freitas, F. Barros, *Distribution and movement of the mangrove gastropod Littoraria angulifera*, **Estuarine, Coastal and Shelf Science**, **250**, 2021, Article number 107145, https://doi.org/10.1016/j.ecss.2020.107145

[59] I. Hossain, M.B. Hossain, *Community structure of macrobenthos in homestead ponds of Noakhali coast, Bangladesh*, **Acta Ecologica Sinica**, **41**(6), 2021, pp. 611-619, https://doi.org/10.1016/j.chnaes.2021.09.009.

[60] Y. Fitria, Rozirwan, M. Fitrani, R.Y. Nugroho, Fauziyah, W.A.E. Putri, *Gastropods as bioindicators of heavy metal pollution in the Banyuasin estuary shrimp pond area, South Sumatra, Indonesia*, **Acta Ecologica Sinica**, **43**(6), 2023, pp. 1129-1137, https://doi.org/10.1016/j.chnaes.2023.05.009

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