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Macrozoobenthos Diversity in Mangrove Forest Waters of Tanjung Rejo Village Percut Sei Tuan Sub-Distrct, North Sumatra

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Abstract

This study aims to identify the species composition, abundance, and diversity of macrozoobenthos in the Waters of Mangrove Forest Dusun XIV Tanjung Rejo Village, Percut Sei Tuan Subdistrict, North Sumtra. Field survey methods and purposive sampling techniques were carried out by taking macrozoobenthos samples using standardized quadrats along randomly placed stations in the mangrove forest. The data obtained were then analyzed using the Shannon-Wiener diversity index, Simpson's dominance index. The results of research on the diversity of macrozoobenthos species obtained 17 species with 3 phyla, 3 classes, 8 orders, 16 families, and 16 genus. Measurement of physical and chemical factors of water obtained an average temperature of 28-31°C; average pH 7.2-7.6; average salinity 22-28°C; and the substrate is mud and silty sand. The type of macrozoobenthos that dominates in the area is Gastropoda. Macrozoobenthos diversity index value (H') 2.3905 at station I, 2.2567 at station II, and 2.1379 at station III, categorized as moderate. Based on these results, the Mangrove Forest Waters Area Dusun XIV Tanjung Rejo Village, Percut Sei Tuan Subdistrict is still within the threshold of good quality standards for the life of macrozoobenthos biota, which means that the environmental conditions are still not too polluted. This study makes an important contribution to the understanding of mangrove forest ecology and the importance of conservation and management of mangrove ecosystems as an integral part of the ecosystem.

Keywords: *Diversity, Macrozoobenthos, Mangrove Forest*

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INTRODUCTION

Mangrove ecosystem is an ecosystem consisting of organisms (plants and animals) that interact with environmental factors and with each other in a mangrove habitat (Cahyaningsih *et al.*, 2022). Mangrove ecosystems have ecological functions, including as a habitat for various types of biota, spawning grounds for aquatic biota, shoreline protection, as well as a place to feed and enlarge aquatic biota. In addition, mangroves also function as biofilters that capture pollutants that can pollute the environment (Fithor *et al.*, 2019).

Macrozoobenthos are organisms that live in bottom sediments or organisms that live on the bottom of the water (Fauzan *et al.*, 2023). Macrozoobenthos have a relatively fixed living habitat, have a large size so that they are easy to identify, have limited movement, and live in and on the bottom of the water. These properties make macrozoobenthos well used as a biological indicator in a body of water (Kadim *et al.*, 2022). Macrozoobenthos are organisms that live on the bottom of the water, and are part of the food chain whose existence depends on the population of lower-level organisms. Macrozoobenthos are also utilized as aquatic bioindicators, because they are very sensitive to changes in the aquatic environment they inhabit. The presence of macrozoobenthos can be seen from the substrate of the bottom of the water that greatly determines the development of these organisms (Alif et al., 2021; Sari et al., 2021)

Macrozoobenthos are recognized for their sensitivity to alterations in water conditions, and macroinvertebrates are commonly utilized as key biological indicators in monitoring endeavors. Present in various aquatic habitats, macroinvertebrates exhibit lower mobility compared to many other aquatic organisms, making them easily collectible, with most having extended developmental periods within aquatic environments. Consequently, macroinvertebrate species should reflect adverse occurrences within the aquatic milieu at any stage of their lifecycle (Kadim et al., 2022). Macrozoobenthos, comprising organisms that crawl, adhere, burrow, or embed themselves in bottom waters or surfaces, predominantly inhabit mangrove areas, favoring hard to muddy substrates. While pivotal in preserving aquatic ecosystem equilibrium, macrozoobenthos are highly responsive to shifts in water quality. Their presence in water bodies is greatly influenced by diverse environmental factors, encompassing both biotic and abiotic elements. Biotic factors include producers like mangrove plants, serving as food sources for macrozoobenthos, while abiotic factors encompass aquatic chemical and physical parameters such as temperature, salinity, dissolved oxygen, pH, and bottom water substrate (Wardiatno et al., 2015).

The waters of the mangrove forest of Tanjung Rejo Village, Percut Sei Tuan District, North Sumatra Province is one of the habitats of macrozoobenthos. The problem at this location is that there is no data on the abundance and diversity of macrozoobenthos, even though the waters in this area are very important as one of the habitats of macrozoobenthos. Ecosystem changes such as conversion of forest land into agricultural land, settlements, ponds, oil palm plantations, and tourist visitor activities will affect the environmental conditions of the river ecosystem. The environmental conditions of these mangrove waters determine the abundance and diversity of macrozoobenthos that live in them. Therefore, an in-depth understanding of the ecological conditions of mangrove waters and their macrozoobenthos populations is crucial for sustainable management and maintenance of biodiversity in the region (Cahyaningsih et al., 2022; Onyena & Sam, 2020).

Research on macrozoobenthos diversity in mangrove forest waters of Tanjung Rejo Village, Percut Sei Tuan District, North Sumatra has an important urgency and significant implications. Mangrove forests are very important ecosystems, not only as a place to live for various types of macrozoobenthos, but also as a support for the sustainability of the marine ecosystem as a whole. With increasing anthropogenic pressures on mangrove ecosystems, a better understanding of macrozoobenthos diversity and its role in maintaining ecosystem balance is crucial. This study can provide in-depth insights into the ecological condition of mangroves and aid in the development of effective conservation strategies. In addition, a better understanding of macrozoobenthos can also provide practical benefits in water quality monitoring and aquatic resource management. Therefore, this study has important implications for the protection and management of mangrove ecosystems as well as the overall sustainability of aquatic ecosystems in the region.

Figure 1. Map of location in Mangrove Forest Water Area, Tanjung Rejo Village, Percut Sei Tuan District, North Sumatra Province

METHOD

This research was conducted in the Mangrove Forest Waters Area of Tanjung Rejo Village, Percut Sei Tuan District, North Sumatra Province and identified the Macrozoobenthos that had been found in the Biology Laboratory of the Faculty of Teacher Training and Education, Islamic University of North Sumatra and was carried out from April to July 2023. This research design has 3 observation stations, each station made 3 plots measuring 2 x 2 m² with a distance of 10 m between quadrats. Sampling using purposive sampling technique which aims to determine the diversity of Macrozoobenthos species captured at 3 observation stations, namely Station I located in natural mangrove forest area, Station II located in mangrove forest area near ponds and Station III located in tourist mangrove forest area.

Procedure

Research tools and materials used in this study are GPS, roller meter, raffia rope, pH meter, digital thermometer, salinometer, bucket, filter, jar, label paper, camera, aquadest, Macrozoobenthos and Mangrove, 70% alcohol. Sampling data including Ecological conditions of Mangrove Forest waters and Macrozoobenthos sample data were collected in the Mangrove Forest Waters area at noon at 11.00 AM-5.00 PM when the sea water experienced tides sampling was carried out at each observation station which amounted to 3 observation stations. Where before the Macrozoobenthos data collection first determine the coordinate points at each station using a GPS device. After that, Macrozoobenthos data collection was carried out on each quadrat that has been determined at each observation. For macrozoobenthos data collection at each station macrozoobenthos sampling is done by exploration, macrozoobenthos samples are taken directly from 3 observation stations. The search for epifaunal macrozoobenthos can be done directly on the surface of the substrate, roots and stems of mangroves, while infaunal macrozoobenthos is done by dredging the substrate and then filtering the substrate using a sieve with a 1 mm mesh to separate from the macrozoobenthos. Furthermore, observations were made on the physical conditions of the macrozoobenthos abiotic environment such as temperature, pH, and salinity and substrate type.

Data analysis

Abundance (K) and Relative Abundance (KR)

a. Macrozoobenthos individual abundance is defined as the number of individuals of each species at each station in cubic units by Odum (1993), with the following

$$K = \frac{\text{Number of Individuals}}{\text{Wide } (M^2)}$$

b. Relative abundance is the result of the abundance of macrozoobenthos individuals of all species at each station by Odum (1993), with the following

$$\text{KR} = \frac{ni}{N} \times 100\%$$

Description

KR	=	Relative Abundance
Ni	=	Number of individuals of the i-th species
N	=	Total number of individuals

Diversity Index (H), Uniformity Index (E) and Dominance Index (D)

a. The diversity index (H') describes the state of the population of organisms mathematically. Macrozoobenthos species diversity can be calculated using the diversity index according to *Shannon Index of General Diversity* by Magurran (1955)

$$H = \sum_{I=1}^{S} Pi\, ln\, pi$$

Description

Pi	=	ni/N
H'	=	Diversity index
n	=	Number of individuals of a species
N	=	Number of individuals of all species
S	=	Number of species
ln	=	Natural logarithm

b. The uniformity index (E) shows the distribution pattern of macrozoobenthos or other biota, while the formula for calculating the Uniformity Index (E) uses by Odum (1993) formula:

$$E = \frac{H'}{Ln\, S}$$

Description

E	=	Uniformity Index
H'	=	Diversity Index
S	=	Total number of species
Ln	=	Natural logarithm

c. The dominance index is used to obtain information about the dominant family in a community. The Dominance Index is calculated using *Simpson's Index of Dominance* by Odum (1993),

$$C = \sum (pi)^2$$

Description:

C	=	Dominance Index
(pi)	=	Proportion of the number of individuals of species i to the total number of individuals

RESULTS AND DISCUSSION

Measurement of Abiotic Factor Parameters in Mangrove Forest Area Dusun XIV Tanjung Rejo Village

The results of measuring the environmental conditions of abiotic factors in the Waters of Mangrove Forest Hamlet XIV Tanjung Rejo Village, Percut Sei Tuan Subdistrict obtained at each observation station can be seen in Table 1.

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Tabel 1. Measurement Data of Abiotic Factors at the Research Site

Station Location	Abiotic Factors			
	Temperature (˚C)	**pH**	**Salinity**	**Substrate Type**
Station I	31	7,2	33	Mud
Station II	32	7,6	22	Mud
Station III	28	7,3	26	Silty sand

Identification Data of Macrozoobenthos Species

Macrozoobenthos found in the waters of Mangrove Forest Dusun XIV Tanjung Rejo Village Percut Sei Tuan Subdistrict consists of 3 classes namely Gastropoda, Malacostraca, and Clitellata. Macrozoobenthos identification can be seen in Table 2.

Table 2. Identification of Macrozoobenthos Species in the Waters of Mangrove Forest Dusun XIV Tanjung Rejo Village, Percut Sei Tuan Subdistrict

No.	Classes	Family	Species	Station			Total
				I	II	III	
1.	Gastropoda	Potamididae	*Pirenella cingulata*	21	14	21	56
2.	Gastropoda	Elobidae	*Ellobium aurisjudae*	27	12	0	39
3.	Gastropoda	Elobidae	*Ellobium aurismidae*	26	11	0	37
4.	Gastropoda	Nassariidae	*Nassarius stolatus*	18	0	15	33
5.	Gastropoda	Naticidae	*Paratectonatica tigrina*	12	12	14	38
6.	Gastropoda	Ocypopidae	*Cerithidea quoyii*	35	18	9	62
7.	Gastropoda	Potamididae	*Teloscopium telescopium*	44	23	13	80
8.	Gastropoda	Throchidae	*Architectonica perspectiva*	0	0	12	12
9.	Gastropoda	Muricidae	*Murex trapa*	0	0	5	5
10.	Gastropoda	Ampullariidae	*Pomacea canaliculata*	3	9	0	12
11.	Malacostraca	Paguroidae	*Dardanus calidus*	0	0	5	5
12.	Malacostraca	Sesarmidae	*Episesarma* sp	25	17	1	42
13.	Malacostraca	Palaemonidae	*Palaemonetes*	0	0	8	8
14.	Malacostraca	Ocypodidae	*Uca annulipes*	37	4	0	41
15.	Malacostraca	Portunidae	*Scylla serrata*	19	15	0	34
16.	Malacostraca	Macrophtalmidae	*Macrophthalmus*	3	1	0	4
17.	Clitellata	Hirudinidae	*Hirudo medicinalis*	0	12	0	12
			Total				**520**

Based on Table 2. above, the Gastropoda Class can be known to consist of 10 species, Melacostraca consists of 6 species and Clitellata consists of 1 species. The number of Macrozoobenthos found during the study at station I was 269 individuals, station II was 148 and station III was 103 individuals.

Abundance (K) and Relative Abundance (KR) of Macrozoobenthos at Each Research Station.

Based on the number of Macrozoobenthos found at each observation station, the population abundance value is obtained as in Table 3.

Table 3. Macrozoobenthos Abundance

No.	Species	Total	Abundance		
			Station I	**Station II**	**Station III**
1.	*Pirenella cingulata*	56	5.25	3.5	5.25
2.	*Ellobium aurisjudae*	39	6.75	3	0
3.	*Ellobium aurismidae*	37	6.5	2.75	0
4.	*Nassarius stolatus*	33	4.5	0	3.75
5.	*Paratectonatica tigrina*	38	3	3	3.5
6.	*Cerithidea quoyii*	62	8.75	4.5	2.25
7.	*Teloscopium telescopium*	80	11	5.75	3.25
8.	*Architectonica perspectiva*	12	0	0	3
9.	*Murex trapa*	5	0	0	1.25
10.	*Pomacea canaliculata*	12	0.75	2.25	0
11.	*Dardanus calidus*	5	0	0	1.25
12.	*Episesarma* sp	42	6	4.25	0.25
13.	*Palaemonetes*	8	0	0	2
14.	*Uca annulipes*	41	9.25	1	0
15.	*Scylla serrata*	34	4.75	3.75	0
16.	*Macrophthalmus*	4	0.75	0.25	0
17.	*Hirudo medicinalis*	12	3	0	0
	Total	520	60.75	33	25.75

In Table 3. it can be seen that the abundance value (K) of the population at station I is 60.75 ind/m2, at station II is 33 ind/m2 and at station III is 25.75 ind/m2. The value shows that station I has the highest population abundance value and station III has the lowest abundance value. Based on Table 4. it can be seen that the highest Relative Abundance (KR) value is found at station III with a value of 20.38%, namely the *Pirenella cingulata* species and the lowest at station I with a value of 0.73%, namely the Macrophthalmus species.

Diversity Index (H'), Uniformity (E) and Dominance (C) at Each Research Station

From the results of the data analysis that has been carried out, the Diversity Index (H') value ranges from 2.1379-2.3905 ind/m2 which is included in the medium category, the Diversity Index (E) value ranges from 0.9285-0.9411 ind/m2 which is included in the high category or close to 1 and the Dominance Index (C) value which ranges from 0.1006-0.1292 ind/m2 which includes the category that no one dominates.

Table 4. Relative Abundance of Macrozoobenthos

No.	Species	Total	Relative Abundance (%)		
			Station I	Station II	Station III
1.	*Pirenella cingulata*	56	7.47	10.29	20.38
2.	*Ellobium aurisjudae*	39	9.60	8.82	0
3.	*Ellobium aurismidae*	37	9.25	8.08	0
4.	*Nassarius stolatus*	33	6.40	0	14.56
5.	*Paratectonatica tigrina*	38	4.27	8.82	13.59
6.	*Cerithidea quoyii*	62	12.45	13.23	8.73
7.	*Teloscopium telescopium*	80	15.65	16.91	12.62
8.	*Architectonica perspectiva*	12	0	0	11.65
9.	*Murex trapa*	5	0	0	4.85
10.	*Pomacea canaliculata*	12	1.06	6.61	0
11.	*Dardanus calidus*	5	0	0	4.85
12.	*Episesarma* sp	42	8.54	12.5	0.97
13.	*Palaemonetes*	8	0	0	7.76
14.	*Uca annulipes*	41	13.16	2.94	0
15.	*Scylla serrata*	34	6.76	11.02	0
16.	*Macrophthalmus*	4	1.06	0.73	0
17.	*Hirudo medicinalis*	12	4.27	0	0
	Total	520	100	100	100

The results of observations of the physical characteristics of the Macrozoobenthos environment, namely the results of temperature observations made at the three stations during the study ranged from 28-32˚C. This value is the temperature value that can still be tolerated by Macrozoobenthos in accordance with the quality standards issued by KepMen LH No. 51 of 2004, the temperature quality standard for marine biota is 28-32˚C. The highest temperature is at station II of 32˚C where many species from the gastropod class are found, namely Telescopium telescopium and the lowest at station III of 28˚C where many species from the gastropod class are found, namely *Prinella cingulata*. This is in accordance with the statement Mawardi *et al*., (2023) revealed that gastropods have different adaptive abilities. Varying environmental factors cause differences in the way of life and distribution of gastropod animals. The difference in temperature that occurs in the waters during the study is due to the influence of weather, solar intensity, and rainfall. According to Sujarta *et al*., (2022) revealed that temperature is one of the physical parameters that has an important factor in the metabolism of aquatic organisms. The temperature of a body of water is strongly influenced by weather, cloud cover, solar intensity, wind speed and rainfall. pH shows the degree of acidity or basicity of a body of water. pH is often also used as a guide to state the good and bad state of water as a living environment, although the good and bad of water depends also on various other factors. The results of pH measurements at the three stations during the study ranged from 7.2 to 7.6. The pH value at the three stations is the ideal value for the life of Macrozoobenthos. The highest pH is at station I which is 7.6 found many species of gastropod class, *Telescopium telescopium*. This is in accordance with the statement of Pellegrin *et al*., (2020)

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revealed that the ideal pH value for the life of aquatic organisms generally exists between 7 to 8.5.

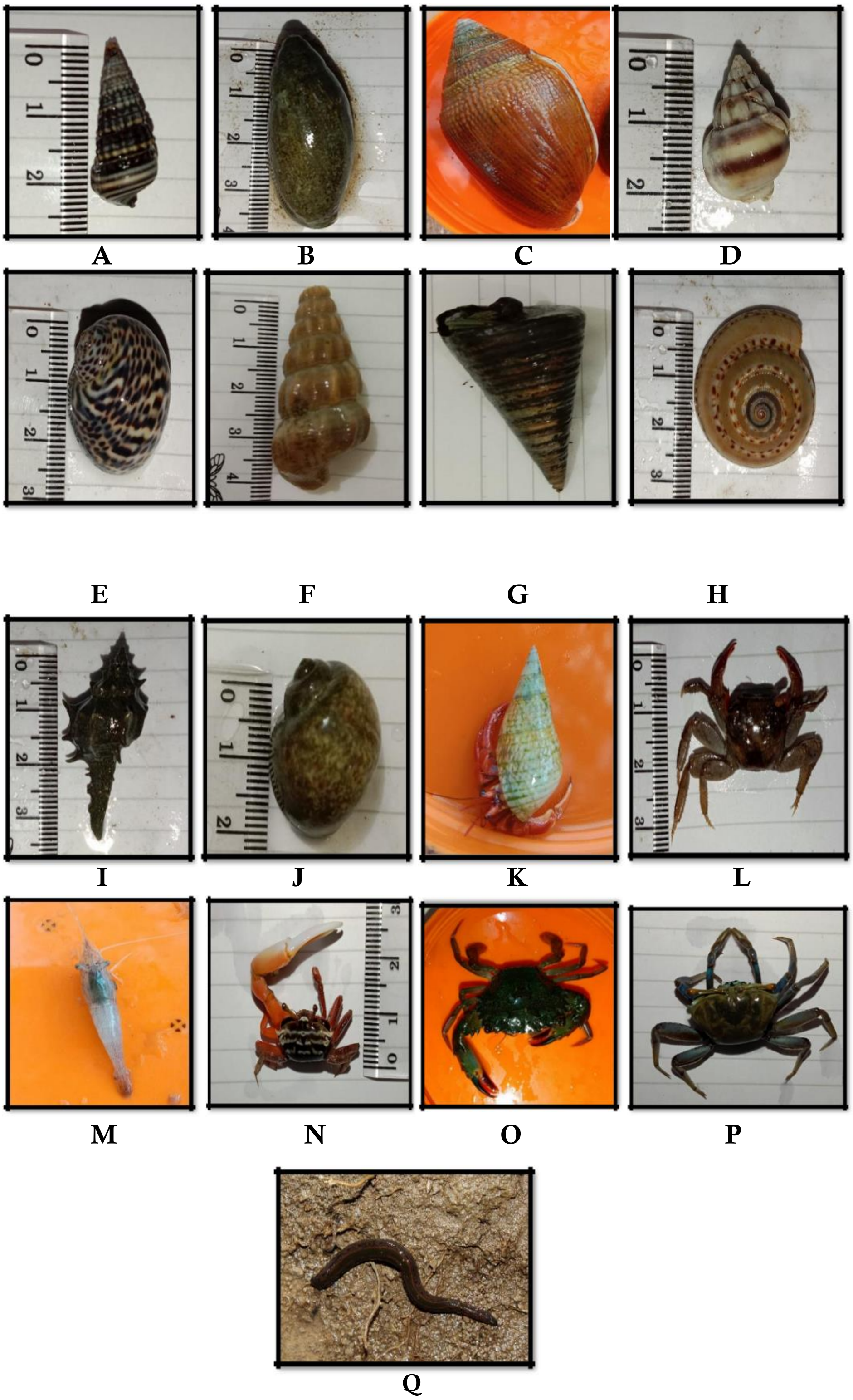

Figure 2. Macrozoobenthos Species in the Waters of Mangrove Forest Dusun XIV Tanjung Rejo Village, Percut Sei Tuan Subdistrict

The measurement results of salinity values at station I is worth 33‰, station II is worth 22‰, and station III is worth 26‰. The value of salinity obtained from observations at all stations is the value of salinity that can be tolerated by macrozoobenthos. This is in accordance with the statement Kadim et al., (2022) revealed that the range of salinity is considered feasible for the life of macrozoobenthos ranging from 15-45‰, because in low and high salinity waters can be found macrozoobenthos such as snails, worms (Annelida) and shellfish. The highest salinity value at Station I with a value of 33 ‰ found many species of gastripod class, namely *Telescopium telescopium,* while the lowest salinity value is at station II with a value of 22 ‰ found many species Telescopium teloscopium. According Golovatyuk et al., (2023) said that, the value of freshwater salinity is usually less than 0.50 ‰, brackish waters between 0.50-30 ‰ and sea waters 30-40 ‰. So the waters of Mangrove Forest Dusun XIV Tanjung Rejo Village, Percut Sei Tuan Subdistrict are still classified as brackish. The factor can be from the high rainfall in certain seasons that bring fresh water to sea waters through the river, and the input of fresh water coming from the aquaculture wastewater drain. Substrate observations at stations I and II are mud at station III is muddy sand so from these results it can be seen that many macrozoobenthos animals are found on mud substrates. Mud substrate can affect the presence of macrozoobenthos animals found. According to Susetya et al., (2018) states that the substrate consists of several fractions of substrate types, namely: sand, mud, muddy sand and clay, some macrozoobenthos live in waters with rocky bottom substrates or hard soil. On these substrates, macrozoobenthos organisms cling and crawl. Macrozoobenthos that live in waters with mud and sand subtrates have a type of life by immersing themselves.

The results of research that has been conducted in the waters of Mangrove Forest Dusun XIV Tanjung Rejo Village, Percut Sei Tuan Subdistrict found Macrozoobenthos consisting of 3 classes namely Gastropoda, Malacostraca, and Clitellata. The gastropod class consists of 10 species, Malacostraca consists of 6 species, and Clitellata consists of 1 species (Table 3). Species that are commonly found in the research location are from the Gastropoda class. This is because Gastropoda has a high level of tolerance to environmental changes, as well as high adaptability and a wide range of distribution. This exposure is in line with the results of research Imamsyah et al., (2020) which states that the ability of gastropods to maintain their lives in an environment because the environmental conditions are favorable such as the type of substrate and relatively high organic matter and good adaptation in various places.

Macrozoobenthos which are generally found in mangrove waters consist of Gastropoda, Bivalvia, Polychaeta and Crustacea classes. This is in accordance with the results of research Rimadiyani et al., (2019) which states that the macrozoobenthos community consists of four groups, namely Mollusca, Polychaeta, Crustacea, and Echinodermata. However, at the research location no Bivalve and Echinodermata classes were found due to environmental factors and the habitat where the bivalves and Echinodermata were found. this is in accordance with Schulenburg & Félix (2017) which states that several factors that limit the distribution and density of species of a biota in nature can be categorized into two spatial distributions and habitat preferences of these biota can be classified into two factors, namely natural factors in the form of genetic traits and behavior or the tendency of a biota to choose a preferred habitat type and external factors, namely everything related to the interaction of biota with their environment.

The number of macrozoobenthos found at each station is 281 individuals at station I, 136 individuals at station II and 103 individuals at station III. From this value it can be seen that station I has the highest number of individuals and station III has the least number of individuals. This is because at station III is a mangrove forest that is made into a tourist spot located close to the beach, due to community activities in the location produces plastic waste that results in the degradation of mangrove ecosystems resulting in a decrease in the function of mangrove forests as a habitat for macrozoobenthos biota. While at station I is a mangrove forest area that is still natural and almost no activity around it. This is in accordance with the statement of Rahman et al., (2023) revealed that macrozoobenthos inhabiting a water area is a determining indicator of water quality and the environment, this is because macrozobentoos life is very sensitive to the damage that occurs around it.

The highest macrozoobenthos abundance value is at station I which is a total of 60.75 ind/m2 and the lowest at station III with a value of 25.75 ind/m2 . High abundance of Macrozoobenthos at station I is supported by the condition of mangrove forests that are still natural and less to experience pollution due to its distance from residential areas and ecotourism. Whereas station III is a mangrove area that is used as a tourist attraction close to the beach. because of community activities in this area causes pollution of plastic waste in the area so that this is what triggers the low abundance of Macrozoobenthos at this station. This is in accordance with Kadim et al., (2022) which reveals that as organisms that live in waters, macrozoobenthos animals are very sensitive to changes in the quality of the water where they live so that it will affect their composition and abundance. This depends on their tolerance to environmental changes, so these organisms are often used as indicators of pollution levels. The highest relative abundance of macrozoobenthos is found at station III with a value of 20.3883%, namely the species *Pirenella cingulata*. The high relative abundance is due to the lack of competitors or natural predators present. The lowest relative abundance of macrozoobenthos is the macrophthalmus species found at station II with a value of 0.0073%. This is thought to be due to the habitat of macrophthalmus which is not in accordance with its natural habitat on muddy sand substrate. Macrophthalmus found in this study were obtained from mangrove forests close to ponds that have muddy substrates.

Diversity Index (*Shanon-Wiener*) Macrozoobenthos during the research conducted in the Waters of Mangrove Forest Dusun XIV Tanjung Rejo Village, Percut Sei Tuan Subdistrict obtained results ranging from 2.1379- 2.3905 ind/m2 included in the category of Diversity Index (H') medium. The Diversity Index at station I which is a natural forest area is 2.3905 ind/m2 so that it can be categorized as moderate, while at station II which is a forest area close to the pond is 2.2567 ind/m2 with a moderate category and station III which is in the ecotourism area is 2.1379 ind/m2 with a moderate category. The moderate level of diversity indicates that the distribution of individuals of each type is uneven, this is due to the smaller number of species and there are several individuals who are more numerous, resulting in ecosystem instability but still tolerable. from this value illustrates that the condition and ecological state of the mangrove forest is quite stable and quite balanced.

The Uniformity Index (E) shows the individual composition of each species contained in a community is in balance. The value of the uniformity index (E) obtained from the three research stations ranged from 0.9285-0.9411. The highest uniformity index at station I is 0.9411 from the value obtained uniformity at each station is categorized as high which means the number of species of each species obtained no one dominates, all species spread evenly. The results of data analysis for the Dominance Index Value (C) at each station are 0.1006 ind/m2 at station I, 0.1119 ind/m2 at station II and 0.1292 ind/m2 station III. None of the three stations has a C value close to 1, so it can be categorized as low, which means that each station has no dominating species, the types of species at each station are uniform and evenly distributed. low dominance index means that the aquatic environment is stable because there is no dominant species.

CONCLUSION

Mangrove forest water areas offer a rich habitat for macrozoobenthos life. Research on macrozoobenthos diversity reveals a fascinating picture of these ecosystems. There, diverse species of macrozoobenthos live, showing remarkable adaptation to the unique environment. The aquatic environment, influenced by factors such as salinity, temperature, and nutrients, plays an important role in determining the distribution patterns and diversity of macrozoobenthos. Furthermore, the ecological role of macrozoobenthos in mangrove ecosystems is significant, from their role in nutrient cycling to influencing food chains and habitat structure. This diversity also reflects the overall health and stability of the ecosystem. A deeper understanding of this macrozoobenthos diversity can be the basis for mangrove forest management and conservation. Protecting the habitats and species within them is key to maintaining the sustainability of these ecosystems, as well as to understanding their linkages with other ecosystems, such as coastal and open ocean ecosystems. Thus, ongoing research and conservation efforts are essential to protect and understand macrozoobenthos diversity in mangrove forest waters.

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