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Vertical distribution macrozoobenthos on mangrove ecosystem in coastal Ternate City

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ABSTRACT

Macrozoobenthos are benthic animals commonly found in substrate-based ecosystems, such as mangrove forests. Their presence in mangrove ecosystems significantly influences the decomposition activities within the substrate or sediment layers. The aim of this study was to identify species composition, species density, community structure of macrozoobenthos, and their vertical distribution within sediments on mangrove ecosystem in Ternate City. The study was conducted from August to September 2021 using the line transect method, with macrozoobenthos samples collected through iron pipe corers. Data analysis included species density, species diversity, dominance index, evenness index, niche width, microhabitat niche overlap, and the relationship between macrozoobenthos density and depth. The results showed that the macrozoobenthos species composition consisted of two species (Uca spp. and Nereis spp.), with a total of 25 individuals. Species diversity within mangrove ecosystem was found to be low, with one dominant species and a relatively even distribution. The species with the broadest habitat niche was the worm (*Nereis* spp.), while significant microhabitat niche overlap occurred between the worm (*Nereis* spp.) and the crab (*Uca* spp.). Simple linear regression analysis indicated that substrate depth did not correlate with macrozoobenthos species density.

Introduction

Macrozoobenthos is a diverse group of seabed-dwelling organisms with various types of substrates and sediment compositions in tidal environments (Krisnafi *et al*., 2021; Xie *et al*., 2003; Zhang *et al*., 2016). Macrozoobenthos play an important role in aquatic ecosystems as key organisms in food webs and as agents for decomposing organic matter. The species and trophic structure of macrozoobenthic communities are strongly influenced by various environmental factors, including sediment conditions, the presence of aquatic vegetation, and dissolved oxygen levels in the bottom layers of waters (Zenteno-Palma *et al*., 2018; Nkwoji *et al*., 2019; Semenchenko *et al*., 2020). Macrozoobenthos can inhabit and be found across various substrate types, sediments, and specific sedimentation forms, particularly on sediment bars in intertidal areas. These areas are predominantly composed of bioclastic substrates, consisting of coral fragments or crushed shell-bearing marine organisms, alongside communities of coral, algae, and other species coexisting with corals. This tendency likely affects the species diversity and distribution of macrozoobenthos (Muhaimin, 2013).

Previous research by Putra (2019) on the species diversity and distribution of macrozoobenthos in mangrove forests identified species such as *Littorina obtusata*, *Monodonta neritoides*, *Nassarius reeveanus*, *Polinices cumingianus*, *Telescopium telescopium*, and *Uca* spp. with a moderate level of species diversity. This diversity level is influenced by the organic content of the substrate, which in turn affects the availability of food resources. According to, (Lee, 2007; Krisnafi *et al*., 2021), this level of diversity is influenced by the organic substrate content which in turn influences the availability of food sources for these organisms.

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The mangrove ecosystem in Mangga Dua, Ternate City, is a biologically rich aquatic environment that supports various resources, including invertebrates like macrozoobenthos. However, the biological system of the mangrove ecosystem in Mangga Dua is currently threatened by environmental degradation due to local community practices, such as improper waste disposal and residential development. These activities damage existing mangrove species and the living organisms within them, including macrozoobenthos. Furthermore, there is a lack of data or literature on the species diversity, community structure, and vertical distribution of macrozoobenthos in this ecosystem. Therefore, this study aims to examine the species composition, density, community structure, and distribution patterns of macrozoobenthos on mangrove ecosystem in Ternate City.

Materials and methods

Location and time of research

The sample collection was conducted in the mangrove ecosystem of Mangga Dua, Ternate City, North Maluku Province, in posistion is N 0°46'25.66" and E 127°22'46.41". The research took place from August to September 2021. The sampling location is shown in Figure 1.

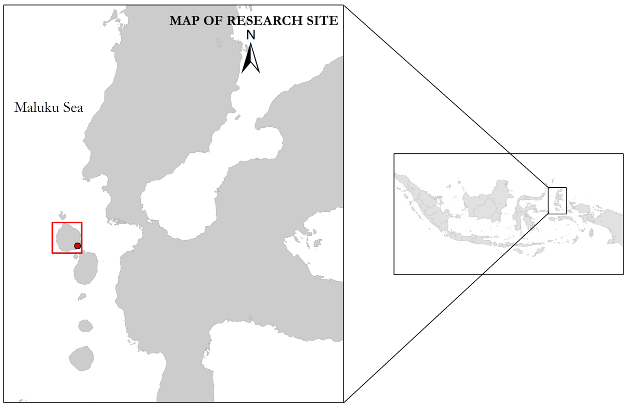

Figure 1. Maps showing the location (red square) of Ternate Including the research site (Mangga Dua).

The sampling procedure used the Line Transect method, which was divided into three transects: left, middle, and right sections of the mangrove forest ecosystem. A measuring tape was initially stretched from land toward the sea along the predetermined transects, with each transect extending 50 meters. The next step involved inserting an iron pipe (PVC) into the substrate to collect sediment and macrozoobenthos samples.

In each transect, macrozoobenthos samples were collected by inserting the iron pipe 30-40 cm deep into the substrate at ten different points. The collected organisms were then counted, placed in plastic bags, preserved with alcohol, and later identified in the Bioecology Laboratory of the Aquatic Resource Management Study Program, Faculty of Fisheries and Marine Sciences. Macrozoobenthos samples were identified using Benjamin Dharma's identification book "Recent & Fossil Indonesian Shells" (2005) and Conchology, Inc. (http://www.conchology.be). Figure 2 provides an example of the iron pipe insertion method.

Data analysis

Species Density (D)

To calculate the species density of macrozoobenthos, the formula proposed by (Krebs 1978, in Munairi *et al.,* 2012) is used:

$$\boldsymbol{D = \frac{X}{A}}$$

Information :
D = Species density (ind/cm³)
X = Number of individuals per species (ind)
A = Measured area (cm³)

Species Diversity (H')

To determine the level of species diversity of macrozoobenthos, the calculation uses (Shannon and Wiener index 1949 ; Odum, 1993):

$$H' = -\Sigma\left(\frac{ni}{N}\right) Ln\left(\frac{ni}{N}\right)$$

Information :
H' = Species diversity index
S = Number of species
Ni = Number of individuals of species (i)
N = Total number of individuals of all species
Criteria based on Krebs (1978)
$H' < 1$ = Low species diversity
$1 \leq H' \leq 3$ = Moderate species diversity
$H' > 3$ = High species diversity

Species Dominance Index (C)

To determine the dominance of a particular species in macrozoobenthos, the Simpson Dominance Index (Odum 1993, in Abubakar *et al.,* 2018) is used, as follows:

$$\boldsymbol{C = \sum\left(\frac{ni}{N}\right)^2}$$

Information :
C = Species dominance index
Ni = Number of individuals of each species
N = Total number of individuals of all species
Criteria based on Odum (1993):
0 < C < 0.05 = No dominant species
0.5 < C < 1 = A dominant species is present

Species evenness index (E)

The evenness of macrozoobenthos species is calculated using the Evenness Index (E). To determine the evenness of a particular species in macrozoobenthos, the species evenness index proposed by Krebs (1978) :

$$E = \frac{H'}{H'max}$$

Information :
E = Species evenness index
H' = Shannon-Wiener species diversity index
H'max = Ln S
S = Number of Species

Niche Width

To calculate the niche width of macrozoobenthos, Levins' (1968) equation (Krebs 1978 *in* Abubakar *et al.,* 2018) is used, as follows:

$$B = \frac{1}{\sum_{i=1}^{S} \mathrm{h\ pj^2 S}}$$

Information:
B = Niche width
Pj = Proportion of an organism in the microhabitat type (i)
S = Total number of microhabitat types

Microhabitat niche overlap

To calculate the microhabitat niche overlap of macrozoobenthos, Horn's (1966) equation (Krebs 1978) is used, as follows:

$$a_{ij} = \sum^{n} P_{ih} P_{ij} \text{ (B)}$$

Information:
aij = Niche overlap/overlap of microhabitat niches between species (i) and species (j)
$P_{ih}P_{ij}$ = Proportion of each species in the (h) -th microhabitat type
B = Niche width

The relationship between depth and the number of macrozoobenthos individuals

The relationship between the species composition of macrozoobenthos and substrate depth is determined using simple linear regression (Galton 1886 *in* Apmayasari *et al.,* 2015), using the following formula:

Y = a + bX

Information :
Y = Species density of macrozoobenthos
X = Depth (in cm, with values 10, 20, 30, and 40)
a = Constanta
b = Coefisien regression

Result

Environmental parameter

The results of environmental parameter measurements for the mangrove forest ecosystem in Mangga Dua Village are presented in Table 1.

Table 1. Environmental Parameter Measurements

No.	Time	Environmental Parameter			
		Temperature (°C)	DO (mg/L)	Salinity (‰)	Soil pH
1	09.00	28	4.2	31	6.7
2	13.00	31	4.3	29	6.5
3	16.00	29	4.5	28	6.6
Range		28-31	4.2-4.5	28-31	6.5-6.7

The temperature measurements in this study ranged from 28°C in the morning, 31°C in the afternoon, to 29°C in the evening. The temperature differences are influenced by the intensity of sunlight during field observations, with the highest sunlight intensity occurring during the afternoon. The dissolved oxygen (DO) measurements ranged from 4.2 to 4.5 mg/L. In the morning, the recorded DO value was 4.2 mg/L, while in the afternoon, it increased to 4.3 mg/L, and in the evening, it further increased to 4.5 mg/L.

Salinity measurements, the morning value was 31‰, which gradually decreased to 29‰ in the afternoon and 28‰ in the evening. This decrease in salinity levels was influenced by the greater input of seawater compared to freshwater from land. Soil pH measurements ranged between 6.5 and 6.7, indicating slightly acidic to near-neutral conditions. The low pH results from organic acids produced during the decomposition of mangrove litter by decomposer bacteria, which can negatively affect the life of macrozoobenthos at the study site.

Species composition

Based on the observations, two species of macrozoobenthos were found in the mangrove forest ecosystem of Mangga Dua (Table 2).

Table 2. Species composition of macrozoobenthos

No.	Kelas	Ordo	Species	Nama	
				Indonesia	Lokal
1	Malacostraca	Decapoda	*Uca* spp.	Kepiting Biola	Kepiting Uca
2	Polychaeta	Phlyllodocida	*Nereis* spp.	Cacing Lur	Cacing Lading

Based on Table 2, it can be explained that the species composition of macrozoobenthos found at the research site includes two classes, namely (Crustacea and Polychaeta), with two orders and different species, namely (Uca spp and Nereis spp).

For the composition of macrozoobenthos species found based on substrate depth during the study, there were 2 species with a total of 25 individuals. The species found along with the number of individuals from all transects are presented in Table 3.

Table 3. Species composition of macrozoobenthos based on depth

No.	Species	Depth of Tube (cm)				Total individuals
		10	20	30	40	
1	*Nereis* spp.	8	4	10	-	22
2	*Uca* spp.	1	2	-	-	3
Total		**9**	**6**	**10**	**0**	**25**

The species composition of macrozoobenthos most commonly found at the research site was at a depth of 30 cm, with a total of 10 individuals from the species *Nereis* spp.

Species density

The results of the analysis of macrozoobenthic species density at each depth in the mangrove forest ecosystem of Mangga Dua are presented

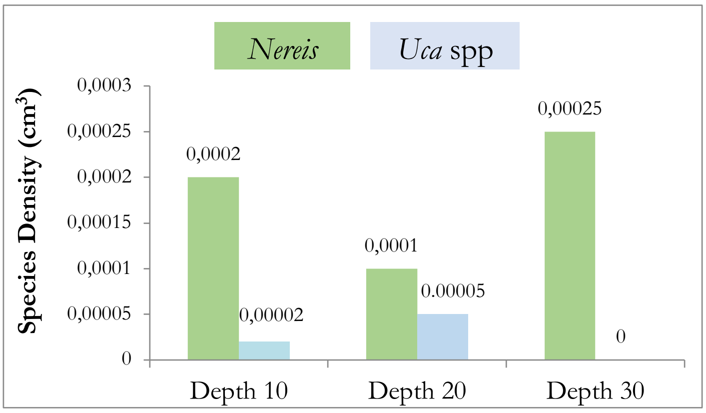

Figure 3. Density of macrozoobenthos

Based on Figure 3, it is known that the species density of the worm (*Nereis* spp.) ranges between 0.0002-0.00025 ind/cm³ at each substrate depth, while the species density of the crab (*Uca* spp.) is 0.00002 ind/cm³ at a depth of 10 cm and 0.00005 ind/cm³ at a depth of 20 cm.

Macrozoobenthic community structure

The results of the community structure analysis of macrozoobenthos in the mangrove forest ecosystem of Mangga Dua at each substrate depth are presented in Figure 4. The overall community structure is presented in Figure 5.

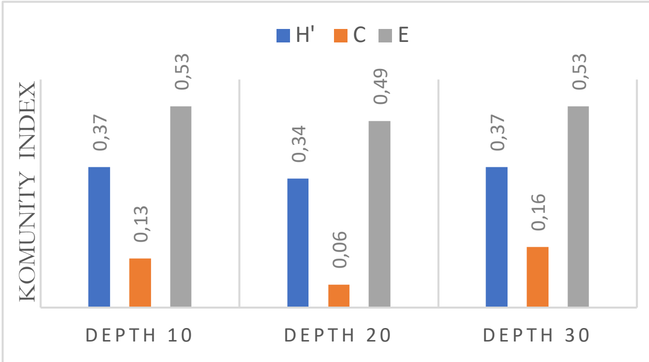

Figure 4. Community structure at each depth

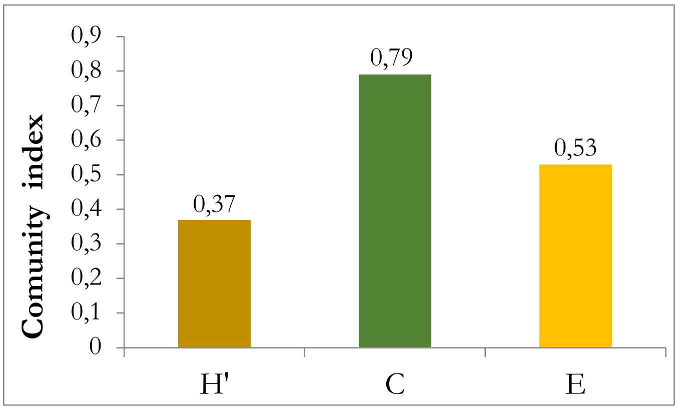

Figure 5. Community structure at each depth

Niche width of macrozoobenthos

The results of the niche width analysis of macrozoobenthos found in the mangrove ecosystem of Kelurahan Mangga Dua are presented in Table 4.

Table 4. Niche Width of Macrozoobenthos

No	Species	Depth (cm)			Total	Niche Width (B)
		10	20	30		
1	*Nereis* spp	8	4	10	22	0.90
2	*Uca* spp	1	2	-	3	0.60
	Total	9	6	10	25	

Table 4 shows that the worm species (*Nereis* spp.) has the highest niche width, with a value of 0.90, compared to the crab species (*Uca* spp.) which has a niche width value of 0.60.

Overlapping microhabitat niches macrozoobenthos

The results of the analysis of overlapping microhabitat niches of macrozoobenthos in the mangrove forest ecosystem of Mangga Dua Village are presented in Table 5.

Table 5. Overlapping niche

Species	*Uca* spp	*Nereis* spp
Uca spp		0.22
Nereis spp	0.15	

Table 5 explains that the overlap of microhabitat niches, or the degree of niche overlap, is quite significant for the polychaete worm (*Nereis* spp.) with the fiddler crab (*Uca* spp.) at a value of 0.22. Conversely, the niche overlap between Uca spp. and *Nereis* spp. is lower, with a value of 0.15.

Relationship between depth and macrozoobenthos density

The results of the Simple Linear Regression analysis to determine the relationship between depth and macrozoobenthos density in the mangrove forest ecosystem of Mangga Dua Village are presented in Figure 6.

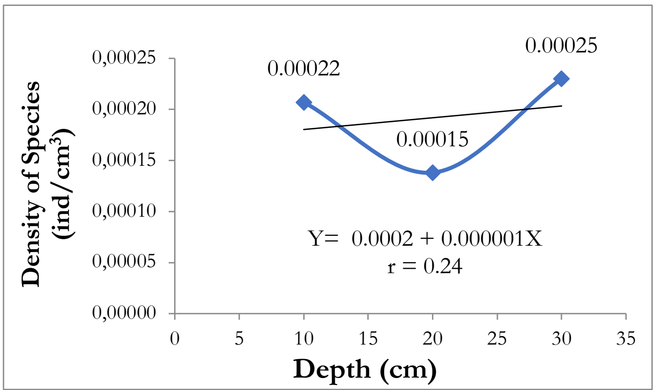

Figure 6. Relationship between depth and macrozoobenthos density

Figure 6 shows that the relationship between substrate depth and macrozoobenthos density is represented by the equation Y = 0.0002 + 0.000001X, where the value of "a" is 0.0002, "b" is 0.000001, the correlation coefficient (r) is 0.24, and the coefficient of determination (R^2) is 0.058.

Based on the value of "b" (the slope), it can be concluded that for every 1 cm increase in depth (X), the macrozoobenthos density (Y) will increase by 0.000001 ind/cm³. Additionally, the positive value of "X" indicates a positive relationship between the two variables. The correlation coefficient (r) of 0.24 suggests a weak correlation, as it falls within the range of 0.20–0.39. The coefficient of determination (R^2) of 0.058, or 5.8%, indicates that the substrate depth (X) accounts for 5.8% of the variation in macrozoobenthos density (Y), with the remaining variation influenced by other factors.

Discussion

The survival and well-being of macrozoobenthos, as well as various aquatic organisms that live in the bottom substrate of waters, are closely related to environmental temperature conditions (Krisnafi *et al.*, 2021; Kennedy & Mihursky, 1971; Bonacina *et al.*, 2022; Lestari & Rahmanto, 2020). The temperature range measured at the research location was between 28-31°C, considered appropriate, this condition is suitable for the survival of macrozoobenthos found in the mangrove ecosystem of Mangga Dua Village. According to Lusianingsih (2011), the temperature range that supports the survival of macrozoobenthos is 20-30°C.

This variation in DO levels is thought to be caused by high salinity which can reduce the photosynthetic efficiency of plants and phytoplankton at the research location. Additionally, water turbidity and muddy substrates may contribute to this. However, the recorded DO values are still within the acceptable range to support the life of macrozoobenthic communities, with a typical range of 4-6 mg/L to support macrozoobenthic life (Anggi, 2013). According to (Best *et al.*, 2006; Choirunnisa & Takarina, 2019), one of the key factors that can significantly influence the distribution, abundance, and diversity of macrozoobenthos is the level of dissolved oxygen in water, because they rely on it for respiration and other metabolic processes (Shi *et al.*, 2014; Lestari & Rahmanto, 2020). The recorded salinity in the mangrove ecosystem of Kelurahan Mangga Dua affected the life of individual macrozoobenthos. Typically, the salinity range that supports the life of macrozoobenthos in aquatic ecosystems is 15-35‰ (Islami, 2013). pH indicates normal conditions. The values found provide ecological information regarding mangrove support. In some cases, macrozoobenthos mortality is more likely to be caused by low pH rather than high pH (Nuriyawan *et al.*, 2016).

At a depth of 10 cm, a total of 9 individuals were found, with the most abundant species being the worm Nereis spp. At a depth of 20 cm, 6 individuals were found from 2 species, with the worm *Nereis* spp. being the most abundant species, with 4 individuals, while the crab species *Uca* spp. had 2 individuals. No macrozoobenthos species were found at a depth of 40 cm.

From the explanation above, it can be understood that individuals of the worm *Nereis* spp. were more commonly found at a depth of 30 cm because this depth had a substrate with a muddy composition, which contained many organic materials resulting from decomposition processes by fungi and bacteria. Organic matter and nutrients are the primary sources that support the life of *Nereis* spp. This is in line with the statement by Munairi and Abida (2012), who stated that organic matter is a primary nutritional source for many organisms in the substrate of mangrove ecosystems, including the worm *Nereis* spp.

The species with the lowest density, such as the crab (*Uca* spp.), indicates that these individuals are not capable of adapting to their habitat. On the other hand, species with high-density values, such as the worm (*Nereis* spp.), indicate that this species has a high adaptability to its habitat, thus being able to thrive in its environment. Besides water quality, factors influencing the species density of the worm (*Nereis* spp.) include predation and biological factors (Munairi & Abida, 2012).

Based on Figure 4, at depths of 10 cm, 20 cm, and 30 cm, the species diversity is low, with no dominant species and an even distribution of species. This aligns with the criteria established by Krebs (1989), which states that species diversity is considered low when H' < 1. Regarding species dominance, if the value of C is between 0 and 0.05, no species dominate, while values between 0.5 and 1 indicate the presence of a dominant species. For evenness, if the value of E is between 0.41 and 0.60, the distribution of species is considered uniform (Abubakar *et al.,* 2018).

Based on Figure 5, it can be observed that the species diversity of macrozoobenthos is classified as low because the H' value is less than 1. The low species diversity is influenced by the small number of individuals in the ecosystem, which is affected by the poor environmental quality. Furthermore, the C value between 0.5 and 1 indicates that there is a dominant species in the study area. The species dominating the area is the worm (*Nereis* spp.), which aligns with Odum (1993) statement that if the species dominance value exceeds 0.5, a species dominates the ecosystem (Abubakar *et al.,* 2018). The E value suggests a relatively even distribution of species. However, the macrozoobenthos species found in the study area are under environmental stress, reflected in the low number of individuals and low species diversity index. This is related to the aquatic environmental conditions of the mangrove ecosystem in Kelurahan Mangga Dua, which are impacted by anthropogenic waste from surrounding communities, disrupting the ecological balance and affecting the distribution of macrozoobenthos species (Handayani, 2016).

In general, niche width is related to the environmental conditions and resources that a species requires to survive and reproduce. The difference in niche width between the two macrozoobenthic species indicates that they utilize available resources differently to support their growth. Species with a narrower niche width, such as the crab (*Uca spp.*), show that they are selective about the resources available in their habitat, whereas species with a broader niche, like the worm (Nereis spp.), are likely utilizing a wider range of resources, even though the available resources in their environment may be limited. A higher niche width occurs when a species utilizes a variety of resources, whereas a lower niche width occurs when an individual depends on a single resource type (Rina et al., 2019).

Based on the analysis, the degree of niche overlap in microhabitats is influenced by the individual macrozoobenthos species, specifically *Uca* spp. and *Nereis* spp., which occupy the same substrate depths. Therefore, a high overlap value is observed between Nereis spp. and Uca spp., which is also due to competition for habitat or food resources within the same microhabitat (Rina *et al.,* 2019).

In this case, substrate depth does not significantly affect macrozoobenthos density in Mangga Dua Village. This is influenced by the high density of the polychaete worm species (*Nereis spp.*) at a depth of 30 cm compared to depths of 10 cm and 20 cm. At 30 cm, the species (*Nereis spp.*) shows a high adaptive capacity to the muddy substrate, as it provides high nutrients that support the worm community. It is known that the natural habitat of Nereis spp. is typically sandy or muddy, particularly in coastal areas near settlements with high decomposition material, estuaries, and mangrove areas (Shofiya *et al.,* 2021).

Conclusion

The macrozoobenthos species composition found in the mangrove forest ecosystem of Mangga Dua Village consists of two species, namely (Uca spp. and Nereis spp.), with a total of 25 individuals. The species diversity of macrozoobenthos in this mangrove ecosystem is classified as low, with some species dominating and a relatively even distribution. The species with the widest habitat niche is the polychaete worm (Nereis spp.). The greatest overlap of microhabitat niches occurs between the worm species (Nereis spp.) and the fiddler crab (Uca spp.). Substrate depth does not show a significant relationship with the density of macrozoobenthos species in Mangga Dua Village.

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