Biodiversity of macrozoobenthos in a mangrove area of North Sumatra, Indonesia

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Abstract. Macrozoobenthos are organisms that inhabit the substrate or attach to the bottom surface of an aquatic body. In mangrove regions, most macrozoobenthos can survive on rigid silt substrates. This study aims to determine the biodiversity of macrozoobenthos organisms in the mangrove ecosystem of Silo Baru Village, Asahan Regency, North Sumatra, Indonesia. This study was conducted for one month, starting in November 2022 and finishing in December 2022. This study employed a macrozoobenthos sampling technique consisting of three repetitions of taking three different points from each location along a 1 x 1 m square transect. Based on the research, the most frequent species identified was *Dosinia dilecta* (35 individuals) belonging to the class of Bivalvia. Based on the results, sampling site B (midstream) has the highest diversity index with 180 ind m^{-2}, followed by sampling sites A (upstream) and C (downstream) with diversity indices of 132.5 and 112.5 ind m^{-2}, respectively. Additionally, midstream (sampling site B) had the highest diversity index and uniformity index, according to the collected data. Meanwhile, sampling sites A (upstream) and C (downstream) had the highest dominance indices with values of 0.24 and 0.23, respectively, that did not differ substantially. In this study, 15 species of macrozoobenthos were identified, 10 of which belonged to the class Gastropoda, two to the class Bivalvia, and three to the class Malacostraca. In total, 170 individuals of macrozoobenthos were identified. This study's findings indicate that the biodiversity of macrozoobenthos at the study sites can be distinguished based on the different types of water flow in a waterbody. The presence of macrozoobenthos in mangrove waterways can serve as a parameter for assessing water quality in the existing ecosystem, enabling conservation and management efforts to be based on such data. Additionally, environmental monitoring of macrozoobenthos is valuable for restoration initiatives aimed at improving habitat conditions.

Key Words: conservation, environmental monitoring, mangrove ecosystem, restoration, water quality.

Introduction. Mangroves are important coastal ecosystems that are vulnerable to environmental changes. Monitoring of this ecosystem is necessary because mangroves serve as habitats for various species of plants and animals (Cinco-Castro & Herrera-Silveira 2020). To conduct this monitoring, one approach is to assess the water quality, which can be done by identifying macrozoobenthos (Dąbrowska et al 2016; Yanygina 2017). Macrozoobenthos species serve as good indicators that provide information about the water conditions in the mangrove area (Yunita et al 2018). This data serves as a basis for measuring water quality and evaluating the potential impacts of external factors such as pollution or environmental changes (Dauer 1983).

In a study conducted by Li et al (2019) in the Poyang Lake Basin, China, it was found that the diversity of macrozoobenthos has decreased compared to the historical period of 2016-2017. Their findings suggest that human activities have had a detrimental impact on the macrozoobenthos habitat, resulting in a decline in macrozoobenthos diversity. This study is supported by Ndale et al (2021), which states that human activities have an impact on the quality of the water, thereby affecting the life of organisms like macrozoobenthos. According to their study, Gilimanuk Bay, Bali was classified as moderately polluted waters based on the structure of the macrozoobenthos community and its relationship with water quality.

Lilisti et al (2020) stated that the human activities conducted in Kalibaru waters, Bengkulu, Indonesia, such as boat fishing, oil refueling, fishery product processing, construction of warehouses, and fishermen's bases, affect the quality of the surrounding ecosystem. Their findings indicate that the analysis of the diversity and homogeneity indices of macrozoobenthos was at a medium level, indicating an unstable community in the Kalibaru waters. Similar results shown by Octavina et al (2019) indicate a relatively low diversity index of macrozoobenthos in the Lamnyong River, Aceh Province, between 2017 and 2019. Consequently, the community structure of macrozoobenthos was categorized as unstable.

The study conducted by Kadim et al (2022) in Gorontalo waters, Indonesia, also explored the biodiversity of macrozoobenthos. The findings revealed that the marine area exhibited a medium level of diversity and evenness. In addition, the study provides valuable data on taxa abundance, community structure of macrozoobenthos, and their association with water quality parameters. The abundance and diversity of macrozoobenthos are greatly influenced by alterations in water quality and the substrate they inhabit. This was proven by Harahap et al (2018) that the macrozoobenthic diversity index (H') values at the the Bilah River, Rantauprapat, Indonesia indicated a classification of mildly polluted groups.

The diversity and abundance of macrozoobenthos are heavily influenced by the water and substrate quality. This diversity and abundance are interconnected with the utilization and hazard of the surrounding ecosystem. Gevorgyan et al (2021) demonstrated that the Debed River in Armenia was contaminated with various heavy metals as a result of mining activities. This pollution had negative consequences on the growth of macrozoobenthos and posed health risks to humans when the water was used for drinking purposes. In addition, the correlation between macrozoobenthos and heavy metals, specifically Hg, was further studied by Heumasse et al (2019). They reported that Hg in the Waelata River, Maluku Province, Indonesia has a correlation with Hg in sediment and macrozoobenthos.

There have been several previous studies on the structure of macrozoobenthos in mangrove areas. For instance, Basyuni et al (2018) demonstrated that salinity, clay content, temperature, and dissolved oxygen (DO) are significant factors influencing the survival of macrozoobenthos in mangrove forests. Furthermore, Hasibuan et al (2021) found a strong correlation between DO and macrozoobenthos diversity. They observed that higher concentrations of DO in the water indicated higher water quality, and vice versa. This relationship could potentially affect the presence and survival of macrozoobenthos.

The community structure of living organisms is closely related to the equilibrium of aquatic ecosystems. The community structure of macrozoobenthos consists of species density, species diversity index, species uniformity index, and dominance index. Furthermore, the biodiversity of macrozoobenthos can be described using these indices. Therefore, this study aims to determine the biodiversity macrozoobenthos organisms in the mangrove ecosystem based on these indices.

Material and Method

Description of the study sites. The study was conducted for two months, from November to December 2022. The research took place in Silo Baru Village, Asahan Regency, North Sumatra that being well-known for its mangrove areas (Figure 1). However, land conversion in the past few years has destroyed a large amount of mangrove areas, leaving only few areas left with the mangroves in the regency include Silo Baru Village. The research locations were determined using purposive sampling technique. The three sampling locations were sampling site A in the upstream mangrove area, sampling site B in the midstream mangrove area, and sampling site C in the downstream mangrove area.

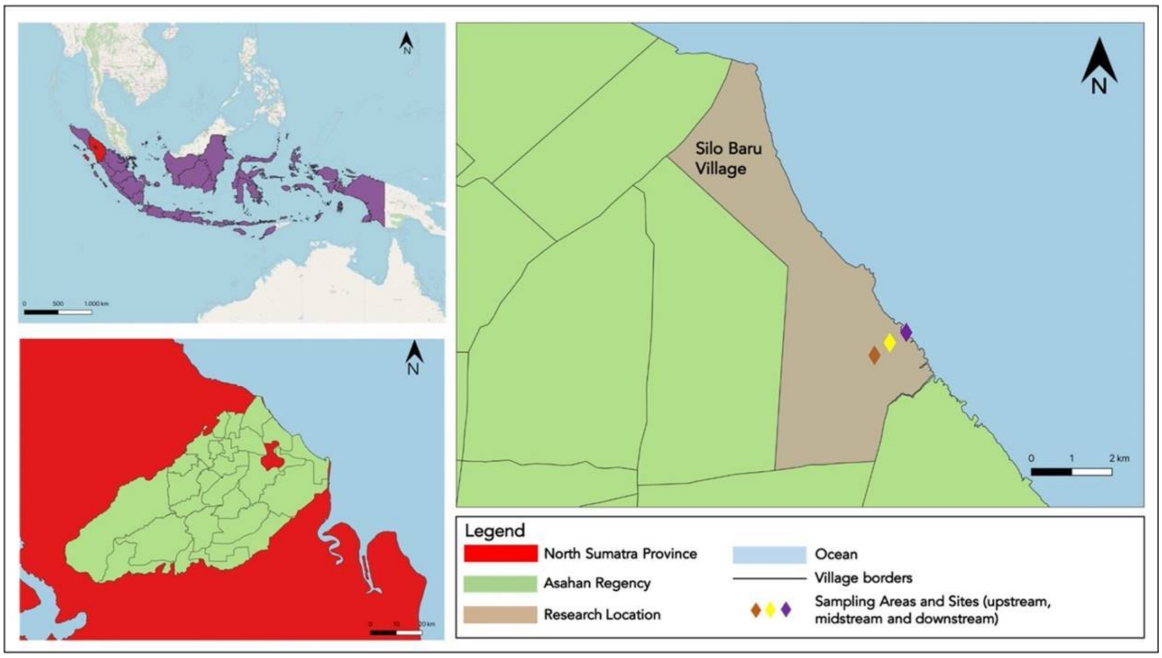

Figure 1. Map of research area (Silo Baru Village, Asahan Regency, North Sumatra).

Tools and materials. This study utilized shovels, cameras, a measuring meter, stationary, filters, ropes, and sample bags. In addition, the material utilized in this study was 70% alcohol.

Sampling procedure. This study sampled macrozoobenthos at three locations (A, B and C) using a 1 x 1 m square transect. Then, sampling was conducted in 20 x 20 cm plots with a depth of 20 cm, with five units diagonally plotted on the transect (Figure 2). From every corner and center, samples were collected. The samples were then filtered with a benthic filter, and the organisms were deposited in sample bags and preserved with 70% alcohol. The samples were subsequently identified using the World Register of Marine Species databases (WoRMS Editorial Board 2024).

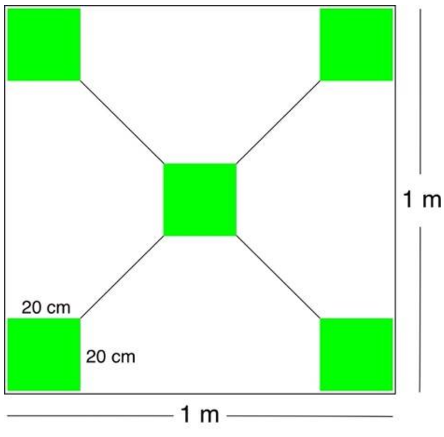

Figure 2. Sampling transect pattern.

Data analysis. Data analysis was performed descriptively. Calculations were carried out using the following formulae:

The species density (D) was determined using equation 1 (Brower & Zar 1977):

$$D = \frac{\Sigma ni}{A} \quad (1)$$

where: D = density (ind m^{-2});
ni = the number of individuals in the i-squared transect;
A = the sampling plot area (m^2).

The species diversity index (H’) was determined using equation 2, as proposed by Shannon-Wiener (Brower & Zar 1977). In addition, Table 1 displays the category of the species diversity index.

$$H' = -\Sigma \left(\frac{ni}{N} \right) \ln \left(\frac{ni}{N} \right) \quad (2)$$

where: H’ = the species diversity index;
ni = the number of individuals in the i-squared transect;
N = the total individuals.

Table 1

Diversity index category

Diversity index	*Category*
H’ > 3	High
1 ≤ H’ ≤ 3	Moderate
H’ < 1	Low

Source: Rijaluddin et al (2017).

The uniformity index (E) was calculated using equation 3. Table 2 displays the criteria for the level of species uniformity based on the uniformity index (Krebs 2008).

$$E = \frac{H'}{\ln S} \quad (3)$$

where: E = the uniformity index;
H’ = the Shannon-Wiener diversity index;
S = total organisms.

Table 2

Uniformity index category

Uniformity index	*Category*
0.6 < E < 1	High evenness
0.4 ≤ E ≤ 0.6	Moderate evenness
0.0 < E < 0.4	Moderate inequality

Source: Odum (1971).

According to Odum (1971), the dominance index (C) can be obtained using Simpson's dominance equation, as shown in equation 4. In addition, Table 3 shows the dominance index category.

$$C = \Sigma \left[\frac{ni}{N} \right]^2 \quad (4)$$

where: C = the dominance index;
ni = the number of individuals from species I;
N = the total individuals from all species.

Table 3

Dominance index category

Dominance index	*Category*
C close to 0 (C < 0.50)	No species dominates
C close to 1 (C ≥ 0.50)	Some species dominates

Source: Odum (1971).

Results. There were 15 species of macrozoobenthos identified in Silo Baru Village, where seven species were found at sampling site A, 10 species were found at sampling site B, and six species were found at sampling site C. Table 4 displays the results of water quality parameter testing conducted at three different sampling sites.

Table 4

Results of water quality test parameters

Parameter	Units	Sampling site		
		A	B	C
Physical				
Temperature	°C	28	30	29
Brightness	m	4.2	3.3	4.7
Substrate texture	-	Sandy clay	Sandy loam	Sandy clay loam
Chemical				
pH	-	6.5	6.7	6.8
DO	mg L^{-1}	2.4	2.1	2.2
Salinity	‰	27.0	29.0	26.5
C-organic	%	7.57	7.86	8.12

Note: A = upstream; B = midstream; C = downstream.

According to Table 4, there is a slight increase in temperature from site A (28°C) to site B (30°C) and then a decrease to 29°C at site C. Concerning the brightness, there is a decreasing trend observed from site A (4.2 m) to site B (3.3 m), followed by an increase to 4.7 m at site C. Based on the chemical parameters, the pH values show a gradual increase from site A (6.5) to site C (6.8), indicating a slight alkaline tendency along the watercourse. In addition, dissolved oxygen (DO) levels display a fluctuative pattern, with site A having the highest value (2.4 mg L^{-1}), followed by site C (2.2 mg L^{-1}), and site B recording the lowest (2.1 mg L^{-1}). Site B has the highest salinity (29.0‰), followed by site A (27.0‰), and site C displays the lowest salinity (26.5‰). Additionally, the percentage of organic carbon (C-organic) shows a progressive increase from site A (7.57%) to site B (7.86%), with the highest value recorded at site C (8.12%).

Table 5 shows density data for each sampling location. In addition, Figure 2 shows the diversity index (H'), uniformity index (E), and dominance index (D) of macrozoobenthos in the research area.

Table 5

Types of macrozoobenthos and density at sampling sites

Class	Species	Total individuals (based on sampling site)			Total individuals (based on species)
		A	B	C	
Gastropoda	*Telescopium telescopium*	×	×	1	1
	Cerithideopsilla cingulata	×	8	×	8
	Neripteron violaceum	8	3	×	11
	Paratectonatica tigrina	×	×	×	0
	Clithon faba	×	9	×	9
	Anentome helena	2	×	×	2
	Theodoxus anatolicus	4	7	×	11
	Nassarius sp.	×	8	11	19
	Cerithium sp.	7	3	12	22
	Ellobium aurisjudae	×	1	×	1
Bivalvia	*Arctica islandica*	×	12	×	12
	Dosinia dilecta	22	×	13	35
Malacostraca	*Ilyoplax* sp.	×	×	1	1
	Metaplax sp.	1	5	×	6
	Callinectes sapidus	9	16	7	32
	Total species	7	10	6	
	Total individuals	53	72	45	
	Density (ind m^{-2})	132.5	180.0	112.5	

Note: × = not found; A = upstream; B = midstream; C = downstream.

According to Table 5, the highest density was discovered midstream (180 ind m^2) in the mangrove forest, whereas the lowest density was found downstream (112.5 ind m^{-2}). With 35 specimens, the species *Dosinia dilecta* from the class Bivalvia was the most frequent.

Based on the data in Figure 3, sampling site B (midstream) shows the highest diversity index. Similarly, sampling site B also exhibited the highest uniformity index. On the other hand, sampling sites A (upstream) and C (downstream) have the highest dominance indices, with values that were not substantially different, 0.24 and 0.23, respectively. The diversity index data from the three sampling sites fall within the moderate category. Meanwhile, the uniformity index of the three sampling locations falls within the category of high evenness. In addition, the data from the three sampling sites' dominance indices indicate that no species dominates.

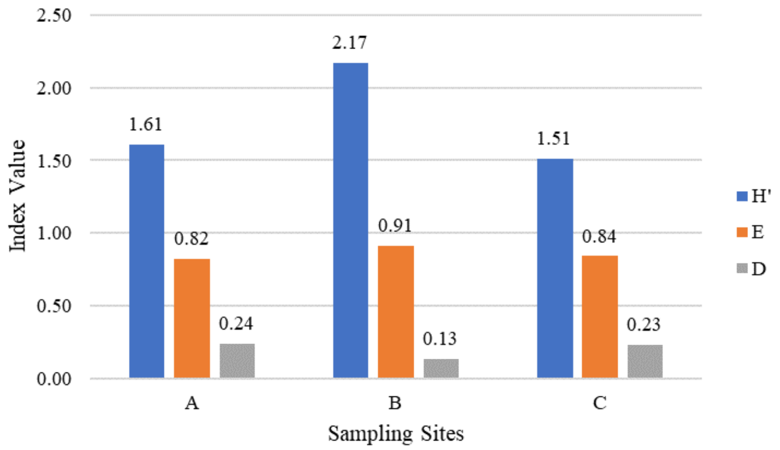

Figure 3. Diversity index (H'), uniformity index (E), and dominance index (D) of macrozoobenthos (A = upstream, B = midstream, and C = downstream).

Discussion

Macrozoobenthos identification. Based on the findings, 15 species of macrozoobenthos were identified across three sampling locations in Silo Baru Village, including ten macrozoobenthos species from the Gastropoda class (phylum Mollusca), two from the Bivalvia class (phylum Mollusca), and three from the Malacostraca class (phylum Arthropoda). Existing sediment at the sampling location influences the abundance of macrozoobenthos. Based on the research, sampling site B has the highest macrozoobenthos density of 180 ind m^{-2}. This condition is influenced by total organic matter (TOM) in the form of very fine sand to medium-sized sand, which promotes the growth of macrozoobenthic organisms by providing substrate as food. At sampling site A, which represented the upstream mangrove vegetation, the density of macrozoobenthos was 132.5 ind m^{-2}, while sampling site C (downstream) represented the lowest mangrove vegetation, with 112.5 ind m^{-2}. This is because medium-sized sand sediments reduce organic matter and alter the feeding sources of macrozoobenthos.

The presence of organic matter in the mangrove area influences the relationship between the downstream, intermediate, and upstream mangrove areas and the macrozoobenthos present. Typically, the midstream region is situated between dense forest and vegetation, which can increase the deposition of organic matter from plant debris and fallen leaves transported by the current (Alongi & Brinkman 2011). The midstream region typically has a slower water flow than the upstream region, resulting in a more significant deposition of organic matter due to sediment and organic material accumulating more readily (Douglas et al 2022). In the midstream region, sediment deposits accumulate and combine, binding organic matter from the water and depositing it there. In general, coarse sand sediment contains less organic matter than fine sand sediment because coarse sand sediment is less capable of binding significant amounts of organic matter than fine sand sediment.

According to Paulus et al (2020), the population density of macrozoobenthos in an aquatic environment is directly related to the environmental conditions that support their survival and development. The availability of sustenance as a source of nutrients and energy for the growth and reproduction of macrozoobenthos will be influenced positively by an ecosystem that provides support. In contrast, if the ecosystem's environmental conditions do not sustain it due to pressure, the food supply as a source of nutrients and energy for macrozoobenthos growth will decrease (Riantoby et al 2021).

D. dilecta from the class Bivalvia has the most significant number of macrozoobenthos, with 35 individuals. Bivalvia is the macrozoobenthos commonly found in mangrove environments (Erika et al 2022). Viable conditions for the survival of bivalves in an environment are a high organic content, the type of substrate, and the ability to adapt to diverse environments (Jailani 2012). Bivalvia are commonly found in mangrove ecosystems due to their ability to acclimate to the varying salinity levels in these environments (da Silva et al 2005). Some aquatic organisms may struggle to persist in mangrove environments due to a mixture of freshwater, saltwater, and brackish water. The ability of bivalves to modulate the salinity of their internal environment enables them to survive in these mixed-water environments. In addition, the porous, muddy substrate in mangrove habitats is suitable for filter-feeding bivalves that extract nutrients from the surrounding water. In mangrove environments, the abundance of sustenance in the form of plankton and detritus in the water column also supports the growth and reproduction of bivalves (Gallardi 2014). Consequently, bivalves are frequently one of the most abundant classes of macrozoobenthos in mangrove habitats.

Indices analysis. The indices analysis of the sampling sites reveals important information about their ecological characteristics. In terms of diversity, all three sites demonstrate moderate levels. Upstream (A) exhibits a diversity index of 1.61, middle (B) shows a diversity index of 2.17, and downstream (C) has a diversity index of 1.51. This indicates a relatively balanced distribution of species within each site. The moderate category of the diversity index data from the three locations can be interpreted as moderate diversity within the observed species population at those three locations. The moderate category indicates that there are not only a few dominant species in the area but also other abundant species that substantially contribute to maintaining the ecosystem's equilibrium at each location. Meanwhile, regarding the evenness or uniformity, upstream (A) and downstream (C) display moderate evenness, as indicated by their uniformity index values of 0.82 and 0.84, respectively. In contrast, middle (B) stands out with high evenness, scoring a uniformity index of 0.91. These findings suggest that middle (B) has a more uniform distribution of species compared to the other two sites. The dominance index values indicate that none of the sites have a dominating species. Upstream (A), middle (B), and downstream (C) exhibit dominance index values of 0.24, 0.13, and 0.23, respectively, indicating a lack of dominance by any particular species in the sampled areas. This indicates that the ecosystems in these three locations are relatively stable and healthy due to the diversity of species populations.

The diversity of organisms in a body of water is influenced by biotic and abiotic factors that combine to form its ecosystem. The availability of food is one of the biotic factors influencing it. In the meantime, abiotic factors that influence the ecosystem include phosphate levels, pH, sediment, and temperature. According to Pelealu et al (2018), physical, chemical, and biological factors influence the diversity and abundance of macrozoobenthos. The abundance of benthos is affected by color, current speed, water depth, turbidity or clarity, and temperature. Furthermore, pH influences chemical factors, organic matter, dissolved gases, nutrient levels, and biological factors that determine the amount of food, producers, and predators in aquatic environments (Setyobudiandi 1997). In addition, the type of growing medium and its organic matter content are significantly influenced by the conditions of the aquatic environment.

The uniformity index for the three sampling locations falls within the high evenness category. This suggests that macrozoobenthic species are distributed equitably. There is a correlation between macrozoobenthos uniformity and macrozoobenthic community stability. According to Susilawati et al (2016), an ecosystem's stability can be determined by the stability of its community and the uniformity of its macrozoobenthos. This high evenness category of the uniformity index indicates a balanced distribution of macrozoobenthic species across the three sampling locations. In addition, it is widely acknowledged that the stability of the macrozoobenthos community is correlated with the uniformity of macrozoobenthos distribution. Therefore, the high uniformity of macrozoobenthos distribution at all three sampling sites may indicate the ecosystem's stability.

According to the findings, no species dominate in the research area. Based on the dominance index category (Odum 1971), if the dominance index is below 0.5 and near 0, the dominance index value is low, or no species dominance was observed during sampling. Food accessibility is one of the factors that can lead to dominance. When an organism receives adequate nutrition, its growth and development will proceed normally. This is consistent with the statement by Mardiyanti et al (2013) that the community structure is unstable due to ecological pressure when the dominance value is equal to or near 1 when a species dominates other species.

Conclusions. Based on the study results, 15 species of macrozoobenthos were identified at three sampling locations, including ten species of the Gastropoda class, two species of the Bivalvia class, and three species of the Malacostraca class. The species *Dosinia dilecta* (class of Bivalvia) had the greatest number of 35 individuals. The middle area of the mangrove forest water has the highest density over the three sampling sites. This is because a mangrove's upstream, midstream, and downstream portions differ in substrate and environmental conditions. The middle portion of the mangrove has a superior substrate compared to the upstream and downstream portions, thereby sustaining a diverse macrozoobenthos community.

Index analysis determined that the highest diversity index and uniformity index were in sampling site B, specifically the middle area of mangrove forest waters, with values of 2.17 (moderate) and 0.91 (high evenness), respectively. In addition, sampling site C has the highest dominance index with a value of 0.24, which is not all that distinct from sampling location A with a value of 0.23. According to the three obtained dominance indices, no macrozoobenthos species dominated at any of the three sites.

The environmental factors that contribute to the differences in substrate and conditions between the upstream, midstream, and downstream portions of the mangrove forest could be the subject of future research. This may involve analyzing variables such as water flow, sediment composition, and nutrient concentrations. In addition, additional research could be conducted to comprehend the ecological functions and interactions of the identified macrozoobenthos species within the mangrove ecosystem, as well as the potential effects of environmental stressors like climate change on these species and their habitats. Lastly, a comparison of these findings to those of other mangrove ecosystems could provide valuable insight into the factors that determine the diversity and community structure of macrozoobenthos in these vital coastal ecosystems.

Conflict of interest. The authors declare that there is no conflict of interest.

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