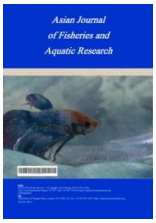

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Analysis and Diversity of Benthic Foraminifera Based on Test Wall Composition in the Surface of Coastal Sediments from Tunda Island, Serang, Banten, Indonesia

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Tunda Island has become one of the marine tourism spots that is much considered by tourists because it has good coastal ecosystems. To find out the suitablecondition of Tunda Island waters, benthic foraminifera were used in this area. Foraminifera have the potential to be a bioindicator, which can be seen from the distribution, simple anatomy of the body and its ability to form hard shells. The purpose of this study was to determine the abundance and diversity of foraminifera based on shell walls on the surface of the coastal sediments of Tunda Island. This research was conducted on August 2019. Six samples were used in this study to analyze the abundance and diversity of benthic foraminifera based on test walls on the coast of Tunda Island. The analysis showed that only 2 sub-orders were found, namely *Rotaliina* and *Miliolina.* The most common sub-orders found in all studied stations are the *Rotaliina* with an abundance of 55% and 45% for the *Miliolina.* Calculation of community structure with diversity values ranging from 1.55 to 2.24 and dominance values ranging from 0.13 to 0.38 indicate that environmental conditions are under pressure both naturally and anthropogenically.

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Keywords: Benthic foraminifera; diversity; sediment; Tunda Island; test wall.

1. INTRODUCTION

Tunda Island is one of the marine sand mining areas in Serang Regency. It considered as a source of stable regional income. Since 2003, The local Regional Government has been trying to the sea sand to meet the demand for sand-filled for new land clearing in various regions, especially DKI Jakarta [1].

Overexploitation of sea sand in small islands, such as Tunda Island, which does not take into consideration the aspects of sustainability has the potential to cause environmental degradation and damage, thereby threatening the preservation of biological resources around the sand mining area and can harm local communities [1].

Currently Tunda Island became one of the marine tourism spots that was much visited by tourists becauseof its attractivity. To determine water quality of Tunda Island using benthic foraminifera abundant in this area. Shallow marine ecosystems have a high diversity of biota, including benthic foraminifera. It has an important role in the food chain, namely as a producer or provider of food for several types of organisms [2]. Foraminifera has been widely used by biologists, geologists, and oceanographers in connection with various variations in changes in the marine environment [3].

Foraminifera has the potential to be used as a bioindicator which can be analyzed from its distribution, simple anatomy, and its ability to form hard shells [4]. The life of benthic foraminifera is influenced by many major environmental factors including depth, current, substrate, sedimentation velocity, sunlight, and interactions with other organisms. Each water is characterized by environmental factors that influence the diversity of foraminifera [3]. Foraminifera build tests of extraordinary variety, ranging from simple tubes or spheres to multichambered, complex forms that defy easy description. They make their tests of a variety of materials as well, ranging from organic substances through agglutinated foreign matter to secreted calcium carbonate, but reportedly including such exotic materials as silica and iron. The test wall has various components and structures [3]. The purpose of this study was to determine the abundance and diversity of foraminifera based on shell walls on the surface of the coastal sediments of Tunda Island.

2. METHODOLOGY

2.1 Research Location

The study were conducted in Tunda Island on August 2019. Data of sediment samples and water quality were carried out on the Tunda Island coast. Data collection stations were divided into 6 stations with different dephts, which were 30, 40, 50, 55, 85, and 100 cm with a distance of about 1 km from each station (Fig. 1). Determination of sampling points using a purposive technique. Purposive sampling is a data source sampling technique with certain considerations [5].

2.2 Sampling and Measurement

Sediment sampling was taken using a shovel at 6 stations. Samples in the form of sea surface sediments with varying depths during low tide in coastal zone. The sediment obtained is directly stored in a ziplock bag.Sediment samples that were already in the ziplock bag were put into the coolboxso that the sample is not damaged as well as to make it easier to be brought to the lab.Sediments inside the ziplock are removed and dried to make it easier to do the granulometry test. After that, the sediment samplesare washed to separate the foraminifera from the attached sediment.

Depth, temperature, salinity, dissolved oxygen, brightness, flow and acid content were carried out in situ during sampling. Three measurements were saved each parameter measured.

2.3 Sediment Sample Preparation and Foraminifera Identification

Before identifying the foraminifera, three steps are carried out. The sample preparation stage for the identification of foraminifera is carried out in several stages, including washing, picking, description, and identification. For the washing of benthic foraminifera, a residue method was prepared [6]. Dry sediment is weighed and mashed, then the sediment is put into anobservation container and dissolved with H_2O_2 (10-15%) sufficient to separate the foraminifera in the sediment from the surrounding matrix. For

± 1 hour, let it stand until no reaction occurs. After no reaction occurs, all residues are washed with running water over the sieve, then the results of the sieve are put into anobservation container and dried again using an oven for 24 hours.

Samples that have been prepared are spread in an observation container, then identification of the foraminifera using a microscope and lamp to facilitate the search for foraminifera. The flicking stage is carried out by spreading the dried sample in an observation container and foraminifera is taken using a observation needle. Specimens that have been separated are classified based on their morphology and based on the composition of the shell wall [7]. The identification process is based on Loeblich and Tappan (1964). The foraminifera flicking specimen are then transferred to the foram slide. The storage of foraminifera in the foram slides is grouped according to the test walls in their columns.

The identification phase is carried out by observing the foraminifera based on morphology (shell shape, room shape and arrangement, number of rooms, ornamentation, the shape of the aperture, position of the aperture, and additional aperture). Foraminifera was then identified to the genus level according to some previous studies such as Phleger (1951), Albani and Yassini (1993), Hottinger, drr. (1993), Loeblich and Tappan (1994), and Yassini and Jones (1995).

Documentation of identification results is done digitally, by selecting one foraminifera organism from each group that has been found, then photographed under a binocular stereoscope microscope with a magnification of 40x to 100x.

2.4 Data Analysis

2.4.1 Value of Abundance Index

The abundance index value is calculated with the following formula [8]:

$$K = \frac{ni}{1\ gram}$$

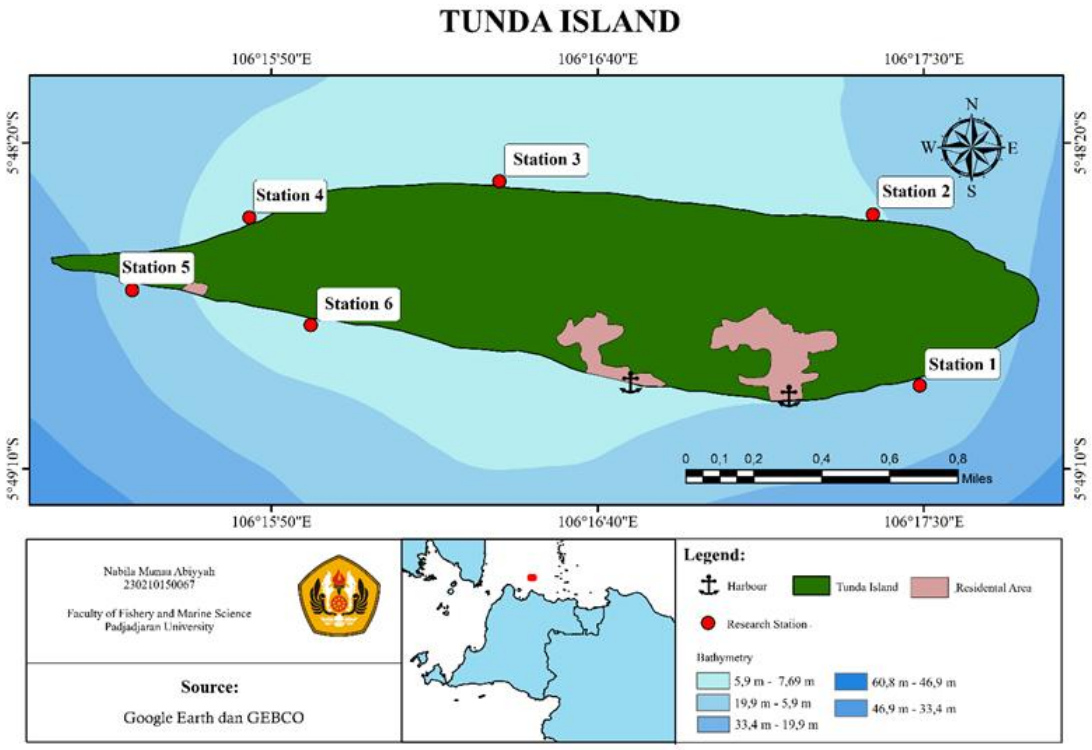

Fig. 1. Map of the study area showing the six stations in Tunda Island

2.4.2 Diversity index value

The Diversity Index (Shannon-Wiener) is calculated with the following formula [8]:

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

The diversity index criteria (Shannon-Wiener) are [9]:

H'<1 = Low diversity,
1≤ H' ≤ 3 = Medium diversity, and medium community stability,
H'>3 = High diversity.

2.4.3 Dominance index value

The Dominance Index (Simpson) is calculated with the following formula [10]:

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

The criteria for dominance index (Simpson) [10]:

0 < D ≤ 0,5 = There is no dominant genus,
0,5 < D < 1 = There is a dominant genus.

2.4.4 Comparison of group percentage of test wall composition

The percentage of each group of test wall compositions to be compared can be calculated using the formula [10]:

$$PK = \frac{ni}{N} \times 100\%$$

3. RESULTS AND DISCUSSION

3.1 Physical and Chemical Parameters

The temperature range in Tunda Island Water, the temperature of each Station is in the range of 29.8 - 33.5°C (Table 1). The highest temperature value is at Station 2 at 33.5°C and the lowest at Station 1 at 29.8°C.

At Station 2 with the highest temperature value 33.5°C, measurements were taken during the daytime so that the temperature tended to be high while the low-temperature value 29.8°C at Station 1 was caused by data collection conducted in the afternoon. A good temperature range for the life of foraminifera biota 21-26°C [11].

The depthin Tunda Island station ranged from 30 to 100 cm. (Table 1). The highest depth 100 cm was found at Station 6 and the lowest 30 cm at Station 1. The depth variation at each sampled station is included in shallow water. At shallow depths, the bottom of coastal waters can be seen clearly.

Salinity Observation Results at each Station are in the range of 24-28 ppt (Table 1). The highest value 27.5 ppt is in Station 2 and the lowest24 ppt is in Station 5. The salinity value at each sampled station shows a value that is not much different. This can be caused by data retrieval done in August which is experiencing the dry season so that there is no abundance of rainwater that enters and causes salinity tends to be normal. The range of good salinity for the life of foraminifera biota is in the range of 20 - 40 ppt [11].

The results (pH) at all Stations are in the range of 8.2 - 8.5 (Table 1). The highest value 8.9 is revealed at Station 3 and the lowest 8.2 is at Station 4. A good pH range for the life of foraminifera biota is 7 - 8.5 [12]. The value of the acidity of the waters is still in accordance with the optimal range that is good for supporting the life of the foraminifera. In the waters of Tunda Island, many types of foraminifera are found with limestone shells because the pH tends to be normal.

3.2 Tunda Island Sedimentary Composition

Based on the results of the analysis of grain size found 3 types of sediments in Tunda Island including sandy gravel mud, sand gravel, and sand silt (Table 2). Sediment in Tunda Island waters found dominant sand. In general, benthic foraminifera is more common in sand-dominated sediments. Sand tends to make it easier for the foraminifera to shift and move to another place.

In sandy and gravel substrate the organic material content is lower so that the foraminifera test were thick, unique ornamentation, oval, and convex like Quinqueloqulina From the sub-order Miliolina with porcelain walls [5]. In the coastal waters of Tunda Island with sandy sediment type with a slight pebble, the types of foraminifera that are often found are Peneroplis, Pseudorotalia, And Quinqueloculina with the many types of foraminifera found, it can be said that the waters of Tunda Island are shallow seas.

3.3 Abundant Benthic Foraminifera on Tunda Island

Benthic foraminifera in Tunda Island waters is divided into 6 data collection stations. 38 species were founded with an abundance of individuals

reaching 1604 individuals. In the coastal waters of Tunda Island, 2 sub-orders of benthic foraminifera were found, namely Rotaliina and Miliolina. The following is the result of the abundance of benthic foraminifera at each Station based on the grouping of test walls (Table 3).

The abundance of each sub-order, namely 880 ind/gr of the Rotaliina sub-order and 724 ind/gr of the Suborder of Miliolina. Station 6 has the most abundance of foraminifera compared to other stations because Station 6 is a coral reef ecosystem and has clear waters so that abundance at the station is found with much benthic foraminifera. While Station 1 has a low abundance when compared to other stations because Station 1 has a low depth compared to other stations.

The discovery of Suborder Rotaliina and Suborder Miliolina whose abundance at each station is not too different shows that the coastal waters environment of Tunda Island supports the abundance of Rotaliina and Miliolina populations which are characterized by porous limestone (hyalin) shells and porcelain walls.

The Rotaliida Order has a hyalin test wall and the Miliolida Order has a porcelain test wall. Foraminifera with hyalin test wall has a thin, brittle, egg-shaped shell, the structure of the trochospira room. The genus foraminifera hyalin test walls found on Tunda Island is the foraminifera of the Suborder Rotaliina (Table 4).

The porcelain-walled Foraminifera has a thick shell, unique ornamentation, oval and convex. The genus of foraminifera porcelain wall found on Tunda Island is the foraminifera of Subordo Miliolina (Table 5).

At Station 1 the proportion of genus Elphidium and Ammonia has a relatively high abundance compared to other genus foraminifera, with Elphidium reaching 51 individuals and Ammonia reaching 34 individuals. It is suspected that the environmental conditions of Station 1 lack the optimal carrying capacity and limiting factors for the growth of foraminifera so that the abundance of foraminifera at Station 1 is fairly low. Only opportunistic types can develop and have a high tolerance for the environment [5].

Table 1. Physical and chemical parameter data of Tunda Island

Station	Depth (cm)	Visibility (%)	Temperature (°C)	Salinity (ppt)	DO (mg/l)	pH
1	30	100%	29.8	25	5.9	8.3
2	40	100%	33.5	27.5	6.2	8.6
3	50	100%	32	26	5.7	8.9
4	55	100%	30.2	25.5	6	8.2
5	85	100%	31	24	5.9	8.3
6	100	100%	31.8	25	5.5	8.4

Table 2. Tunda Island surface sediment type

Station	Sediment
1	Slightly gravelly sandy mud
2	Slightly gravelly sandy mud
3	Slightly gravelly sand
4	Silty Sand
5	Slightly gravelly sandy mud
6	Slightly gravelly sandy mud

Table 3. Abundant Benthic Foraminifera on Tunda Island

Abundant Benthic Foraminifera Per Station (ind/gr)							
Suborder	Station						Total
	1	2	3	4	5	6	
Rotaliina	116	90	47	105	102	420	880
Miliolina	13	72	171	110	46	312	724
Total	129	162	218	215	148	732	1604

Table 4. Abundance of Suborder Rotaliina Foraminifera Benthic on Tunda Island

Suborder	Species	Total
Rotaliina	*Ammonia beccarii* (Linne)	15
	Ammonia tepida (Cushman)	27
	Amphistegina lessonii (d'Orbigny)	16
	Anomalinoides globulosus (Chapman and Parr)	4
	Asterorotalia trispinosa (Thalmann)	1
	Bolivina nitida (Brady)	2
	Bolivina sphatulata (Williamson)	3
	Calcarina calcar (d'Orbigny)	122
	Caribbeanella ogiensis (Matsunaga)	3
	Cymbaloporetta bradyi (Cushman)	9
	Elphidium advenum (Cushman)	16
	Elphidium jenseni (Cushman)	56
	Elphidium macellum (Fichtell & Moll)	61
	Eupatellinella fastidiosa (Mc.Culloh)	6
	Fijiella simplex (Cushman)	3
	Florensina philippinensis (Mc.Culloh)	2
	Heterolepa ornata (Cushman)	9
	Hyalinea baithica (Schroeter)	2
	Loxostomum limbatum (Brady)	1
	Neoconorbina petasiformis (T.C.Cheng &Zheng)	2
	Orbulina universa (d'Orbgny)	51
	Operculina ammonoides (Gronovius)	8
	Operculina complanata (DeFrance)	7
	Pseudorotalia schroeteriana (Parker & Jones)	391
	Rectobolivina columellaris (Brady)	1
	Rosalina bradyi (Cushman)	30
	Rosalina globularis (d'Orbigny)	31
Total		879

Table 5. Abundance of Suborder Miliolina Foraminifera Benthic on Tunda Island

Suborder	Species	Total
Miliolina	*Alveolinella quoyi* (d'Orbigny)	1
	*Massilina granulocostata (*Germeraad)	17
	*Miliolinella suborbicularis (*d'Orbigny)	7
	Quinqueloculina cuvieriana (d'Orbigny)	76
	*Quinqueloculina incisa (*Vella)	99
	Quinqueloculina parkeri (Brady)	10
	Quinqueloculina seminulina (Linne)	59
	Spiroloculina scrobiculata (Cushman)	5
	Triloculinella pseudooblonga (Zheng)	15
	Peneroplis carinatus (d'Orbigny)	176
	Peneroplis pertusus (Forskal)	259
Total		724

At Station 2 the foraminifera community found with the highest abundance was owned by the foraminifera of Quinqueloculina (54 individuals) and Calcarina (31 individuals). This can be interpreted as the condition of the water of Station 2 are quite good, with the presence of the Quinqueloculina foraminifera which characterizes areas that have good enough sunlight penetration. However, it turns out that in Station 2 there is also an Elphidium foraminifera type with a high abundance of 20 individuals, the presence of the Elphidium genus at Station 2 is thought to be caused by a lot of human activity because of its location which is close to the settlement. So contaminated with pollutants that can affect the presence of a certain genus of foraminifera.

The location points of Station 3 and 4 have coral reef spots so that they are often used as a snorkeling and diving area by tourists. Quinqueloculina also has a high abundance at Station 3 (43 individuals) and Station 4 (31 individuals). This genus lives at the bottom of the waters as benthic and burrows in the bottom of the waters and phytoplankton as its food source so that this species is always in an area that always gets sunlight penetration. Generally, live in shallow water. Then the foraminifera found abundantly at Station 4 is Pseudorotalia which has an abundance of 54 individuals.

At Station 5 the predominant types of foraminifera are the genus Peneroplis (34 individuals) and Pseudorotalia (32 individuals). At Station 5 the same as Station 3 and Station 4 which also has coral reef spots, the location of Station 5 is far from residential areas, access to this location is somewhat difficult. However, even though it is far from residential areas, Station 5 area has quite a lot of rubbish which is thought to have originated from human activities carried from other islands or from Tunda Island itself. So that at Station 5 also found the Elphidium genus which is quite abundant that is 28 individuals.

On the other hand, the foraminifera composition at Station 6 has the highest abundance for each type of foraminifera found compared to other Stations, foraminifera identified and abundant at Station 6 including those of the Pseudorotalia foraminifera type (292 individuals), Oversight (188 individuals), Quinqueloculina (102 individuals), Calcarina (60 people), Orbulina (42 people).

At Station 6 there are also coral reef spots at the sampling location at a depth of 100 cm there is already small corals that can be said to be in good condition so that genus such as Peneroplis and Calcarina with high abundance is a characteristic of foraminifera that live on coral reefs in shallow water. Orbulina was also found with a high abundance of 42 individuals. Orbulina sp. is a type of foraminifera that characterizes deep-sea sediments, the presence of Orbulina at Station 6 is thought to be due to a fairly high current in this area, where the current itself helps the foraminifera move to other places [13].

In addition, the type of substrate at Station 6 also supports the life of foraminifera which is sandy mud. Benthic foraminifera is often found and lives well on sand sediment and sandy mud [3]. The same is true for every station that has a similar type of substrate, sand and sandy mud, but the condition of Station 6 is clean from rubbish and has clarity on large areas of coral reefs.

According to fishermen who are on Tunda Island, sand mining has not been done for a long time. So that the impact of sand mining does not affect the abundance of benthic foraminifera on Tunda Island. However, during the identification process, several foraminiferas were found whose shells were damaged. The overflow factor or absence of foraminifera at each station is caused by other factors such as waste, ie, garbage sent from the islands around Tunda Island and waste water that is discharged directly into the waters around Tunda Island.

3.4 Value of Benthic Foraminifera Diversity Index on Tunda Island

Diversity index values indicate the diversity of species of foraminifera on Tunda Island at each station having different values ranging from 1.55 – 2.24. The highest value is found at Station 4 with a value of 2 and the lowest value is found at Station 1 with a value of 1.55. The value of benthic foraminifera diversity index obtained at each station has an diversity index of 1.55; 1.81; 2.04; 2.07; 2.16; 2.24. The index value at each station shows that the index value of benthic foraminifera diversity on the coast of Tunda Island has a moderate diversity index value because the diversity index value is more than 1 and less than 3. Index value diversity of aquatic biota with a range of 1-2 indicates that waters are of moderate polluted quality and a diversity index value of range 1-3 indicates waters of mildly polluted quality [14].

3.5 Value of Benthic Foraminifera Dominance Index on Tunda Island

The results of the calculation of the dominance index foraminifera on Tunda Island ranged from 0.13 to 0.38. The dominance index value indicates the dominance of the foraminifera types at each station on Tunda Island. Benthic foraminifera dominance index values obtained at each station are 0.13; 0.16; 0.17; 0.19; 0.23 and 0.38. The highest dominance index value is at Station 1 with a value of 0.38 and the lowest value is found at Station 4 with a value of 0.13. If the value of dominance approaches 1, it means that in the community there is a genus that dominates other genera, whereas if it approaches 0, it means that there is no genus in the community structure that extremes dominates the other genus in the community [15].

4. CONCLUSION

In the waters of Tunda Island, 2 suborder found from benthic foraminifera have different shell wall compositions, namely Rotaliina with porous calcareous shells and Miliolina with porcelain limestone shells.

Tunda Island coast has an abundance of foraminifera of 1604 ind/gram. Consists of 55% Suborder Rotaliina and 45% Suborder. The most common shell wall group found on the Tunda Island Coast is the Suborder Rotaliina.

The highest abundance was found in Station 6 with the number of foraminifera of 732 ind/gram and the lowest was in Station 1 with the number of foraminifera of 129 ind/gram. The coastal waters of Tunda Island are dominated by Pseudorotalia schroeteriana and Pemoplis species.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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