The community structure of intertidal macrozoobenthos on muddy substrate in Lubuk Damar, Aceh Tamiang, Indonesia

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Abstract. Large intertidal areas with varying texture percentages may influence the composition, presence, and abundance of macrozoobenthos. This study aims to determine the community structure of benthic animals on muddy substrates at various distances, from January until November 2017. This study used the line transect method with the following variations in site: A: 0-100 m, B: 101-200 m, C: 201-300 m, D: 301-400 m and E: 401-500, with 10 replications. 11 phyla were found in the research location, namely Annelida, Platyhelminthes, Nematoda, Pogonophora, Sipuncula, Brachiopoda, Nemertina, Mollusca, Arthropoda, Cnidaria, and Echinodermata. Phylum Sipuncula dominated 93% compared to the 10 other families. The macrozoobenthos density at each sampling distance and time were significantly different. Additionally, the highest abundance was 12,187 ind/m², while the lowest was 500 ind/m². The diversity index ranged from 1.1 to 4.4, dominance between 0.1 to 0.7, and evenness between 0.2 - 0.9, respectively. At each observed distance, there were differences in type and number of macrozoobenthos, which was assumed to be caused by the different percentages of texture substrate at each sampling point. Furthermore, texture types with average compositions of 57% sand, 30% silt, and 12% clay had a higher diversity index than the other percentages’ composition.

Keywords: benthic; diversity; invertebrate; low tide; mangrove ecosystem

1. Introduction
Mangrove plays an important role in coastal ecosystems, including in the ecological, social, and economic aspects [1]. They also have unusually high productivity levels, which exceed 2 t ha⁻¹ yr⁻¹ supports the food web in both land and sea (pelagic and benthic) and contributes significant carbon to some offshore fisheries [2]. A survey on benthic communities have shown an important concurrent with
the increasing realization of their significant role in the trophic cycle [3]. Macrozoobenthos constitute a group of important fauna in mangrove ecosystem [4], an important community in the marine ecosystem, play a key role in the cycle of nutrition, decomposition, and as a food source for higher trophic levels [5]. Moreover, macrobenthic communities in soft bottom are key components in the functioning of coastal and marine ecosystems [6] as well as an important link in the food web in coastal wetlands [7]. Emphasized by [8] the importance of monitoring the invertebrate community structure consistently every year, to obtain data on the management of marine biological resources and conservation.

The mangrove macrobenthos are species that live in mangrove muds or depend on mangroves for all or part of their life-cycle. It encompasses some phyla, including Porifera (sponges), Mollusca (molluscs), Arthropoda (crabs, lobsters, prawns, etc.), Annelida (segmented worms), Nematoda (roundworms), Sipunculoidea (peanut worms), Platyhelminthes (flatworms), and Ascidians within the phylum Chordata [9]. The biodiversity of macrobenthos in the intertidal zone includes major polychaetes up to 83.5%, amphipods at 14.5%, and leftovers, consisting of various taxa e.g., isopods, crabs, hermit crabs, decapods, pelecypods, and gastropods [10].

The location of study on intertidal mangrove ecosystem was Lubuk Damar, Aceh Tamiang, Aceh Province. The substrate texture in this location was 39.67% sand, 50.95% silt, and 11.45% clay [11]. Furthermore, the mangrove vegetation included_Xylocarpus granatum, Soneratia alba, Aegiceras floridum, Acrostichum sp., Avicinena sp., Brugui`era parviﬂor, Brugui`era sexangula, Excoecaria agallocha, Lumit`era sp., Rhizophora apiculata, Rhizophora mucronata. Previous research on the relationship between benthos abundance and its distribution has not been performed. However, there was a 2011 study in form of an unpublished master's thesis on soil quality and the diversity of mangroves species in relation to the abundance of benthos. This research is a necessary first step to ascertain the aquatic resources related to benthos, as it helps provide recommendations in the field of mangroves or aquatic resource management.

![Figure 1](image)

Figure 1. Research location of three stations in the intertidal zone, Lubuk Damar, Aceh Tamiang, Indonesia, A1,2,3: 0-100 m, B1, 2,3: 101-200 m, C1,2,3: 201-300 m, D1,2,3: 301-400 m, and E1,2,3: 401-500 m.

This study aims to determine the community structure of macrozoobenthos in muddy substrates, based on the distance from the highest tide line to the lowest tide line in Lubuk Damar intertidal
mangrove ecosystem. Furthermore, it is expected to contribute erudition on the pattern of distribution of macrozoobenthos species in the intertidal area of the deep mangrove ecosystem, as a consideration for its management and aquatic resources.

2. Methods

2.1 Description of the study sites
Sampling was carried out from January 2017 until November 2017 in the mangrove ecosystem of Lubuk Damar, Aceh Tamiang. The substrate and macroinvertebrate samples were collected from three stations of the beach, including from the high tide line to lowest tide (A: 0-100 m, B: 101-200 m, C: 201-300 m, D: 301-400 m, and E: 401-500 m). The location and sampling stations are shown in figure 1.

2.2. Substrate and macrozoobenthos sampling
In this study, sediment samples were obtained with a PVC core at 2 inches and 20 cm depth. The substrate analysis was conducted in Soil Laboratory, Faculty of Agriculture, University of Syiah Kuala, Banda Aceh, Indonesia. Macrozoobenthos was obtained from three stations, six line transects, and thirty sites with low tide. Every site there were ten replications. Which were collected using a PVC core of 5 inches (12.6 cm) and depth of 20 cm. Macrozoobenthos samples were sieved with 1 mm, preserved in 5% formaldehyde, and kept for further analysis. Furthermore, in the laboratory, samples were washed through the 1 mm sieve and stored in 70% ethanol.

Macrozoobenthos were sorted and morphology identified at species level. General macrozoobenthos involved Fauvel [12], [13], [14], [15], while special identification involved Sternaspis [16], Brachiopoda [17], Sipuncula [18] and [19], Decapoda [20]. Laboratory works were performed in Bio-micro Laboratory, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University, West Java, Indonesia.

2.3. Data Analysis
The abundance and distribution of Macrozoobenthos communities based on the distance between the high and low tides were tabulated and determined via means of Microsoft Excel. The density is defined as the number of individuals present per unit area or per square meter and was calculated based on Shannon-Wiener [21]. Furthermore, the Diversity index (H') in each line was calculated according to [22], while dominance was ascertained using the Simpson Index of Dominance (D) and Evenness index (J) [23].

3. Result and discussion

3.1. Substrate
Further investigation was carried out to confirm the substrate type at various distances within the intertidal zone and was measured from the highest tide at 0 m. The sample point distance was divided into 5 points with the expectation of a difference in substrate condition, both in terms of texture and substrate type. From the results of 4 replications of substrate sampling, the average value or percentage was different for each distance. The texture percentage varied between 10% to 70% for each texture type in distinct stations (figure 2).

Figure 2 showed that in all stations the sand texture had a higher percentage than silt and clay. Point A at distance 0-100 m from the highest tide, had a greater percentage of 68% compared to other points, while that of silt was 25% and clay 11%. Point B had the following texture percentages: sand 46%, silt 42%, and clay 12%. Point C, which was located between 201 m- 300 m had a higher sand percentage than point B, namely 53%, 36% silt, and 11% clay. The location of point D within the 301 - 400 m distance had the following texture percentage: 53% sand, 37% silt, and 11% clay. The farthest distance from the high tide above 401 m totaled 51% sand, 36% silt, and 12% clay.
Figure 2. Percentage of substrate texture based on distance in the intertidal zone of the Lubuk Damar coast, Aceh Tamiang.

According to these conditions, the substrate at the study site was grouped into the Sandyloam, Siltloam, and Loam texture classes. Texture classes were further classified into A (loamy sand and sandy loam), B vary (Silt loam, loam, and sandy loam), C (Sandyloam), D (Sandyloam and loam), and E (loam and sandy loam). It is assumed that the existing variations influenced the density of benthic biota at that location. [24] stated that habitat characteristics can explain these variations in the community structure of infauna animals, therefore habitat changes affect the composition of the community trophic level on a higher scale. In addition, the substrate conditions also influence the types of invertebrates that are more abundant or dominant. For example, in the research which stated that sediment structure is dominated by very fine sizes (silt, clay), macrobenthic invertebrates will be dominated by molluscs [25].

In general, the substrate type in the intertidal zone of the Lubuk Damar coast within 0-500 m from the highest tide was not significantly different. However, it had a varied texture percentage, especially in point A, where three stations had the same substrate type, namely sandy loam. The substrate type at station 3 was also same as that of point A to E.

3.2. Abundance and diversity

From the results of this study, 11 phyla namely Annelida, Arthropoda, Brachiopoda, Cnidaria, Echinodermata, Platyhelminthes, Pogonophora, Mollusca, Nematoda, Nemertina, and Sipuncula, were found on the coastal intertidal zone in Lubuk Damar. The largest percentage was Sipuncula, while the remaining 93% consisted of the other 10 phyla (figure 3). Ten phyla were found in very limited numbers when compared to Sipuncula. The Annelida also had a high percentage of about 5% which was dominated by the Polychaeta family, while the other phyla were within the 0.01-0.7% range. The phyla at 0.01% included Cnidaria, Echinodermata, Nematoda, Platyhelminthes, and Rhodophyta. Phylum Arthropoda, Brachiopoda, Mollusca, and Nemertina were present at the study site between 0.3-0.7%. However, given that the research location had a higher number of phyla than on the Mangalore coast where there were only 4, namely Mollusca, Arthropoda, Annelida, and Echinodermata. [26], the estuary of the Susoh sub-district, Aceh Barat Daya, had 3 classes namely Malacostraca, Gastropoda and Bivalvia [27].

The results showed that Sipuncula was dominant in certain locations, as the research location had the characteristics of a Sipuncula habitat. Based on various research reports, it specified that presence of appearance in an area depend on sediments, depth, and latitude [28]. It was emphasized by [29] vertical distribution is limited by substrate characteristics. The Sipuncula is a deposit feeder that eats various kinds of food. Therefore, they ingest anything on the substrate surface, including detritus and sestonophages [28]. Several intertidal areas showed the varying compositions of macrozoobenthos. This is supported by previous research which stated that the sediment structure is dominated by very fine sizes (silt, clay), therefore, macrobenthos invertebrates are dominated by mollusks [29]. The diversity...
of the macrobenthos community is influenced by their adaptability and the abundance of food [30]. Furthermore, in the intertidal area of Bodo Creek, Nigeria, macrobenthos were found in compositions of 66.7% Polychaeta, 19.4% Mollusca, and 8.3% Decapoda [31].

During the study year, the density description based on the distance at each observation station is shown in figure 4. At station 1, precisely the texture sandy loam class, the highest density was located at point C (201-300 m) with a density of 10731 ind/m² while the lowest was at point E with a density of 5574 ind/m². In station 2 (figure 5) the highest density was located at point C with a total of 12187 ind/m² while the lowest was point A at 4599 ind/m². The highest density in station 3 (figure 6) was point B at 1527 ind/m², while the lowest was 500 ind/m². Therefore, this location has a higher density compared to that of other locations in Indonesia, for example in Taman Hutan Raya, Bali [32], Palabuhanratu [33], Indramayu, West Java [34].
The density at each point of observation signified that the macrozoobenthic density is influenced by substrate conditions. Based on the 3 existing stations, there is an expected density at points B, C, and D. These points describe the texture type in sandy loam to loam classes.

3.3. Index (Diversity, Dominance, and Evenness)
Based on the analysis in terms of diversity (H'), dominance (D), and evenness (J'), the Lubuk Damar intertidal zones at stations 1, 2, and 3, the index of diversity ranged from 1.1 to 4.4, dominance from 0.1 to 0.7, and evenness between 0.2 -0.9 (table 1). The range of H' values in the research location had a higher range and is distinct from other locations, such as in China [35]. The macrozoobenthic diversity index in Lubuk Damar tends to be higher when compared to Buleji and sunehri Karachi coast [36]. Furthermore, the various structures at the research location signify that each distance and texture class of the substrate provides an overview of the diversity, dominance, and uniformity of macrozoobenthos. The conditions described at the study site agree with previous studies [37] that substrate and habitat characteristics influence their diversity in fauna communities [38].

The results of the index analysis showed a tendency for station 3 to have a more stable H' value and a higher range than other stations, precisely between 2.4 - 4.4. The diversity index value was assumed to be stable, as the texture of the substrate class was sandy loam, from point A-E. Therefore, the texture substrate sandy loam class had a relatively high H' macrozoobenthos level with a more stable range. Furthermore, from figures 2 and 6, it is observed that the percentage of sand at station 3 did not exceed 60%, while the other 2 stations were higher, above 60%. Station 3 sand percentage was more even, compared to point A-E. The silt percentage was also stable at less than than 30% and loam below 20%.

| Station | Sites | Diversity (H') | Dominance (D) | Evenness (J') |
|---------|-------|----------------|---------------|--------------|
| 1       | A     | 1.4            | 0.6           | 0.3          |
|         | B     | 1.3            | 0.7           | 0.3          |
|         | C     | 1.1            | 0.7           | 0.2          |
|         | D     | 1.3            | 0.7           | 0.3          |
|         | E     | 2.2            | 0.5           | 0.5          |
|         | A     | 1.2            | 0.5           | 0.4          |
|         | B     | 1.3            | 0.7           | 0.3          |
| 2       | C     | 1.3            | 0.6           | 0.3          |
|         | D     | 1.8            | 0.5           | 0.4          |
|         | E     | 1.9            | 0.5           | 0.4          |
|         | A     | 3.0            | 0.3           | 0.7          |
|         | B     | 2.9            | 0.4           | 0.6          |
| 3       | C     | 4.4            | 0.1           | 0.9          |
|         | D     | 3.4            | 0.2           | 0.7          |
|         | E     | 4.2            | 0.1           | 0.9          |

The D and J’ indexes, respectively, ranged between 0.1-0.7 and 0.2-0.9, as shown in table 1. The two index values represent conflicting conditions: the smaller the D value, the higher the J index. The dominance index is a description of the biota that dominates an area. The research location has a D index above 0.5 at station 1 and 2, while station 3 was below 0.4. When index D is compared with H' (figure
6), then the relationship can then be described. The H’, D, and J’ indexes of the research results when compared to other intertidal areas were classified to have an H’ index which ranges higher than the mangrove areas of Ngarah Rai Bali Forest Park at 0.67-2.00 [39] and the Shirgaon intertidal zone, Maharashtra, India, between 1.5-1.7. Therefore, index D of the study sites has a wider range than the intertidal zone of Shirgaon, Maharashtra, India [40]. The evenness index has a value range higher than Uran coast, Navi Mumbai [41].

Index J’ depicts the distribution of individuals: the smaller the uniformity index, the smaller the population distribution, which is interpreted as the number of distributions per species [42]. Index J’ is the opposite of index D, for example in stations 1 and 2 there were high D values, which resulted in low J’ values. In contrast to station 3 which has been discussed in the previous paragraph, station 1 and 2 had a relatively smaller diversity. Furthermore, as shown in figure 2, when the substrate texture type is 57% sand, 30% silt, and 12% clay, then index H’ has a higher range than the station having textures of sand 50-52%, silt 37-38%, and clay 11%. The difference in substrate texture type influences the abundance and diversity of macrozoobenthos. This agrees with the statement that when the density of macrozoobenthos correlates with soil texture, organic carbon, pH [32] and muddy sediments in the intertidal area, there is a complex interaction between physical, chemical, biological, or sediment actors and benthic organisms living within or on it [44].

4. Conclusion
These results agree with previous studies that the relationship between abundance and macrozoobenthos species diversity is influenced by their habitat. The dominance of certain species is believed to occur due to the composition of different texture types. In this study, a novelty is presented that the macrozoobenthos community structure in the intertidal area is influenced by texture composition. Furthermore, the results showed that high diversity values were observed in the sandy loam substrate class. Texture types with average percentages of 57% sand, 30% silt, and 12% clay have a higher diversity index than the other texture types.

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References
[1] Basyuni M, Gultom K, Fitri A, Susetya I E, Wati R, Slamet B, Sulistiyono N, Yusriani E, Balke T, and Bunting P 2018 Biodiversitas 19 (1):311-317
[2] Manson F J, Loneragan N R, Skilleter G A, Phinn S R 2005 An evaluation of the evidence for linkages between mangroves and fisheries: a synthesis of the literature and identification of research directions Oceanogr Mar Biol Annu Rev. 43, 483–513
[3] Pillai N G 1976 Indian J. Mar Sci (6):1-5
[4] Onerizal, Simarmata F S P, and Wahyuningsih H 2009 Natur. 11(2): 94-103
[5] Dauer D M, Ranasinghe J A, Weisberg S B 2000 Estuarie. (23):80-96
[6] Lu L 2005 Mar Pollut Bull. 51: 1034-1040
[7] Chen L, Yan T, Xiong Y, Zhang Y, and Lin G 2016 Estuar Coast Shelf Sci. 187: 160-167
[8] Rifai H, Perisha B, Zulpiak F, Renyaan J, Anggiani M, and Rasyidin A 2020 Omni-Akuatika 16(1): 69-76
[9] Ellison A M 2008 J Sea Res. 19:2-15
[10] Anandan K, Varshney PK, Jaiswar A K, Prakash C 2003 J. Indian Fisheries Asso. 30: 9-17
[11] Darmarini A S, Wardiatno Y, Prartono T, and Soewardi K 2017 Biodiversitas 18: 1438-1444
[12] Fauvel P 1953 Annelida Polychaeta in The fauna of India including Pakistan, Ceylon, Burma, and Malaya (Ed Seymour-Sewell, R B) (Allahabad: The Indian Press, Ltd.) p 1-507
[13] Gosner K L 1971 Guide to Identification of Marine and Estuarine Invertebrates (Cape Hatteras
to the Bay of Fundy John Wiley) 693 p

[14] Kozloff E N 1974 *Marine Invertebrate of the Pacific Northwest* (University of Washington Press) 511p

[15] Fauschald K 1977 *The Polychaete Worms. Definitions and keys to the orders, families, and genera*
Natural History Museum of Los Angeles *Count Sci Series* 28: 1–190

[16] Sendall K and Salazar-Vallejo S I 2013 *ZooKey*. 286:1-74

[17] Emig CC 2003 *Proof that Lingula (Brachiopoda) is not a living fossil, and emended diagnoses of the Family Lingulidae* Carnets de Géologie/Notebooks on Geology, Maintenon, Letter 2003/01 (CG2003_L01_CCE)

[18] Cutler E B, Cutler NJ, and Nishikawa T 1984 *Sipuncula of Japan: Their systematics and distribution.* Publication of the Seto Marine Biological Laboratory. Kyoto University 29(4-6): 249-322

[19] Hylleberg J 2014 *Classification and identification of sipunculans from Thailand, with description of new species, and a new subgenus* Phuket Marine Biological Center 32 p

[20] Poore G C B 2004 *Marine decapod crustacea of southern Australia* A guide to identification. (CSIRO Publishing) 574 p

[21] Odum E P 1971 *Fundamental of ecology* (Philadelphia: W.E. Sounders)

[22] Shannon C E 1948 *Bell Syst Technic J.* 27: 379-423, 623-656

[23] Brower E, James, Zar J, and Ende CV 1998 *Field and Laboratory Methods of General Ecology* (New York: MCGraw-Hill)

[24] Coblenzt K E, Henkel J R, Sigel B J, and Taylor C M 2015 *PeerJ* 3ex1014:1-13

[25] Dandan R T and Diocoton R C 2019 *Aloha Int. J. of Multidiplinary Advancement* (AIJMU) 1(4): 76-81

[26] Daggula N, M T Lakshmipathi, A Padmanabba, Reddynaik V, Lingesh, Kovvuri C, H S Jishi P 2019 *J. Ento Zool Stud*. 7(1):256-263

[27] Sidik R Y, Dewiyanti I, Octavina C 2016 *Jurnal Ilimah Mahasiswa Kelautan dan Perikanan Unsyiah* 1(2): 287-296

[28] Kendra M, Grebmeier JbM, and Cooper LW 2018 *Polar Biol*. 41: 163-174

[29] Hylleberg J 1975 *(On the ecology of the Sipunculan phascolion strombi)* (Montagu). In Rice ME, Rodorovic M (eds) Proceedings of the international Symosium on the biology of the Sipuncula and Enchiura. Belgare. 241-250

[30] Murina G V V 1984 *Ecology of Sipuncula* Mar Eco Prog Series. 17: 1-7

[31] Dandan R T and Diocoton R C 2019 *Aloha Int. J. of Multidiplinary Advancement* (AIJMU) 1(4): 76-81

[32] Yokohama H, Tamaki A, Koyama K, Ishihi Y, Shimoda K, Harada K 2005 *Mar Ecol:Prog Ser.* 304:101-116

[33] Zabbey N and Arimoro F O. 2017. *Environmental forcing of intertidal benthic macrofauna of Bodo Creek, Nigeria: Preliminary index to evaluate cleanup of Ogoniland. Regional Studies in Marine Science.* 16:89-97

[34] Fitriliana YR 2006 *Biodiversitas*. 7(1): 67-72

[35] Wardiatno Y, Qonita Y, Mursalin, Zulmi R, Krisanti M, Mashar A, Hariyadi S, Hakim A A, Sahidin A, Widigdo B, Nursiyamah S 2017 *Earth Envirom Sci*. 54:1-13

[36] Sihombing V S, Gunawan H, Sawitri R 2017 *Biodiversitas* 18(2): 601-608

[37] H Jiao, D Zheng, Z You, N Xu, D Lou, and C Huang 2015 *J Ocean Univ China*. 14(2): 375-384

[38] Ali Q M, Ghory F S, Ahmed Q, Siddique S, Mubarak S, Memon 2019 *Pakistan J. of Mar Sci* 28(2):137-154

[39] Gray J S 1974 *Oceanogr. Mar. Biol. Annu. Rev.* 12: 223-261

[40] Coblenzt K E, Henkel J R, Sigel B J, and Taylor C M 2015 *PeerJ* 3ex1014:1-13

[41] Fitriliana Y R 2006. *Biodiversitas* 7(1): 67-72

[42] Satish M K, A D Adsul, ST Indulkar, and R Pai 2018 *Int. J. of Life Sciences* 6(1):156-160

[43] Pawar P R and A I Tawaha ARM 2017 *Advan Environ Biol*. 11(11): 34-50.
[44]  Krebs C J 1985 *Ecology: The Experimental analysis of distribution and abundance* Third edition (New York: Harper and Row Publisher)

[45]  Onrizal, Simarmata F S P, Wahyuningsih H 2009 *Natur*. 11(2): 94-103

[46]  Chapman MG and Tolhurst T  J 2007 *J Exp Mar Biol Ecol* 343(1): 96-109