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Population structure of *Lingula* (Bruguière, 1791) in Alue Naga waters, Banda Aceh City, Indonesia

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ABSTRACT

Lingula sp. is one of the genera of the Brachiopoda phylum that lives in the intertidal zone or areas that are affected by tides. The purpose of this study was to determine the population structure of *Lingula* sp. through the approach of population structure, density, distribution patterns, length and weight relationship and with physical and chemical parameters in the waters of Alue Naga, Syiah Kuala District, Banda Aceh City. The method used in this research is a purposive random sampling method. The results show that the growth pattern of *Lingula* sp. is classified as negative allometric at three research sites in Alue Naga waters, based on the value of b <3. The density of *Lingula* sp. was the highest at site 1 with a total of 17.7 ind/m². While the density of *Lingula* sp. was the lowest at site 3 with a total of 9.7 ind/m². The distribution of *Lingula* sp. at the three sites were uniform, with morisita index (I_d) values of 0.352, 0.257, and 0.208 for sites 1, 2, and 3 respectively. In addition, the environmental factors of the three research sites in Alue Naga waters are within the normal limits of life for *Lingula* sp.

Introduction

Geographically, Syiah Kuala District is located at 05 ° 36'17 ".02 North Latitude and 95 ° 21'36" .93 East Longitude (BPS Kota Banda Aceh, 2013). One of the species that can be found in this District is *Lingula* sp. which is a member of the Brachiopoda phylum that lives in the waters of Alue Naga, Syiah Kuala District, Banda Aceh City. Phylum Brachiopoda are marine animals with hard shells on both their upper and lower surfaces, where one shell is larger than the other (Bitner, 2009; Carlson, 2016; Harper *et al.,* 2017).

For *Lingula* sp. their shell gives them a special shape resembling an oil lamp (Santagata, 2015). Some Brachiopods still exist today, but the majority existed 350-750 million years ago. According to Jackson *et al.* (1971) and Jain (2017), *Lingula* sp. is one of the species of Phylum Brachiopoda that lives in the intertidal zone and is called a living fossil.

Lingula sp., also commonly known as lamp shells due to its shape that resembles an oil lamp, has a size range of 5-80 mm, though some fossil species measures up to 30 cm (Romimohtarto and Juwana, 2007; Emig *et al*., 2013; Luo *et al*., 2015; Shimizu *et al*., 2017; Ye *et al*., 2018).

Lingula sp. are commonly found in Indonesian waters, especially in the waters of Ambon and Kalimantan (Jackson and Stiasny, 1937). Previous research regarding *Lingula* sp. has also been done by Agustina *et al.* (2019) and Octavina *et al.* (2021) who studied growth patterns, density and distribution patterns of *Lingula* sp. in Ujong Pancu Beach and Syiah Kuala Beach. However, no research has been conducted on *Lingula* sp. which examines the structure of their population. In general, the literature on *Lingula* sp. are still very limited. Currently, the consumption of Lingula sp. by local communities has been increasing, therefore

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researchers want to learn more about their population structure. Information about *Lingula* sp. from existing studies would be used as a reference for researchers to conduct research in Aceh waters, especially in Alue Naga waters, Syiah Kuala District, Banda Aceh City.

Materials and Methods

This research was conducted from April to June 2020 at Alue Naga Waters, Syiah Kuala District, Banda Aceh City. Identification of *Lingula* sp. was conducted at the Marine Biology Laboratory, Faculty of Marine Affairs and Fisheries, Syiah Kuala University using the http://species-identification.org/index.php portal. The research location is shown in Figure 1 below:

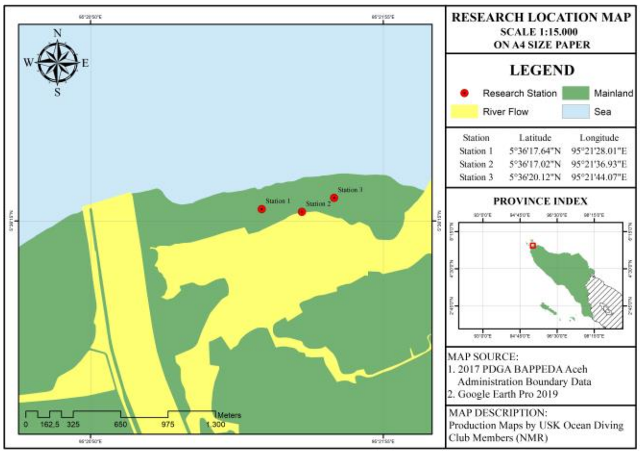

Figure 1. Map of the research location.

Data analysis

a. Density

To determine the density, the number of *Lingula* sp. found in an area is divided by the size of the area. Referring to Brower *et al.* (1997), namely by using the following formula:

$$D = \frac{Ni}{A}$$

Information :

D = Density of *Lingula* sp. (Ind/m^2)
Ni = Number of individuals (Ind)
A = Lookout area (m^2)

b. Distribution Pattern

The distribution pattern of the total number of individuals in an area can be determined by linking the water quality and substrate factors. The reference formula used based on Brower *et al.* (1997) can be seen below:

$$I_d = \frac{\sum ni^2 - N}{N\,(N-1)}$$

Information:

I_d = Spread index
Ni = Number of individuals (Ind)
N = Total individuals (Ind)

After analyzing the formula above, it will then be grouped based on the number of its I_d values. If the I_d value is <1, the distribution of individuals is uniform, while if the Id value is >1 it means that the distribution of individuals is grouped.

c. Length and weight relationship

The length-weight relationship is a basic component of species biology at the individual and population level. Length-weight data can be used to obtain estimates of seasonal variations in growth or productivity as well as physiological investigations (Romimohtarto and Juwana, 2007). For *Lingula* sp. this can be determined from the relationship between shell length and body weight (wet weight) which is analyzed using the following equation:

$$Y = {}_aX^b$$

Information :

Y = Total weight (g)
X = Total length (mm)
a and b = Constanta

The results of the analysis of the length-weight relationship of *Lingula* sp. will produce a value, namely (b) which gives the rank of the growth pattern. Ricker (1970) states that the isometric pattern (b = 3) is defined as a balanced length and weight relationship, while the allometric pattern (b ≠ 3) is defined as an unbalanced length and weight relationship. Growth is defined as positive allometric if b >3, which means the weight gain is faster than the length gain. The allometric pattern is negative if b <3, this means that the length increases faster than the weight gain.

d. Substrate

The substrate data analysis mechanism is done by determining the percentage of sand, dust, and clay. In general, determining the percentage of sand, dust and clay content can be done by referencing the following substrate triangle from the USDA (The United States Department of Agriculture) (Gee and Bauder, 1986).

Results

Table 1 shows that the highest density value was found at site 1 with a total of 17.7 ind/m^2. The high density at site 1 is due to the condition of the substrate at this site (sandy substrate), which is suitable for *Lingula* sp. growth. This is reinforced by

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the statement of Simanjuntak *et al.* (2018) that the sediment texture will affect the population structure of benthic animals. Benthic type organisms prefer a sandy texture and have a wider distribution because they are able to adapt to sea water habitats.

Table 1. Density of *Lingula* sp.

time of week	Density of *Lingula* sp. (ind/m^2)		
	*St.1 (Sand)	*St.2 (Sand)	*St.3 (Clay Sand)
1	9.5	7.2	3.1
2	3.8	2.7	1.9
3	2.3	2.2	2.2
4	0.8	0.7	0.5
5	0.6	1.9	0.8
6	0.7	1.8	1.2
Total	17.7	16.5	9.7
Average	2.95	2.75	1.61

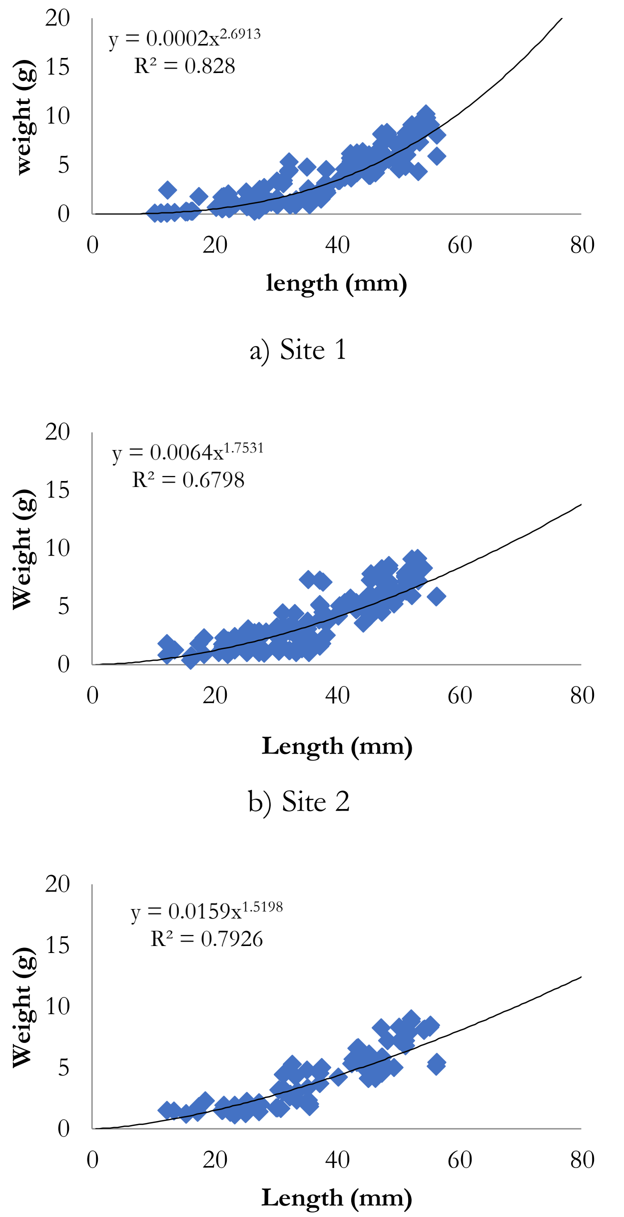
The results in Table 2 indicate that the distribution pattern of *Lingula* sp. based on the morisita index value (Id) at the three sites are uniform. The morisita index value at site 1 is 0.352, while at site 2 is 0.257 and at site 3 is 0.208.

Table 2. Distribution pattern of *Lingula* sp.

Sites	Id	Distribution Pattern
1	0.352	
2	0.257	Similar
3	0.208	

The relationship length and weight of *Lingula* sp. shell shows a significant correlation with R^2 values ranging between 0.67 to 0.89 (Figure 3). These values are close to one, which means that shell length (X axis) is a good predictor for body weight (Y axis) with a high degree of correlation at the 91% confidence level.

Based on Figure 4a, it can be seen that the highest frequency (number of *Lingula* sp.) among the three sites is for the length growth category of 24.6 - 29.3 mm with 32 individuals at site 1, and for the length growth category of 43.9 - 48, 6 mm with 32 individuals at site 1, while the lowest was in the length growth category of 10.2 - 14.9 mm with 2 individuals at site 2.



a) Site 1

b) Site 2

c) Site 3

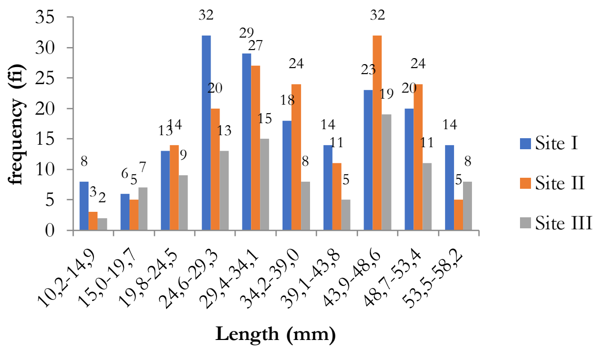
Figure 3. (a, b, and c) long strenuous relationship of *lingula* sp.

In Figure 4b, it can be seen that for the frequency of *Lingula* sp., the highest of the three sites is the weight growth size category of 1.1 - 2.1 g with 60 individuals at site 1, while the lowest was in the weight growth size category of 0.05 - 1.09 g with a total of 0 individuals.

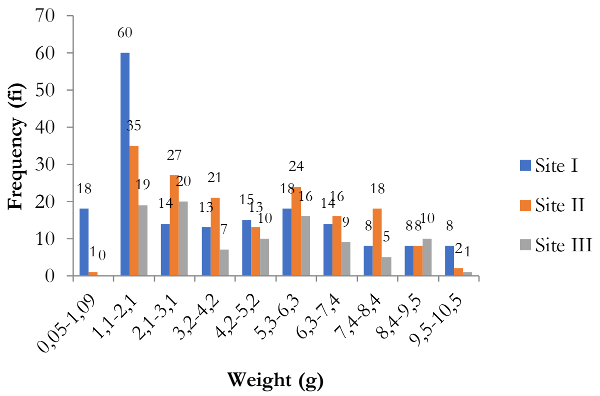
Discussion

The factor that caused the density of *Lingula* sp. at site 1 to be higher is that the degree of acidity (pH) measured in the waters was at an average of 7.9. This is reinforced by the statement of Cholik (2007) and Zaky *et al.* (2016) which states that the ideal pH range of water that supports the life of benthos, including *Lingula* sp., ranges from 6-9.

Octavina *et al.* (2021) and Sun *et al.* (2018) states that waters with a pH that is too high or too low will affect the survival of the organisms that live in it. Therefore, the pH that supports the life of *Lingula* sp. at site 1 greatly affects the high density of *Lingula* sp.



a)



b)

Figure 4. (a and b) Length and weight interval class of *Lingula* sp.

Table 4 above also shows that the lowest density was recorded at site 3 with a total value of 9.7 Ind/m^2. The potential cause of the low-density value at site 3 can be seen in the different substrate conditions. The substrate at site 3 is clay sand, which is different from the substrate at sites 1 and Site 2. Octavina *et al.* (2021) states that benthos is more likely to be abundant in coastal waters that have sandy sediment substrate, because benthos is a group of suspension-feeding, digging and deposit-eating animals. This is also confirmed by the results of this study, therefore, because the substrate does not support growth at site 3, which resulted in low density.

Field observation results of *Lingula* sp. over the three observation sites, can be seen in Table 2. Michael (1984) and Fujii *et al.* (2019) states that the distribution patterns of organisms in nature can be divided into three types, namely uniform (if the individuals are evenly distributed in the population), random (if individuals are scattered in several places but there are also clustered elsewhere) and grouped (if the individuals are always in groups and rarely scattered).

Table 2 shows that the distribution pattern of *Lingula* sp. based on the morisita index value (I_d) at all three sites are similar, with the morisita index value at site 1 is 0.352 while at site 2 is 0.257 and at site 3 is 0.208. The uniformity of *Lingula* sp. distribution at all three sites are thought to have been influenced by the aquatic environment and the type of substrate. Krebs (1972) and Liang *et al.* (2020) states that the distribution pattern can be influenced by the type of substrate, the physical and chemical parameters of the waters, the availability of food and the adaptability of an organism in an ecosystem.

The length-weight relationship of aquatic organisms is used to predict the growth patterns of these organisms. This relationship can be estimated through the distribution trends of length and weight data obtained from the measurement of the morphometric components. The estimation of parameter b, the coefficient of the length and weight relationship, is analyzed using a power regression approach simplified through linear transformation (Petetta *et al.*, 2019; Azmy and Jin, 2019).

Based on the value shown in the graph, the length and weight relationship at the three sites show a value of b <3, indicating a negative allometric growth pattern. Effendie (1997) and Yang *et al.* (2013) states that negative allometric growth happens when the increase in length is faster than weight gain. Whereas site 1 shows a very significant negative allometric growth shown by a more uphill curve, the third site shows a much more gradual slope.

The balance of this growth pattern can be seen from the b value in the relationship between length and body weight (Zeng and Yang, 2021; Octavina *et al.*, 2021). The increase or decrease of growth pattern that occurs affect the b value and the R^2 value contained in *Lingula* sp. Negative allometric growth in *Lingula* sp. Is estimated to be related to its flat and elongated shape, since to achieve this shape the increase in shell length has to be faster than the increase in weight.

The results of the spatial analysis show the constant value of b for *Lingula* sp. The highest was recorded at Site 1 with a b value of 2.69 and R^2 value of 0.828 and Site 2 with a b value of 1.72 and R^2 value of 0.679 while the lowest was at Site 3 with a b value of 1.51 and R^2 value of 0.792. Overall, the three sites have b values of <3, which means that the allometric growth pattern is negative at all sites. This is in accordance with the statement from Findik *et al.* (2014) that if the value of b is smaller than 3, the growth pattern is said to be negative allometric and vice versa.

The factors that influence the high b value at site 1 are mainly linked to internal factors, namely genes and age. This is indicated by the larger size interval at site 1 compared to the other sites. As stated by Topper *et al.* (2015), Goto *et al.* (2014) and Collin *et al.* (2019) that differences in growth patterns that occur can be caused by two factors, namely internal factors that tend to be difficult to control, such as heredity (genes) and sex, and external factors, namely parasites, disease, food, and temperature.

The difference in height and low-class interval at the three sites does not appear to be influenced by water quality, but it is suspected that the factors that influence the high value of the *Lingula* sp. are more linked to internal factors, namely genes and age. This is indicated by the larger size interval at site 1 compared to the other sites. As stated by Holmer *et al.* (2018) and Balseiro *et al.* (2014) that differences in growth patterns that occur can be caused by two factors, namely internal factors that tend to be difficult to control, such as heredity (genes) and sex, and external factors, namely parasites, disease, food, and temperature.

Based on the length class interval in Figure 4a and the weight class interval in Figure 4b, it can be concluded that the frequency (number of *Lingula* sp.) in the length class interval is higher than the growth frequency in the weight class interval. This is presumably due to the elongated and flattened shape of *Lingula* sp. and its life at the bottom of the substrate which makes *Lingula* sp. to increase its body length faster than its body weight in order to adapt to its environment.

Conclusion

Lingula sp. density was highest at site 1 with an average value of 2.95 ind/m^2. While the density of *Lingula* sp. was lowest at site 3 with an average value of 1.61 ind/m^2. Distribution patterns of *Lingula* sp. for all three sites were uniform, with morisita index (I_d) values for sites 1, 2, and 3 measured at 0.352, 0.257, and 0.208 respectively. *Lingula* sp. tends to form a negative allometric growth pattern, which is when the increase in length is faster than the weight gain. The physico-chemical factors of the aquatic environment were classified as normal and able to support the life of *Lingula* sp. in Alue Naga Waters, Syiah Kuala District, Banda Aceh City.

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