Study of *Anadara antiquata* stock in Kuala Puteri Beach, North Sumatra

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Abstract. *Anadara antiquata* is utilized as alternative protein source with important economic value. Its high market demand causes uncontrolled catching by the communities on the coastal waters of Kuala Puteri, North Sumatra, which leads to natural population decline. The research objective was to analyze the stock of *A. antiquata* in the Kuala Puteri beach including density, distribution, growth patterns, growth parameters, long frequency distribution, mortality rates, and recruitment. Method used was simple random sampling using sero pipette during low tide, on 5 plots for each station, observed for 7 days on each of the 8 months of the study, and data analysis for each parameters. The highest *A. antiquata* density was at station 2 out of 3 total stations (444 ind m^{-2}) and the lowest was at station 1 (290 ind m^{-2}). *A. antiquata* distribution patterns at each station are a group with growth pattern of negative allometric. The frequency distribution of *A. antiquata* shell length from May to October 2020 shifted to left indicating recruits and formation of new shell length classes. Based on minimum shell length (16.2 mm) and maximum shell length (61.9 mm), the captured *A. antiquata* was estimated to be 1.3-4.8 years old. The theoretical lifespan at zero (t0) shell length is 0.02 years or 0.24 months. The total mortality rate for *A. antiquata* was 0.82 $year^{-1}$, the natural mortality rate was 1.29 $year^{-1}$, and the fishing mortality rate was 0.47 $year^{-1}$. The recruitment peak occurred in September 2020 at 23.29% with an optimal exploitation value (e = 0.5). This means current fishery management can be continued.
Key Words: *A. antiquata*, distribution, growth, mortality, recruitment.

Introduction. *Anadara antiquata* is a fishery commodity that has high economic value and is widely consumed by the people of North Sumatra to meet protein needs. This type of shellfish is very popular with people because it has a high nutritional content. Abdullah et al (2013) reported that *A. antiquata* meat contained 79.69% water, 1.57% ash, 2.29% fat, 12.89% protein, 3.56% carbohydrates, 0.83% amino acid arginine, and 1.74% amino acid glutamate. Awang-Hazmi et al (2007) also reported that this shellfish contains 98% Ca, 0.05% Mg, 0.9% Na, and 0.02 phosphate which are very good for consumption. Furthermore Maani et al (2017) reported that *A. antiquata* contains 7.06-16.87% protein, 0.40-2.47% fat, 2.36-4.95% carbohydrates, and 69-88 kcal of energy in 100g meat.

Kuala Puteri Beach is one of the beaches located in Serdang Bedagai Regency, North Sumatra. Many fishermen who live around the area take *A. antiquata* as a marine catch, both for consumption and sale to the market. The catch of *A. antiquata* in these coastal waters is expected to increase throughout the years, in line with the increasing market demand for this commodity. If this condition is allowed to continue without any restrictions, it will reduce the stock of biota in nature. Until now, data and information on the population dynamics of *A. antiquata* in the coastal waters of Kuala Puteri have never been obtained. Based on this, research is necessary for monitoring the sustainability of *A. antiquata* stock in Kuala Puteri beach.

Material and Method

Description of the study sites. The research was conducted for 8 months (April-November 2020) in the waters of Kuala Puteri Beach, North Sumatra. The study was focused on 3 stations using purposive sampling method. Station 1 represents the upper zone which is the high tide area, station 2 represents the middle zone which is the middle area between high and low tide, and station 3 represents the lowest tide area (Figure 1).

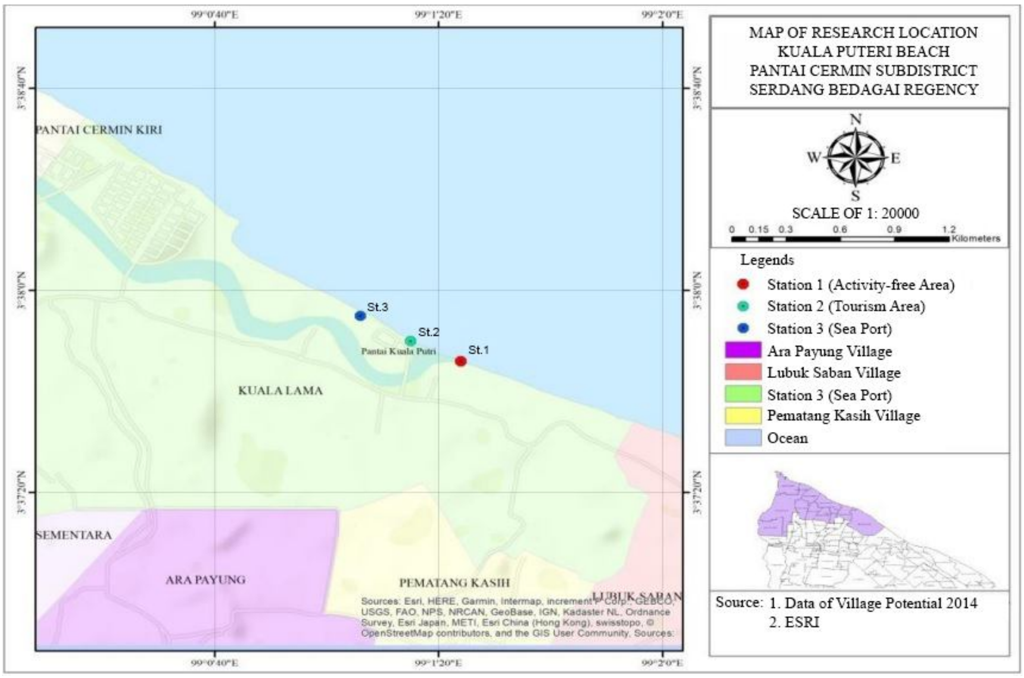

Figure 1. Map of the research location.

Sampling of A. antiquata. *A. antiquata* samples were taken using Sero measuring pipette at low tide in the morning (05.00-10.00 am). At each station a plot measuring 10 m x 10 m was made with a distance between the plots of 20 m. The *A. antiquata* obtained were collected and separated based on size, then the weight of the catch of each individual was calculated at each station. Sampling was carried out with time intervals of 7 days/month in 8 months of observation (Harahap et al 2018).

Data analysis

Abundance. The abundance of *A. antiquata* was analyzed using the equation according to Michael (1994) as follows:

$$D_i \text{ (ind m}^{-2}\text{)} = \frac{n_i}{A}$$

where: n_i = number of individuals (ind);
A = plot area (m^2).

Distribution pattern. The distribution patterns were analyzed based on the Morista distribution index (Michael 1994) as follows:

$$Id = n\left[\frac{\left(\sum_{i=1}^{n} x_i^{\,2}\right) - N_i}{N_i\left(N_i - 1\right)}\right]$$

where: Id = Morista distribution index;
n = number of stations;
Ni = total number of individuals;
x_i^2 = number of square.

Relationship between shell length and body weight. The relationship between shell length and body weight of *A. antiquata* was analyzed using growth pattern analysis (Sparre & Venema 1999):

$$W = {}_aL^b \text{ or } \mathrm{Ln}\, W = \mathrm{Ln}\, a + b\, \mathrm{Ln}\, L$$

where: W = weight (g);
L = length of shell;
a and b = constants.

Frequency distribution of shells length. The frequency distribution of *A. antiquata* shell length was analyzed by determining the number of class interval needed, using the formula according to Power & Walker (2006) as follows:

$$K = 1 + 3.3 \log N$$

where: K = growth coefficient;
N = number of individuals.

Growth parameters. Growth parameters were analyzed using the Fisat II program based on shell length frequency data. From this value, von Bertalanffy's growth parameter equation is obtained which describes the shell length as a function of age (Sparre & Venema 1999):

$$L_t = L_{00}\ (1 - e^{-K(t-t_0)})$$

$$\frac{L_t}{L_{00}} = 1 - e^{-K(t-t_0)}$$

$$\frac{1 - L_t}{L_{00}} = e^{-K(t-t_0)}$$

where: L_t = length of shell at time t;
L∞ = total length of the asymptote;
K = growth coefficient;
t = specific individual age;
t_0 = theoretical age at zero length.

The shell length data was used because the growth of *A. antiquata* greatly affects the size of the shell length. The growth equation is plotted in the form of the von Bertalanffy growth curve, and from this equation the theoretical age of *A. antiquata* can be deduced.

Mortality rate. Natural mortality rate (M) was analyzed using the equation:

$$\text{Log } M = 0.0066 - 0.279 (\log L_\infty) + 0.6543 (\log K) + 0.643 (\log T)$$

where: L∞ = total length of the asymptote;
K = growth coefficient;
T = average water temperature.

The total mortality rate (Z) was analyzed using the equation:

$$Z = K \frac{L\infty - L'}{Lc - L'}$$

where: L' = average total length;
L∞ = total length of the asymptote;
Lc = length of shells caught first.

The catch mortality rate (F) was analyzed using the equation:

$$F = Z - M$$

where: Z = total mortality rate;
M = natural mortality rate.

Recruitment. Recruitments were analyzed using the patterns from the FISAT II program. Input data in the form of growth parameters such as maximum shell length (Loo), growth coefficient (K), and shell length at time t = 0 (until), were obtained from the results of Elefan I's analysis in the FISAT II program. The relative results per recruitment can be seen from the analysis of results per recruitment of Holt and Beverton in the FISAT II program, by inputting data on maximum shell length (Loo), length of the first captured shell (Lc), natural mortality (M), growth coefficient (K), and the total mortality rate (Z).

Results and Discussions

Abundance. The results of the analysis (Table 1) show that the highest *A. antiquata* density was at station 2 with a total of 444 ind m^{-2}, and the lowest is at station 1 with a total of 290 ind m^{-2}.

Table 1

Abundance of *A. antiquata* at every station

Month	*Abundance (ind m^{-2})*		
	Station 1	*Station 2*	*Station 3*
May	39	65	57
June	29	56	54
July	59	72	66
August	61	92	82
September	49	83	72
October	53	76	64
Total	290	444	395

Station 2 has a higher density than stations 1 and 3. This is because station 2 is a catching area for *A. antiquata* shells in the waters of Kuala Puteri Beach, North Sumatra. At this station, there are often fishermen who catch *A. antiquata*. In addition, the environmental conditions at station 2 are more supportive for *A. antiquata*'s life compared to the other two stations. This can be seen from the availability of natural feed in the form of C-organic content which is also higher at station 2 compared to stations 1 and 3 (Table 2).

Table 2

C-organic content at each station

Parameter	*Station*		
	1	*2*	*3*
C-organic (%)	1.68	2.45	1.90

High C-organic content will have a positive impact on the density of *A. antiquata* in the water. Habonaran et al (2015) stated that the C-organic content in the substrate affected the density of macrozoobenthos, including *A. antiquata*. Hamidah (2000) also states that the C-organic content in the substrate is a food source for the bivalve animal group. Taqwa et al (2014) stated that the level of C-organic in the substrate will affect the life of aquatic organisms. Furthermore, Widiana et al (2016) also stated that there was a close relationship between *A. antiquata* population density and the C-organic content in the substrate. This is because the C-organic content in the substrate represents the fertility of the waters.

Distribution pattern. Based on the *A. antiquata* abundance data obtained, then the distribution index analysis was carried out at each station using the Morista distribution index analysis as presented in Table 3.

Table 3

Distribution index at each station

Station	*Distribution index*
1	3.87
2	1.05
3	1.67

The criteria for distribution patterns according to Mulya (2019) can be grouped based on the Morista distribution index value, namely: if the distribution index value (Id) = 1.0, then the population distribution is random; if Id = 0, then the population distribution is normal; and if Id ≠ 1 or Id ≠ 0, then the population distribution is grouped. The results of the analysis (Table 3) show that the distribution of *A. antiquata* at each station is included in the grouping distribution pattern. Since it requires specific water temperature of 24-31^{o}C, water current and salinity, the community's pattern contributes significantly to the preservation of bivalve species, in order to maintain survivability of the *A. antiquata* population (Syukur et al 2021).

Relationship of length and weight. The relationship between length and weight was analyzed using linear regression. The analysis showed that *A. antiquata* caught at each observation station for 8 months had a length and weight relationship as in the equation Log W = 0.0086 + 1.9167 log L or in exponential form: $W = 0.0086L^{1.9167}$, with the correlation coefficient (R^2) = 0.6364. The relationship of length to weight *A. antiquata* can be seen in Figure 2. The value of b shows the growth pattern of *A. antiquata*, while the closeness of the shell length and body weight can be seen through the correlation coefficient (R^2) so that through this equation it can be determined whether the population of *A. antiquata* in Kuala Puteri Beach, North Sumatra can be estimated from its body weight through the length of its shell.If the value of b = 3, then the growth is said to be isometric or the increase in shell length equals weight gain, and if the value of b > 3 or b < 3, then the growth is called allometric or the increase in shell length does not equal the increase in weight (Effendie 1997).

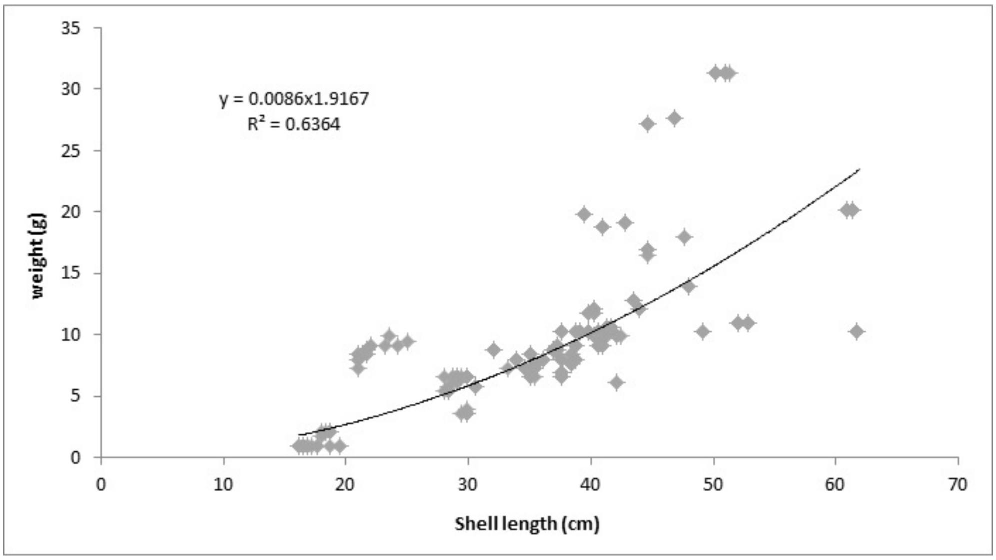

Figure 2. The relationship of length and weight of *A. antiquata.*

In Figure 2, we can see the b value of 1.9167, which means that the growth pattern of *A. antiquata* in the coastal waters of Kuala Puteri, North Sumatra is grouped into an allometric growth pattern, or increase in shell length does not equal weight gain. The value of b obtained looks smaller than 3, so it can be said that the growth pattern of *A. antiquata* in the coastal waters of Kuala Puteri, North Sumatra is negative allometric, meaning that the increase in shell length is faster than its weight, or weight gain is slower than increase shell length. This can be seen from the body shape of *A. antiquata* obtained, generally small to medium size. *A. antiquata* is small to medium-sized, has a very fast shell length, but very slow weight gain. On the other hand *A. antiquata* is large, the increase in shell length will be slower, but the body weight gain will be faster. Although the growth pattern of *A. antiquata* at Kuala Puteri Beach, North Sumatra shows a negative allometric growth pattern, the analysis of the relationship between length and weight shows that the correlation coefficient (R^2) is greater than 60%, which illustrates the close relationship between length and weight. The condition factor estimated from the length-weight relationship can provide an indication of the "well-being" of a given species and can be used an indicator of food abundance for a species on specific place and time (Derbali & Jarboui 2021).

Length frequency distribution. The number of *A. antiquata* caught during the study was 1,129 individuals. The shell lengths obtained ranged from 16.2 to 61.9 mm, with an average value of 36.86 mm. The most common *A. antiquata* found at the study sites was those with a shell length between 37.95 and 37.95 mm. The frequency distribution of *A. antiquata* shell length can be seen in Figure 3.

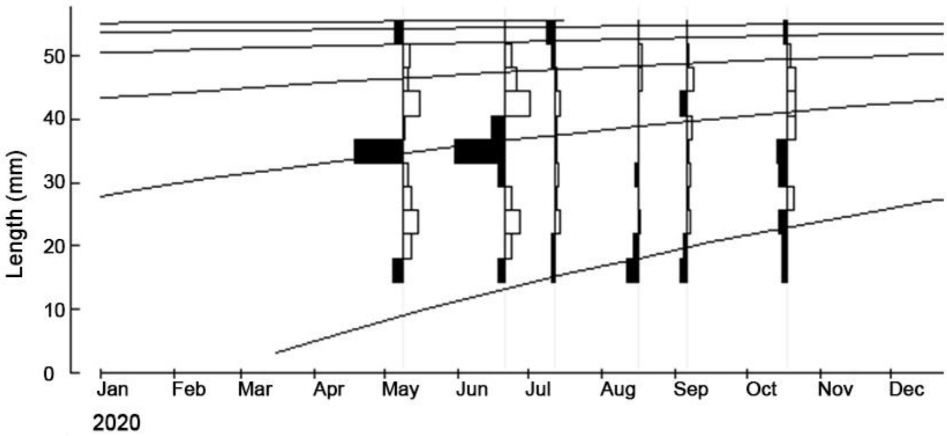

Figure 3. Shell length frequency distribution.

From Figure 3, it can be seen that the length distribution of *A. antiquata* shells in May-October 2020 shifted to the left. The fashion of the shell length class from May to June is constant. This illustrates that there are new recruitment, who form a new class of shell lengths. Based on Bhattacharya's methods (Sparre & Venema 1999), it can be seen that the *A. antiquata* obtained consists of 1-3 age groups, or that 1-3 generations are living together at one time. In the *A. antiquata* population, there were differences in the age groups resulting from spawning at different months, namely the young, adult, and old age groups.

Growth parameters. The results of the analysis of growth parameters based on the frequency of shell length data per month (Figure 4) indicate that the infinite shell length ($L\infty$) of *A. antiquata* captured for 8 months of observation at each station is 56.39 mm, with a growth coefficient value (K) of 0.78 and zero shell life at 0.02 years. The growth coefficient is an important factor in determining the growth rate of *A. antiquata* to reach that infinity length, or the value of K is the time it takes to reach the infinity length ($L\infty$). Based on the minimum shell length (16.2 mm) and maximum shell length (61.9 mm), *A. antiquata* caught in the waters of Kuala Puteri Beach, North Sumatra has a lifespan of 1.3-4.8 years.

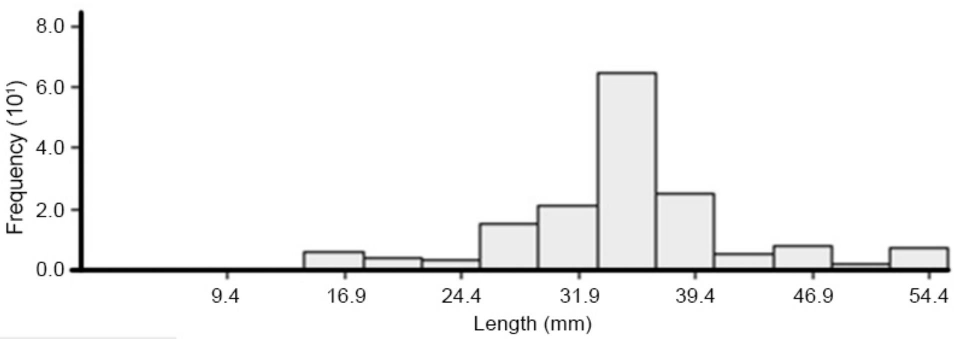

Figure 4. Growth parameters.

Theoretical age at zero shell length (t_0). The theoretical age of the zero shell length was estimated using the Pauly empirical formula (Pauly 1983), which includes the values of $L\infty$ = 56.39 cm and K = 0.78 per year. Based on the $L\infty$ value and the K value obtained, an analysis was carried out to obtain the t_0 value, by entering the $L\infty$ and K values into the Pauly's formula through the equation : Log_{10} (-to) = -0.3922 – 0.2752 log_{10} $L\infty$ – 1.0380 log_{10} K. The results of the calculation obtained the value of t_0 *A. antiquata* 0.02 years or 0.24 months. From the analysis of growth parameters, the von Bertalanffy equation is obtained as follows: $L_t = 56.39\ (1 - e^{-0.78\ (t\ +\ 0.02)})$.

Mortality rate and exploitation rate. The total mortality rate can be estimated using the catch curve method converted to length in the Fisat II program, which is based on data on the length of the captured *A. antiquata* shells. The variables used were $L\infty$ = 56.39 mm, K = 0.78 and t_0 = 0.02 years. Based on these variables, the total mortality rate for *A. antiquata* was 1.29 year^{-1}, the natural mortality rate was 0.82 year^{-1}, and the catch mortality rate was 0.47 year^{-1}. Based on the total mortality rate and catch mortality rate, the exploitation rate was calculated as being 0.36. This value illustrates that overexploitation of *A. antiquata* has not occured in the waters of Kuala Puteri Beach, North Sumatra. Sparre & Venema (1999) stated that if the rate of exploitation is less than 0.5, then there has not been overexploitation of biota in an area. Based on this, it can be said that the decline in the population of *A. antiquata* in the waters of Kuala Puteri Beach, North Sumatra was caused by natural mortality. This can be seen from the value of the natural mortality rate which is higher than the catch mortality rate (Table 4). Natural mortality can occur because *A. antiquata* that is not caught will die naturally due to predation, reaching old age, lack of availability of natural food, or low environmental carrying capacity for its growth.

Recruitment. The results of the analysis show that during the 8 months of the study there were additional new individuals every month which affected the population dynamics of *A. antiquata* in the waters of Kuala Puteri Beach, North Sumatra. The recruitment percent of *A. antiquata* can be seen in Figure 5.

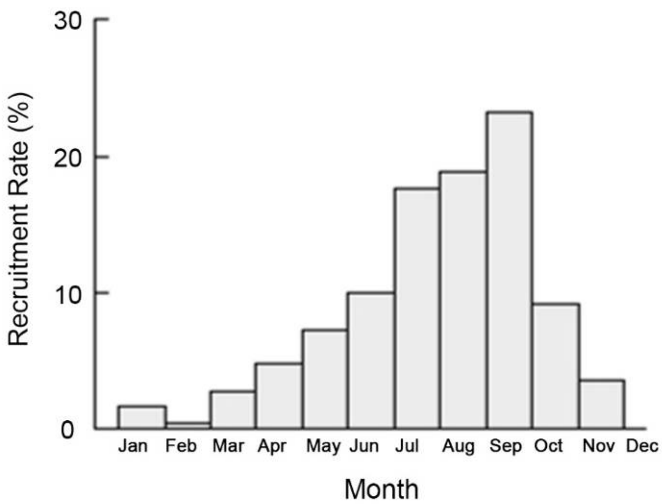

Figure 5. Recruitment percentage in 1 year (each letter represents month from January to December respectively).

The results obtained indicate that there has been recruitment of *A. antiquata* every month in the waters of Kuala Puteri Beach, North Sumatra with fluctuating values. The addition of new individuals that occurs is not too large, but it is important for the sustainability of the shellfish population in nature. The peak of recruitment occurred in September at 23.29%, after two months of *A. antiquata* spawning. With the data obtained, the exploitation value (e) of *A. antiquata* is 0.5 which categorized as optimal exploitation state. From the exploitation value, this concluded that current fishery management of *A. antiquata* in Kuala Puteri beach can be continued as it is.

Conclusions. The distribution pattern of *A. antiquata* in Kuala Beach, North Sumatra is grouped on each station. It was identified that the growth pattern is negative allometric, which means the increase of shell length is faster compared to the bodyweight itself. Based on the shell length frequency, the distribution of *A. antiquata* from May to October 2020 was shifted to the left, and the recruitment took place by forming new shell length classes. Estimated age of the *A. antiquata* population in Kuala Putri Beach waters is around 1.3-4.8 years old, while the theoretical age of the population in the waters is around 0.02 years (0.24 months). Total population mortality rate of *A. antiquata* was estimated at 1.29 $year^{-1}$, while the natural mortality rate was 0.82 $year^{-1}$. The peak of recruitment occurred in September 2020 at 23.29%, after two months of *A. antiquata* population spawning.

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

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