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Research Article
Ecology of Mussel Shells (*Donax compressus* Lamark, 1800) in Tiku Beach Agam District, West Sumatra, Indonesia

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Abstract

Background and Objective: Mussel shells are a group of shells that had active movement and migration when the tide occurs. It will migrate towards the beach when the high tide came and towards the sea when the low tide came. In Tiku beach, *Donax compressus* had been used for consumption and sell. There is no information about ecology of this species. **Methodology:** This study was conducted using survey method and systematic sampling method. **Results:** The results showed total average density of mussel shells around 217.78±40.47 individual m^{-2} (n = 2940). The distribution pattern of mussel shells in the edge flat, the middle flat and the precipice flat is clumped. The growth pattern of mussel shells is isometric. **Conclusion:** The growth rate of mussel shells based on the maximum scallop shell length in theory $L_\infty = 46.2$ mm and coefficient growth k = 0.410/year. Theoretically, maximum age of shells around 4.6 years.

Key words: Ecology, mussel shells, Tiku beach, systematic sampling, survey method

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Mussel shells are filter feeders animals that eats phytoplankton and detritus suspended in the water. This shell is equipped with a pair of organs called inhalant siphon and exhalant siphon. Its function as a tool that helps to get inside the food from the outside of the body and release it back[1].

Mussel shells are a shells group that had active movement and migration when the tide occurs. It will migrate towards to the beach when the High tide and heading out to the sea when the low tide[2]. Hines and Comtois[3] said that the movement of these shells is to find food. On *Donax deltoides*, the dominant food derived from groups of diatoms like *Asterionella* spp. *Nitzschia* spp. and *Chaetoceros* spp.[4,5]. Mussel shells is a type of shell that live in the sandy of intertidal beach[6]. Distribution and abundance of these shells in coastal areas affected by the particle size of substrate, steepness of the beach, waves flow and organic content of the substrate[7,8].

Mussel shells usually live with immersing themselves in the substrate. Immersing movement is assisted by movement of the muscles leg and external factors such as currents, waves and tidal activity. This movement is repeatedly called digging cycle. It takes approximately, three seconds. Immersing movement reach a certain depth or the depth where the shells are comfortable[1,2]. According to Murray-Jones and Johnson[4], mussel shells *D. deltoides* can dig the substrate 10-15 cm depth.

Distribution of mussel shells along the intertidal beach had two types, vertically and horizontally. The distribution of vertical related to the depth digging of the substrate. Shells that have large size usually dig substrate deeper. This is for protection from predators[3]. The distribution of horizontal associated with distribution the size of the shell. The shell that has a larger size usually found on the precipice flat of the intertidal area while the shells with small and medium-sized spread on the middle flat and the edge flat[4]. According to Philip[9] distribution of mussel shells are influenced by the particle size of the substrate, tide activity and the distance from the sea waves.

Mussel shells have important roles on the food web in coastal ecosystems as food source for birds, fishes and crabs[10]. Beldi *et al.*[11] state *D. trunculus* also can be used as bio-indicators that accumulate heavy metals in the oceans.

Distribution of mussel shells (*Donax* spp.) covers the tropics to temperate area and very rarely found in polar regions[6]. In West Sumatra, commonly found the mussel shells in coastal areas like districts of Pasaman, Agam, Padang Pariaman, Pesisir Selatan and Padang City[12].

In Tiku beach, Agam district, found *Donax compressus* species of mussels shells. For the local community, these shells are known by the name "rimih". It used by public for consumption and sell. Due to continuous taking regardless of the harvesting period can cause a decrease in the population density of this shells. Based on the presence and importance of mussel shells ecosystem, it is necessary to do study about ecology of these shells in order to remain sustainable and can be utilized in a sustainable manner.

MATERIALS AND METHODS

This study was conducted using a survey method with a systematic sampling technique. Samples were collected once every two weeks for three months. Sampling was carried out at high tide and low tide in the intertidal zone and divided into three parts: The edge flat, middle flat and recipice flat[9]. Each flat taken three transects within one period of taking. Position transect marked, so that subsequent taking does not occur at the same place. The distance between the first and subsequent taking is 10 m.

Data analysis

Population density:

$$K = \frac{\text{No. of individual species}}{\text{extensive of area}}$$

Data of population density from mussel shells in each flat statistically analyzed with two-way analysis of variance (Two-way ANOVA) and if there are significant differences, it will continued with DNMRT test[13] at 1%.

Distribution pattern: The pattern of distribution of shells calculated using Morista Spread Index[14].

$$I\delta = \frac{n\sum X^2 - N}{N(N-1)}$$

Where:

- δI = Morista spread index
- N = Total No. of individuals in the Species contained in the sample n
- X = No. of individuals per plot
- n = No. of plots

Criteria of values Morista index:

δI <1: Regular distribution patterns (uniform)
δI = 1: Random distribution patterns (random)
dI> 1: Aggregated distribution patterns (clumped)

Growth pattern: Growth pattern of mussel shells are analyzed based on the relationship between length and dry weight of mussel meat using regression analysis with the formula[15]:

$$P = a\,L^b$$

Where:
P = Relationship eggshell length and dry weight of meat (g)
L = Length of mussel shells eggshell (mm)
a = Intercept (constant)
b = Slope (constant)

Growth rate: Growth rate of mussel shells used Von Bertalanffy formula based on the frequency of eggshell length which were obtained during the study. Length of clam eggshell divided into groups of individuals. There are juveniles (<11 mm), young (11-22 mm) and adult (>22 mm)[16]. Von Bertalanffy function obtained by the analysis of ELEFAN I on FISAT II program[16]. Von Bertalanffy formula:

$$L_t = L_\infty \left[1 - e^{-k(t - t_o)}\right]$$

Where:
L_t = Length of mussel shells eggshell at age t
L_∞ = Maximum length of mussel shells eggshell in theory (asymption)
k = Coefficient of shell growth
t_o = Early age of shells in theory
t = Shells age

Determine early age (t_o) can be used formula:

$$t_o = \frac{1}{k} \text{In}\left[\frac{(L_\infty - L_t)}{L_\infty}\right]$$

Determine the maximum age of shells theoretically (t_{max}) used the formula:

$$t_{max} = \frac{[\text{In}\, L_{95\%} - \text{In}\,(L_\infty - L_{95\%})]}{k}$$

Specification:
t_{max} = Maximum age of shells in theory
$L_{95\%}$ = 95% maximum length of mussel shells eggshell during the study
L_∞ = Maximum length of mussel shells eggshell in theory
k = Coefficient of growth

RESULTS

Environmental factors: In Table 1, it can be seen that the average of water temperature during the study in Tiku beach Agam district was 30.25±0.52°C (n = 6) with a range of 29.5-31°C. Average salinity in Tiku beach was 32.83±1.17% (n = 18) with a range of 32-35%. The pH in Tiku beach was 7 (neutral). The temperature, salinity and pH in Tiku beach were still tolerate by marine life including bivalves and Donacidae group. Organic content of the substrate in the intertidal Tiku beach on the average ranged from 4.32-5.47%. The results of measurements of environmental factors in each flats at Tiku beach on intertidal zone can be seen in Table 1.

Table 1: Measurement of water chemistry and physics also percentage of substrate particle size on edge, middle and precipice flat in Tiku beach Agam district, West Sumatra, Indonesia

		Flats		
Parameters		Edge	Middle	Precipice
Temperature (°C)		30.25±0.52	30.25±0.52	30.25±0.52
Salinity (%)		32.83±1.17	32.83±1.17	32.83±1.17
pH		7	7	7
Levels of organic substrate (%)		5.28±0.71	5.47±0.19	4.32±0.67
Substrates particle size (%)				
Particle criteria	Particle size (mm)			
Gravel	> 1.70	-	-	1.60±0.35
Hoggin	355-850	-	0.11±0.16	6.30±1.02
Fine sand	125-180	89.12±1.18	87.56±2.81	87.27±1.31
Mud	<6.3	10.88±1.18	12.41±2.21	4.83±1.07

Table 2: Average levels of organic substrate (%) based on the depth of substrate in edge, middle and precipice flat in Tiku beach Agam district, West Sumatra, Indonesia

	Flats		
Depth (cm)	Edge	Middle	Precipice
Surface	-	-	-
0-2	6.51	5.70	4.97
2-4	4.78	5.47	4.61
4-6	5.06	5.52	4.78
6-8	5.18	5.18	3.42
8-10	4.87	5.46	3.82

Table 3: Average density of mussels shells (Individual m^{-2}) based on the depth of substrate in edge, middle and precipice flat in Tiku beach Agam district, West Sumatra, Indonesia

	Flats		
Depth (cm)	Edge	Middle	Precipice
Surface	1.33±1.46 (n = 6)	4.67±1.84 (n = 539)	2.89±1.96 (n = 4)
0-2	14.44±3.81 (n = 65)	496.67±81.59 (n = 438)	0.89±1.09 (n = 7)
2-4	6.44±2.59 (n = 29)	56.44±13.19 (n = 448)	0.67±1.12 (n = 6)
4-6	9.78±3.12 (n = 44)	27.11±7.53 (n = 374)	1.11±1.31 (n = 7)
6-8	12.89±4.35 (n = 58)	9.11±2.14 (n = 430)	2.22±2.18 (n = 7)
8-10	3.33±2.02 (n = 15)	2.67±1.46 (n = 456)	0.67±1.12 (n = 7)

Table 4: Distribution pattern of mussels shells (*D. compressus* Lamark, 1800) in Tiku beach Agam district, West Sumatra, Indonesia

Mean	Morista Index (d)	Criteria
Edge	1.05	Clumped
Middle	1.03	Clumped
Precipice	1.63	Clumped

Based on the depth of the substrate, the average of organic substrate of all flats, the highest is at depth 0-2 cm was 6.51% and tends to decrease toward deeper substrate (Table 2). This happen because the organic material get into the water tends to settled on the surface of the substrate which was carried by sea waves.

Population density of mussel shells: Based on the depth of the substrate, the highest density overall mussel shells found at the depth substrate >0-2 cm was 512±79.78 individual m^{-2} (n = 2304) and the lowest at the depth substrate >8-10 cm was 6.67±2.80 individual m^{-2} (n = 30). Mussel shells density tends to decrease from the surface substrate to the deeper substrate. They were not found at the depth of substrate more than 10 cm. It can be seen in Table 3.

Although, mussel shells had high relative density in middle flat at depth 0-2 cm, but different age groups of mussel shells also occupied different depth and flats. It can be seen in Fig. 2-4.

Frequency distribution of size length of mussels shells eggshell: The frequency distribution of the length of mussel shell eggshells on the each flats shows the variation of the number and different patterns. The length of mussel shell eggshell are obtained during this study measured <2-42.3 mm (n = 2940). Mussel shells eggshell size distribution in each flats can be seen in Fig. 5, while mussel shells eggshell size distribution based on the depth of the substrate in each flats also showed a different pattern (Fig. 6).

Distribution pattern of mussel shells: The distribution pattern of mussel shells based on value of Morista index in Tiku beach Agam district can be seen in Table 4.

Growth pattern of mussel shells: Mussel shells growth pattern based on relationship of eggshell length (mm) and weight of dried meat (g) is isometric. It means mussel shell eggshell length growth balanced with increasing of the body weight[15]. The regression equation between shell length and dry weight of mussel shell meat was $P = 6E\text{-}06\ BKD^{2.99}$ (r = 0.985; n = 297). Based on the value of the coefficient r was 0.985 shows that the length of eggshell of mussel shells and the dry weight of mussel shells meat has a very close relationship (Fig. 7).

DISCUSSION

Environmental factors: Temperature in Tiku beach, Agam district is 30.25±0.52°C. This is belong to normal temperature for tropical area around 29.5-31°C and temperature tolerance limits for marine organisms to live including bivalve group is Donacidae. Mussel shells belong to a group of shells that has extensive distribution includes tropical and temperate regions. In fact, these shells also found in temperate regions that are cold with temperatures >5°C, although, the No. of species slightly[6].

Temperature is an important factor affecting the growth, physiological and reproductive cycle process of bivalves. Fluctuations of temperature that occur on some sandy beach will affect the spawning season for groups of bivalves[8]. Mussel shells *D. serra* in Namibia Beach experiencing reproductive cycle that lost due to the phenomenon of surface water temperature changes. In addition, juvenile of mussels *Mesodesma donacium* had decreased growth rate one-half times in the temperature of El-Nino (24.2±0.5°C) compared to the normal temperature (17.4±0.5°C) in the coast of Chile, Peru[33].

Average salinity in Tiku beach is 32.83±1.17% (n = 18) with a range of 32-35%. This range is still belongs to salinity tolerance limits for groups of bivalves. Mussel shells *D. denticulatus* in Margarita sea, Venezuela, can tolerate salinity up[8] to 35%. Salinity is the saltiness of seawater dose. High and low levels salinity of the marine water depends on several factors: The circulation of seawater; evaporation, precipitation and river flow into the water. Substances such as salts derived from the seabed through the process called outgassing, the seepage of the earth's crust at the bottom of the sea in the form of gas to the surface of the seabed[34]. Low salinity gives a negative effect on spermatogenesis process because it will cause conglomeration of spermatocytes. However, the low salinity does not give effect to the growth rate of juvenile clams *Mesodesma donacium.*

Acidity (pH) is the No. of hydrogen ions in sea water to control the type and speed the rate of reaction of some chemicals in the water. Clean waters and ideal pH for the growth of marine organisms[14] ranging from 6.7-8.9. The average pH in Tiku beach is 7 (neutral) and belongs to a good range of marine life including for groups of bivalves. The pH value indicates the degree of acidity or alkalinity of water. Waters with pH = 7 is neutral, pH <7 is acidic water conditions, while pH>7 is alkaline waters condition[35].

Organic content of substrate in the intertidal Tiku beach (Table 1) on the flats ranged 4.32-5.47%. Organic substrate concentration is highest in the middle flats is 5.47% and the lowest on the precipice flat is 4.32%. This happens because in the middle flat, there are many organic materials that go into the sea, fine sandy substrate and mud. The organic material derived from fragments of dead shells and organic material inputs from the mouth of the river near the beach. There is relationship between different type of substrate also had different levels of organic substrate. Marganof[36] states the substrate with a fine particle size have organic matter higher than the substrate with coarse particle size.

The average of organic content of substrate in the Tiku beach is belong high to very high condition (Table 2). According to Djainudin *et al.*[37], the percentage of organic content are <1% (very low), 1-2% (low), 2.01-3% (moderate), 3.01-4% (high) and 4.01-5% (very high). Organic material suspended in water is a food source for groups of filter feeders shells. Availability of food will affect the distribution, growth and reproduction of shells. High levels of organic substrates in the Bay of La Guardia Margarita Island, Venezuela, causes mussel shells *D. denticulatus* had high density[8].

The substrate composition in the Tiku beach is gravel, coarse sand, fine sand and mud. The edge flat has fine sand and mud substrate, the middle flat has coarse sand, fine sand and mud substrates. The precipice flat has gravel, coarse sand, fine sand and mud. But in each flats, the highest percentage of substrate particle size is fine sand. The beach with a sandy substrate is suitable habitat for mussel shells[6]. According to Mlay *et al.*[38], the composition of the substrate particles was influenced by No. of environmental factors such as amount of the sea water waves and suspended material. Substrate particle size is very important for organisms that live in the base substrate of waters such as bivalves. Substrate particle size affects the distribution and density of mussel shells along the intertidal area[39].

Population density of mussel shells: Total average density of mussel shells *Donax compressus* Lamark, 1800 at Tiku beach, Agam district, West Sumatra, Indonesia is nearly 217.78±40.47 individuals m^{-2} (n = 2940). The highest density is in the middle flat 596.67±71.16 individuals m^{-2} (n = 2685). The lowest is in the precipice flat 8.44±1.61 (n = 38). The current study about it in Tiku beach got 24.37 individuals m^{-2} (n = 457). The average density in this study is higher than the current study. This is happen because these shells is in the spawning season. Wilson[40] found that the shells *D. variabilis* has a density of 12,000 individuals m^{-2} during the peak of spawning at Carolina beach. Furthermore, Herrmann *et al.*[17] also found a density of mussels *D. hanleyanus* reached 2475 individuals m^{-2} during the peak of spawning at spring in the Santa Teresita beach, Argentina.

Based on Fig. 1, you can see the highest relative density of mussel shells happen in middle flat at depth 0-2 cm is 83.24%. The edge flat also had high relative density of mussel shells at depth 0-2 cm is 29.96%. But for precipice flat had high relative density of mussel shells at surface is 34.20%. This is happened because of some environmental factors, there are different type of substrate and level of organic content. The edge and middle flat had fine sand substrate and high level of organic content substrate (Table 1). The precipice flat also had fine sand substrate but had low level of organic content substrate. Fine sand substrate is a suitable habitat for mussel shells to live[6]. Organic material suspended in the water is a food source for group of mussel shells[8].

Based on Fig. 2, 3 and 4, you see that juvenile group of mussel shells at edge flat had the highest relative density in depth of substrate 0-2 cm. It is 80.22%. However, in the middle flat, juvenile group still had high relative density at depth 0-2 cm. It is 91.73%. But in the precipice flat, juvenile group had high relative density at the surface substrate. It is 100%. This is happened because of the edge and middle flat dominate with fine sand substrate. But in the precipice flat, had coarse sand mix gravel substrate but fine sand substrate only found in the surface substrate. The juveniles of mussel shells are only able to live in the fine substrate. The coarse

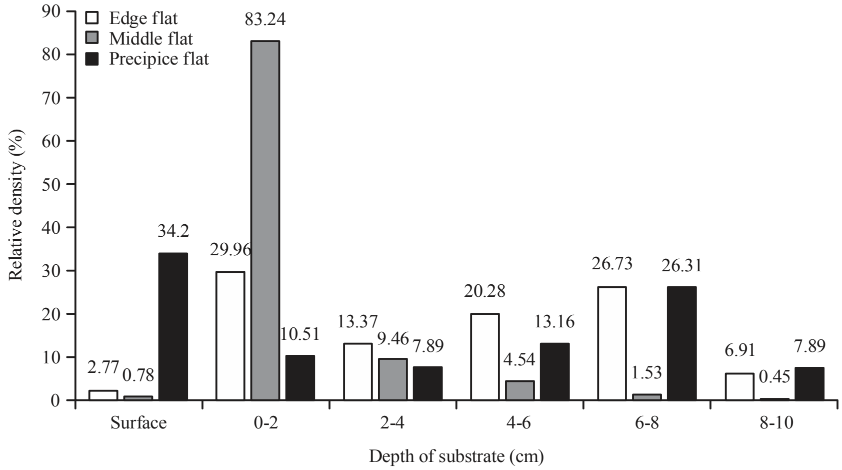

Fig. 1: Relative density of mussel shells based on the depth of substrate in each flats at Tiku beach, Agam district, West Sumatra, Indonesia

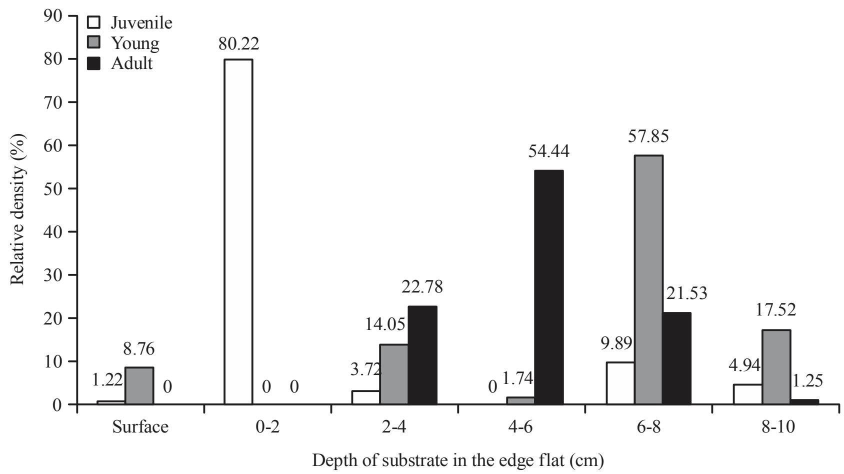

Fig. 2: Relative density of mussel shells (%) each age groups in the edge flat in Tiku beach, Agam District, West Sumatra, Indonesia

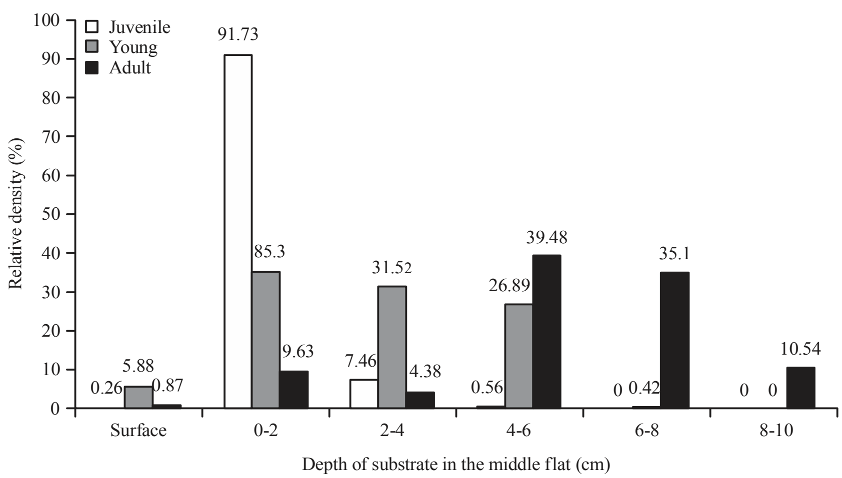

Fig. 3: Relative density of mussel shells (%) each age groups in the middle flat in Tiku beach, Agam district, West Sumatra, Indonesia

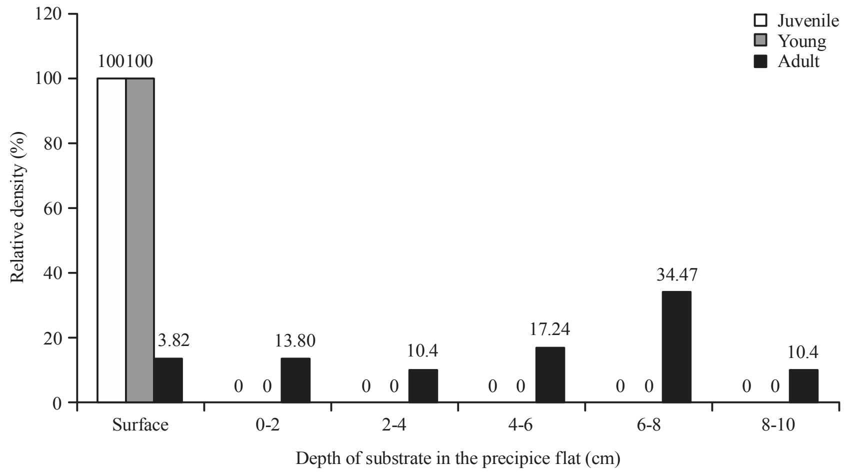

Fig. 4: Relative density of mussel shells (%) each age groups in the precipice flat in Tiku beach, Agam district, West Sumatra, Indonesia

sand substrate does not provide suitable habitat for juvenile group of mussel shells. According to Mlay *et al.*[38], the particle size of the substrate is a very important factor in the distribution and abundance of fauna included mussel shells in all geographic areas. It is not only type of substrate can affect the abundance of mussel shells but also spawning season. According to Herrmann *et al.*[16], juvenile group of mussel shells will be very abundant if mussel shells are in the spawning season. Difference of mussel shells density based on the depth of substrate caused differences ability of the group to digging in the substrate. According to Bergonci and Thome[41], depth digging of substrate for shells group in proportion to its size. Group of juvenile shells sized 0-11 mm has a siphon that relatively short till these shell group occupies the top substrate layer. It is easy to reach food on the surface of the substrate. According to Zwarts and Wanink[42], the size of the siphon will affect the ability of shell to digging the substrate in order to obtain a food source.

The group of young mussel shells also had different density in different flats and the depth. In the edge flat, young group of mussel shells dominate in the depth 6-8 cm with relative density 57.85%. In middle flat, the young group dominate in the depth 0-2 cm with relative density 35.30% and in the precipice flat, they were dominate in the surface substrate with relative density 100%. This is happen because young group of mussel shells can live in fine and coarse sand substrate but can't live in the gravel substrate[17]. In the edge and middle flat dominate with fine sand substrate. But in the precipice flat, fine sand substrate found in the surface substrate. The deeper substrate change fine sand to gravel and coarse sand. So, in the precipice flat young group can live in the surface substrate.

The adult group of mussel shells, in the edge flat, had high relative density at depth 4-6 cm is 54.44%. In the middle flat, the adult group had relative density at depth 4-6 cm is 39.48%. But in the precipice flat, they had relative density at depth 6-8 cm is 34.47%. This is happened because adult group had ability to adapt in different type of substrate not only in fine sand substrate but also in coarse sand substrate and gravel substrate. In the edge and middle flat had fine sand and coarse sand substrate. In precipice flat, percentage of sand substrate tends to decrease from the surface substrate toward the deeper substrate. This is happened because the particles of sand substrate was replaced by the gravel and coarse sand substrate. This is the reason why this flat dominate by adult group of mussel shells at more than 0 cm depth. Adult group of mussel shells can live with particle size of the fine, coarse sand and gravel, while the juvenile mussels are only able to live in the fine sand substrate and the young mussel shells live in the fine mix coarse sand substrate[17].

The middle flat also has fine sandy substrate and little less coarse sand. Mussel shells density on this flat is the highest compared to others flat. The high density of mussel shells in the middle flat due to the condition of the substrate match and the high organic substrate is 5.47%. Organic material substrate is a source of food for every age group of mussel shells that filtering organic particles and phytoplankton deposited in the bottom of waters (filter feeders). Turner and Belding[43] found that the mussel shells *D. variabilis* also has the highest population density in the middle flat in South Atlantic coast.

The precipice flat has substrate mud mixture, fine sand, coarse sand and gravel. These flat have high organic content is 4.32% lower than the other flats. On the precipice flat, density of mussel shells found as the lowest (Fig. 1). This is due to the age group of mussel shells that able to adapt the conditions with coarse sandy and gravel substrate and environment that always submerged and receive limited sea waves. The precipice flat had rough and sandy substrate always accept the sea waves. It will provides a suitable habitat for groups of adult mussels[17]. The precipice flat is a zone that always submerged by seawater in spite of the tidal phase. The result, mussel shells tend to have a high density on the surface substrate. This is happen because the movement of mussel shells toward surface during a tidal wave coming. According to Ellers[2], mussel shells usually move up and down the substrate along with the arrival of a tidal wave.

In Table 4, it can be seen that the distribution pattern of mussel shells in all the flats are clumped. Juvenile mussel shells group tend to be clumped in the middle and edge flat but little in the precipice flat. While the adult group concentrated on the precipice and middle flat. For mussels young groups tend did not show a different pattern of spread among the three flats. At the edge flat also showed different patterns of distribution among age groups of mussel shells.

The same pattern was found in the mussel shells *D. deltoides* along the coast of Australia. Groups of adult shells are commonly found in the precipice flat (subtidal) and the group of juvenile shell in the middle flat. While the group of young mussels are found in all of intertidal flats[4]. The same zone also found in mussel shells *D. hanleyanus*, *D. trunculus* and *D. denticulatus*[41]. Along the sandy beach habitat occurs zonation patterns of macrofauna distribution. The zonation pattern of distribution is controlled by substrate particle size, the effect of sea wave size and suspended material[38,39,44].

The difference in the distribution pattern of each group mussel shells on the edge flat based on the depth caused of temperature fluctuations changes on the surface substrate. The edge flat has a dry substrate surface due to the sun's heat radiation during the tides. This causes group of shells which has size small moving toward to a deeper substrate in order to get a little wet substrate conditions. Negar *et al.*[45] states that the juvenile group of Donacidae mussels are very tolerant of high temperatures. Groups of adult mussels are better able to withstand from changes in the substrate temperature compared groups of juvenile and young mussels. It is indicates that the mussel shells had separated size groups by the depth of the substrate according to the physiological needs. According to Turner and Belding[43], mussel shells can feel some variations in environmental conditions along the face of the tidal phase. This condition will spur shells to change behavior patterns till find a suitable environmental conditions. Changes in behavior patterns will affect the distribution of each group of mussel shells. Wilson[40] state that the shells Donax have different migration strategies depending on the condition of the intertidal beach.

The results for analysis of variance on average density of mussel shells in the flats and substrate depth were significantly different and there is interaction between the depth and the flat (Two-way ANOVA, Fhit = 276.66, 199.12 and 190.54, p>0.01). Test of differences for average density of the mussel shells between the edge, middle and the precipice flat is very significant. Based on the depth of the substrate, the average density of mussel shells on the substrate surface is significantly different with the density of mussel shells on the substrate depth 0, 2, 4 and 6 cm, whereas between the substrate surface and the depth of more than 8 cm were not significantly different.

Size length frequency distribution of mussels shells eggshell: The edge flat has fine sand substrate found mussel shells populations with eggshells size <2-40.4 mm (n = 217) (Fig. 5). On these flat shows the frequency of eggshell distribution pattern prevalent for each age group of mussel shells, namely juvenile, young and adult mussel shells. The middle flat has mussel shells eggshell distribution that concentrated on the group of juvenile scallops with size <2-42.3 mm (n = 2685). While, the precipice flat concentrated in the two age groups of young clams and adult mussels with eggshell size from 11.8-42.2 cm (n = 30).

Differences in the frequency distribution of mussel shells eggshells on each flats influenced by the particle size of substrate. The edge flat with fine sand substrate is a suitable habitat for all of age groups of mussel shells instead the precipice flat had mix of fine sand, coarse sand and gravel substrate provide a suitable habitat for adult mussel shells. According to Khayat and Muhandai[46], differences in substrate can lead to differences in the size length frequency distribution of mussel shells eggshells. Furthermore differences in Kopah shell eggshells size distribution caused by the influenc e of food sources and salinity.

Mussel shells eggshell size distribution based on the depth of the substrate in each flats also showed a different pattern (Fig. 6). The edge flat showed the frequency distribution age group of juvenile mussels spread on the substrate surface to a depth of more than 2 and 6 cm. While at a depth of more than 4 cm is occupied by groups of large shells and not found shells with size small and medium. These results indicate there is a separation distribution of mussel shells eggshell size in every 2 cm depth of the substrate. In particular substrate, depth will only be occupied by the same age group shells.

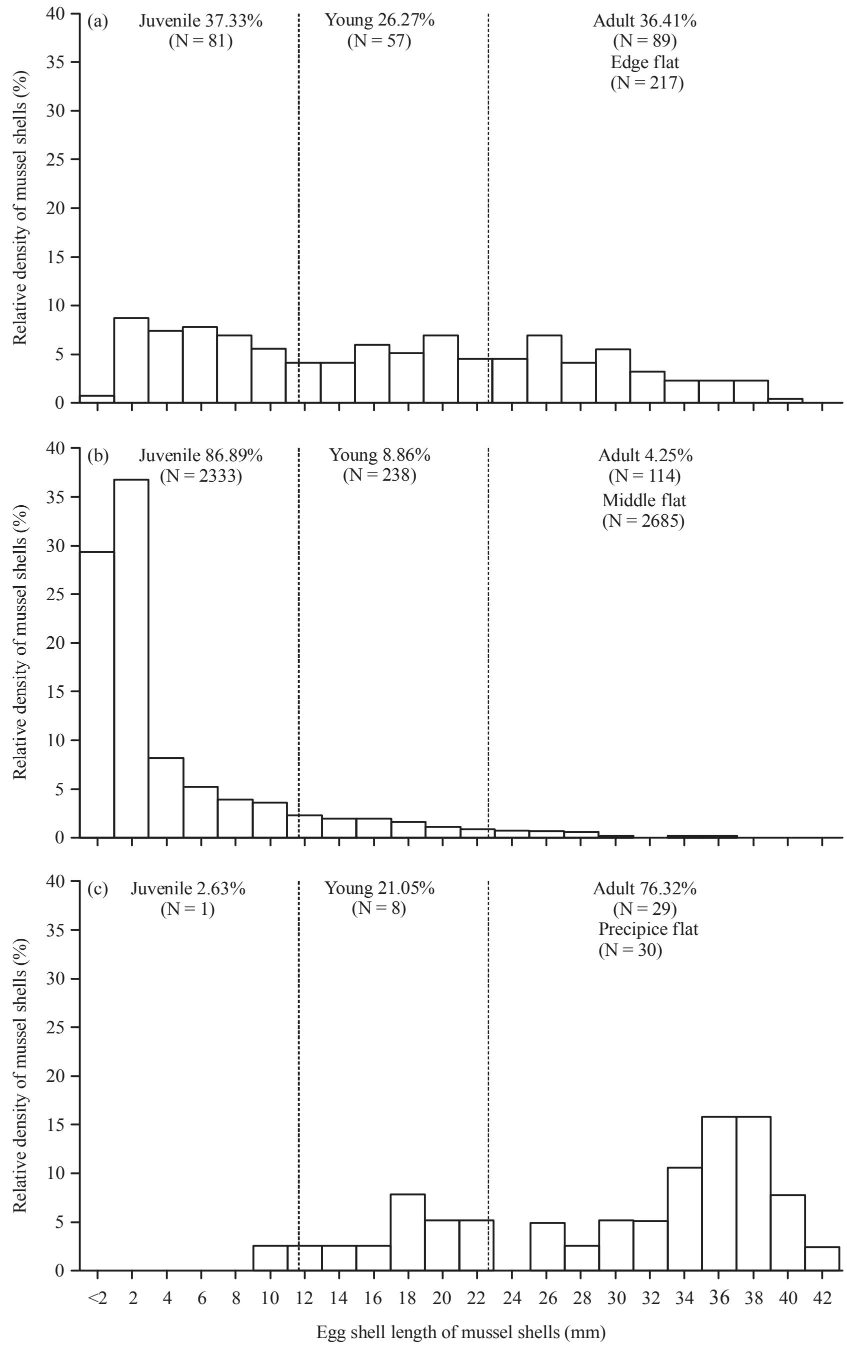

Fig. 5(a-c): Distribution of eggshells size of mussel shells on (a) Edge flat, (b) Middle flat and (c) Precipice flat in Tiku beach Agam district, West Sumatra, Indonesia

On the middle flat show frequency distribution pattern of mussel shells eggshell is different in every 2 cm depth of the substrate. The results showed that the size of the group of juvenile shells are found at depths of more than 2 cm. The size of mussel shells eggshell found greater along with increased depth of the substrate. On the precipice flat show the eggshell size distribution of juvenile and young age groups only spread on the surface substrate. While at a depth of 2-10 cm is occupied by a group of adult mussels with shell length of more than 25 mm.

Distribution pattern of mussel shells: The value of Morista index mussels shell in each flat are the edge (d = 1.05), middle (d = 1.03) and precipice (d = 1.63) (Table 3). Based on the

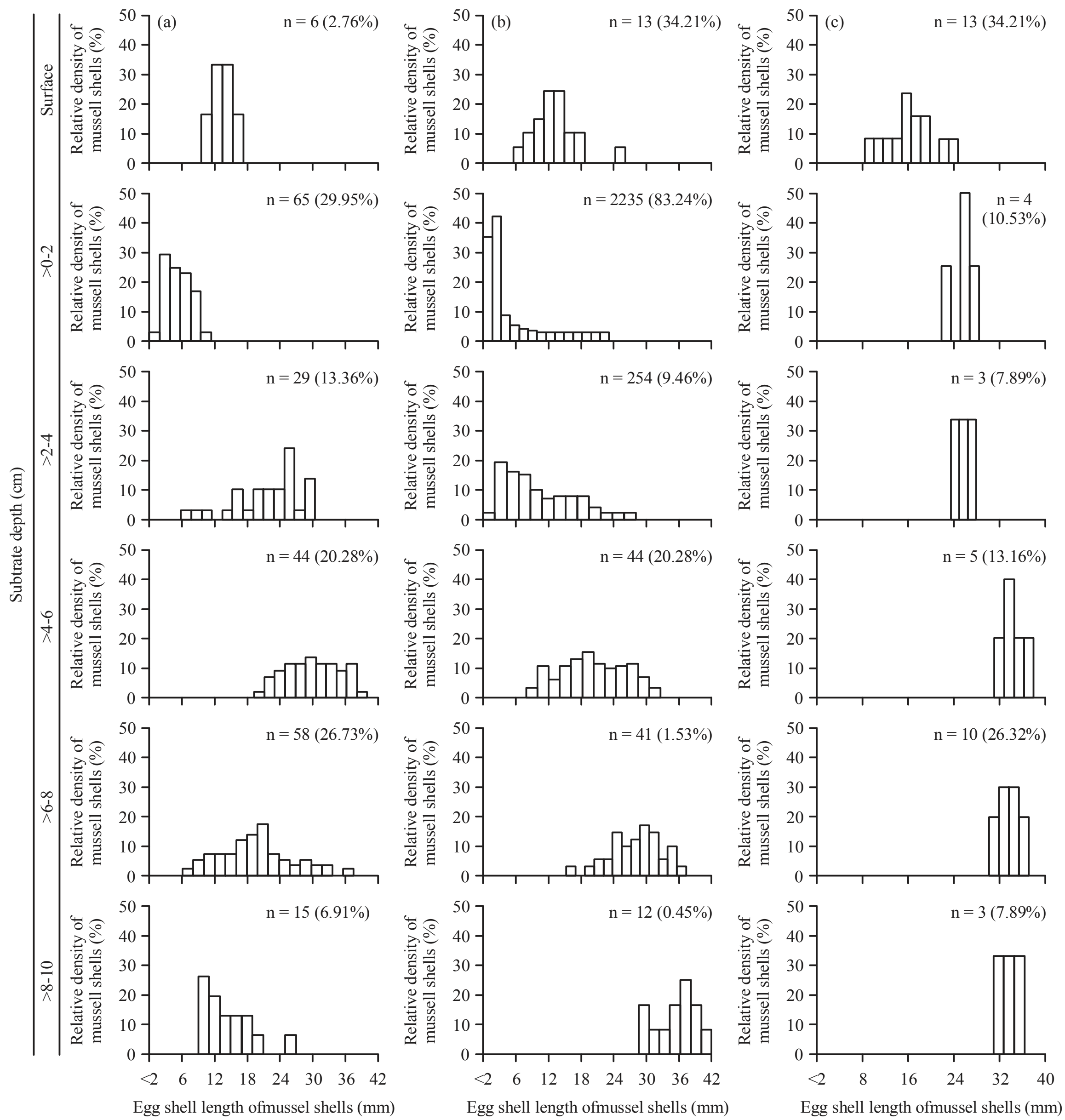

Fig. 6(a-c): Frequency distribution of eggshells size of mussel shells based on the depth of substrate on (a) Edge, (b) Middle and (c) Precipice flat in Tiku beach, Agam district, West Sumatra, Indonesia

criteria value of the Morista index known that the spread pattern of mussel shells on the Tiku Beach is group (clumped). This distribution pattern was characterized by high population density in some sampling locations and low population density on other locations. Some studies have found that the mussel shells *D. compressus* in Muko-Muko beach Bengkulu and *D. semigranosus* in Hongkong beach[47] also has a clumped distribution pattern.

Growth pattern of mussel shells: Mussel growth was influenced by various environmental factors such as the season, region, salinity, temperature, substrate type and the availability of food. Karayucel and Karayucel[48] found that the water temperature is positively correlated to the growth of mussel shells *Mytilus edulis* L. in the Loch Kishorn Scotland. Furthermore, difference in the type of substrate affects the growth pattern of kopah shell (*Gafrarium tumidum* Roding, 1798) in a certain size. According to Arun[49], the growth pattern of shells constantly changed during the growth phase. The growth of small shells will be faster than large shells.

In addition, the pattern of growth is also influenced by the presence of shell predators that prey on juvenile clams group.

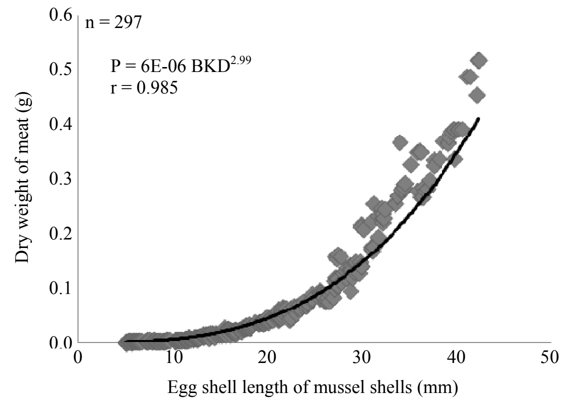

Fig. 7: Relationship of egg shells length (mm) and dry weight of mussel shell meat in Tiku beach, Agam district (g), West Sumatra, Indonesia

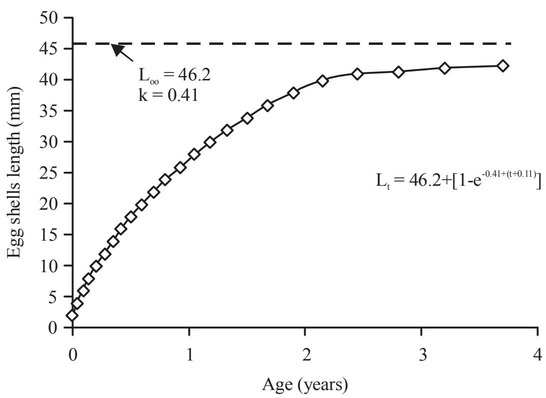

Fig. 8: Model estimation of population growth curve of mussels shells with Von Bartalanffy formula (VBGF); L∞ = Asymptot (maximum length of mussel shells in theory), k = coefficient of growth

there was a pattern shift length frequency distribution of mussel shells that is affected by the presence of predators, mangrove crab (*Tlalamita prymna*) and snails month (*Natica stellata*). Whereas the growth pattern of blood clam is naturally determined by the presence of groups of juvenile mussels.

Mussel shells growth rate: Based on the growth coefficient (k) and the maximum eggshell length (L∞) of mussels shell (*D. compressus*) is high compared with mussel shells in the other tropical species such as *D. cuneatus*, *D. faba* and *D. incarnates*. This species tends to have coefficient of growth and smaller the maximum eggshell length (Fig. 8). Even though in the same species of mussel shells in different locations showed difference of coefficient growth and

Table 5: Comparison of Von Bartalanffy growth parameters (L∞) and (k) from several types of mussel shells (*Donax* spp.) in different locations[17]

Species	Area	k	L∞	References
D. compressus	Indonesia	0.41	46.2	Result of this study
D. cuneatus	India	0.06	22.87	Nayar[18]
D. faba	India	0.10	26.15	Alagarswami[19]
D. incarnates	India	0.09	29.04	Ansell *et al.*[20]
D. hanleyanus	Argentina	0.47	44.00	Herrmann *et al.*[21]
D. hanleyanus	Uruguay	0.80	33.00	Defeo[22]
D. hanleyanus	Brazil	0.09	28.82	Gil and Thome[23]
D. denticulatus	Venezuela	1.79	30.02	Marcano *et al.*[8]
D. dentifer	Columbia	0.62	29.30	Riascos and Urban[24]
D. dentifer	Costa Rica	0.30	46.00	Palacios-Villegas *et al.*[25]
D. trunculus	Italy	0.30	47.56	Zeichen *et al.*[26]
D. trunculus	Prancis	0.70	36.33	Ansell and Lagardere[27]
D. trunculus	Spanyol	0.55	52.84	Maze and Laborda[28]
D. trunculus	Portugal	0.58	46.00	Ramon *et al.*[29]
D. trunculus	Turki	0.62	44.15	Deval[30]
D. deltoides	Australia	1.59	56.00	Laudien *et al.*[6]
D. serra	Afrika Selatan	0.47	85.00	Laudien *et al.*[6]
D. marichonvichi	Peru	1.00	46.00	Arntz *et al.*[31]
D. vittatus	Prancis	0.61	33.15	Ansell and Lagardere[27]
D. striatus	Venezuela	0.29	20.20	McLachlan *et al.*[32]

maximum scallop eggshell length. This shows that differences of geographic affect the growth rate of mussel shells (Table 5). Meanwhile, the value of coefficient growth and eggshell length of mussel shells *D. compressus* in others area has reported yet.

The overall growth rate of the shells is also influenced by the type of substrate, food source and environmental ecosystem. Group of tropical shells usually have faster growth compared with temperate shells but had shorter of lifespan[8].

Most species of mussel's shells (*Donax* spp.) have relatively short lifespan of about 1-2 years. In some studies, Herrmann *et al.*[17] estimate the age of mussel shells *D. hanleyanus* North Coast Argentina is about 5 years with a maximum eggshell ength of 44 mm. It is contrast with Cardoso and Veloso[50] estimate the maximum age *D. hanleyanus* in Brazil beach about 1.5 years.

Estimation results of maximum age of mussel shells *D. compressus* in Tiku beach is approximately 4.6 years (Fig. 8). These estimated of life longest compared to other age of *Donax* mussel species in the tropics and subtropics. *Donax faba* and *D. cuneatus* in Indian Beach has a lifespan no more than 3 years[17]. Furthermore, Marcano *et al.*[8] reported that the shells *D. denticulatus* in Margarita beach, Venezuela and Caribbean coast, has lifespan is about 1.5 years. Herrmann *et al.*[17] said that the maximum age difference of some *Donax* species related to its position in latitude (latitude).

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