Density, length-frequency distribution and growth pattern of *Penaeus monodon* in Karang Gading estuary

Nurul Fauziah, Miswar B. Mulya, Ternala A. Barus

Biology Department, Faculty of Mathematics and Natural Science, Universitas Sumatera Utara, Medan, North Sumatera, Indonesia. Corresponding author: M. B. Mulya, miswarbm_bio@usu.ac.id

Abstract. Tiger shrimp (*Penaeus monodon*) has enormous potential in fishery products in North Sumatra. Intensification of tiger shrimp capture carried out by fishermen in the estuary area of Karang Gading, Deli Serdang can affect the density, long frequency distribution, and growth patterns of tiger shrimp. This research aimed at analyzing the density, length-frequency distribution and growth pattern of tiger shrimp in Karang Gading estuary area. The main location of tiger shrimp sampling was determined by purposive sampling method and three sampling sites were chosen as research areas. The sampling of tiger shrimp was carried out for 2 months by the interval of 30 days, by using mini-ring trawl with 10 m length and surface area of 3 m x 2 m (6 m^2). Based on research, the biggest tiger shrimp density was found in the second station (5.167 ind m^{-2}), while the smallest density was found in the third station (2.167 ind m^{-2}). The length-frequency distribution was dominated by class interval of 3.84-4.61 mm as many as 20 shrimps, while the class interval of 2.29-3.06 mm had 1 shrimp for each size class. The growth pattern showed that negative allometric, where the biggest b value was found in the first station (2.131), so the length-weight equation was $W = 1.0623L^{2.131}$, while the smallest b was found in the third station (1.1468) and its length-weight equation was $W = 3.4959L^{1.1468}$. The physico-chemical characteristics in Karang Gading estuary still support tiger shrimp's life. The nursery ground preservation of tiger shrimp in this area must be controlled well by the government and local communities.

Key Words: allometric, community, distribution, growth, physico-chemical, shrimp.

Introduction. Tiger shrimp (*Penaeus monodon*) is a shrimp with teal-colored body, big stripes all over the body with a hard and sturdy carapace. This prawn mainly lives on estuary and sea waters (Soetomo 2000). Tiger prawn was considered as one of important fisheries asset on fish market (CABI 2019), with export trade reaching 361444.9 tons per year (KKP 2019).

According to Verdian et al (2020), tiger shrimp contains 73.39% water, 1.66% ash, 18.35% protein, 0.86% fat, and 5.73% carbohydrate, and Venkateswarlu (2019) stated the composition of tiger shrimp in Nellore waters has a water content of 27%, 48.6% protein, 10.9% fat, 7.4% carbohydrates and 6.1% ash.

Distribution of tiger shrimp was found majorly on west Indo-Pacific waters, Australia, South-East Asia, South Asia and South Africa (Perez Farfante & Kensley 1997; CABI 2019). It is reported to be found on Alexandria waters, Egypt (Khafage et al 2019), also on Mexico and Cuba (Petatan-Ramirez et al 2020). In Indonesia, tiger shrimp can be found along western (Sumatera, Java, Borneo) and eastern waters (Sulawesi, Maluku, Papua), including North Sumatera.

Because of its location at the coastal area, Karang Gading estuary community mostly has an occupation as fishermen. Based on KKP (Ministry of Fishery & Marine) Statistics, tiger shrimp was included on the fishery list of the community. Due to high density of mangrove species, Karang gading can sustain the organic material necessary for living organisms in the ecosystem (Mulya & Arlen 2018).

Syam et al (2014) conducted a research on tiger shrimp in North Sumatra, discussing about the density of mangrove forests that affects the production of tiger shrimp in Tanjung Ibus pond, Langkat, then Dimenta & Arismen (2017) reported on the state of tiger shrimp population in Belawan waters. Until now, there has been no data on density, length frequency distribution and growth patterns of tiger shrimp in Karang Gading estuary, so research is necessary on these particular parameters.

Material and Method

Description of the research sites. This research was conducted in Karang Gading estuary, Deli Serdang Regency, at three stations. The first station is located in Paluh Tabuan Tambak (close to the local community's fishery pond and dominated by *Avicennia marina*), the second station is located in Muara Canggang (a natural mangrove area that leads to the offshore and is dominated by *Scyphiphora hydrophylacea*) and the third station is located in Pucung (close to the oil palm plantation area and dominated by *Rhizophora apiculata*). The tiger shrimp's sampling points can be seen in Figure 1.

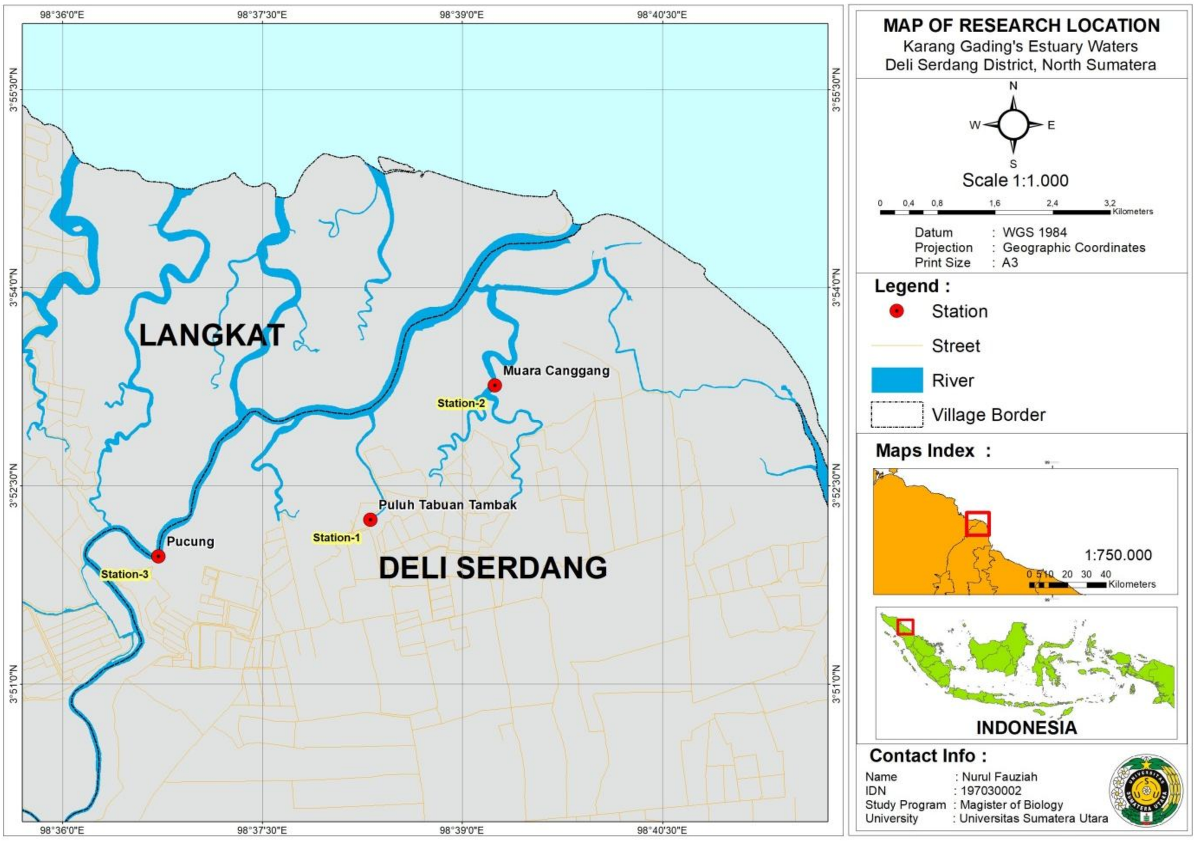

Figure 1. Research area, Karang Gading estuary, Deli Serdang, North Sumatera, Indonesia.

Research procedure. This study was conducted for 3 months of observation (July – September) with intervals of 30 days and samples of tiger shrimp were taken using a mini ring trawler with the length of 10 m with opening area of 3 m x 2 m (6 m^2) at 07.45 WIB to 11.45 WIB by throwing the mini ring trawler into the water column, then pulled using a motor boat owned by local fishermen at a speed of 10 GT along 1000 m (withdrawn twice at different points). The collection was carried out in 3 stations/day, and was done for 3 days. All tiger shrimps obtained at each station were put in a cool box with ice that already contained a plastic bag and has been labeled for analysis.

Meanwhile, the following physico-chemical parameters were measured on the spot, which included water temperature, light intensity, water depth, current speed, pH, salinity, and dissolved oxygen (DO). Other parameters, namely biological oxygen demand (BOD_5) and nitrate-phosphate were measured into the laboratory by taking 1 L of estuary water sample in a bottle, which has been carried for further testing at the laboratory. Substrate fraction was observed by taking substrate sample using a shovel on each station and stored in sample cups, which have been brought to Central Laboratory of Faculty of Agriculture, Universitas Sumatera Utara to be analyzed.

Data analysis

Density of tiger shrimp. The density of tiger shrimp can be obtained by calculating the number of shrimp captured at each station per area of net openings used, following the formula of Michael (1995):

$$K = \frac{n}{A}$$

where: K = tiger shrimp density (ind m^{-2});
n = amount of tiger shrimp on each station (ind);
A = net opening area of mini ring trawl (6 m^2).

Length-frequency distribution of tiger shrimp. Determination of tiger shrimp's size structure was obtained by grouping carapace length data with its class interval. To determine class interval frequency and class intervals, the following formula was used (Effendie 2002):

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

where: K = amount of class;
N = number of tiger shrimp individuals.

To calculate the class interval, the following formula was used (Effendie 2002):

$$I = \frac{\log NTt - \log NTrK}{K}$$

where: I = class interval;
K = class amount;
NTt = maximum class value;
NTr = minimum class value.

To calculate percentage of each interval, the following formula was used (Effendie 2002):

$$P = \frac{Ki}{K} \times 100$$

where: P = percentage of each class interval;
Ki = amount of tiger shrimp on i-class interval;
K = total of tiger shrimp.

Growth pattern of tiger shrimp. Growth pattern of tiger shrimp can be obtained by using the following formula (Effendie 2002):

$$W = aL^b \text{ or } \ln W = \ln a + b (\ln L)$$

where: W = tiger shrimp weight (g);
L = tiger shrimp carapace length (cm);
a and b = constant of regression result.

The growth pattern is isometric if b = 3. If b > 3, then the growth pattern is allometrically positive, whereas if b < 3, then the growth pattern is allometric negative. (Effendie 1997).

Correlation analysis. Correlation analysis is used to analyze the relationship strength between the physico-chemical water parameters and the density of tiger shrimp. The correlation analysis was conducted with Pearson correlation analysis (SPSS version 22.00) with the coefficient value obtained between +1 to -1 (Sarwono & Budiono 2012).

Results

Density of tiger shrimp. The study found that the highest tiger shrimp density value was at station 2 (5.167 ind m^{-2}), followed by station 1 (3.333 ind m^{-2}) and the lowest was at station 3 (2.167 ind m^{-2}). The density of tiger shrimp at each observation station can be seen in Figure 2.

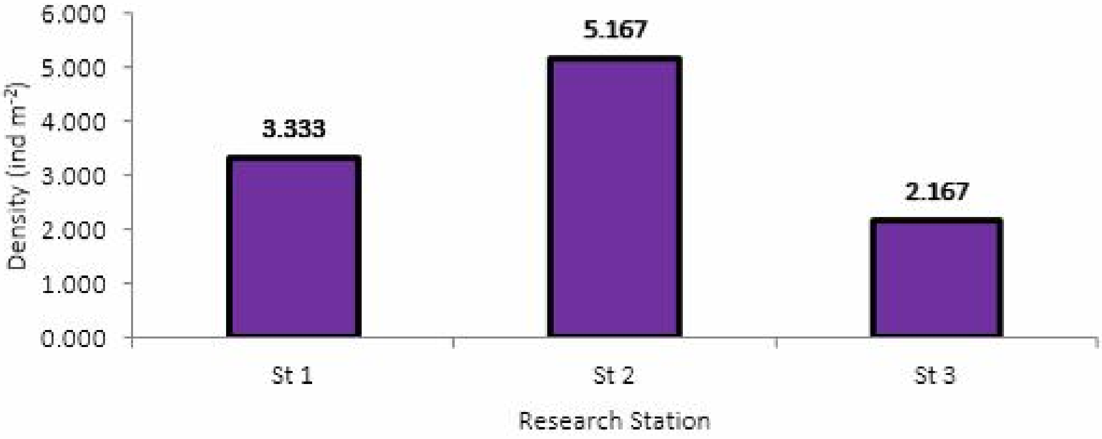

Figure 2. Density of tiger shrimp in each station.

Length-frequency distribution. Based on the results of the study, the maximum carapace length found in this study was 9.25 mm and the minimum length was 2.29 mm (Table 1).

Table 1

Length-frequency distribution of tiger shrimp

Class interval (mm)	*Percentage of size class (%)*
2.29-3.06	1.56
3.07-3.83	17.18
3.84-4.61	31.25
4.62-5.39	10.94
5.4-6.16	15.63
6.17-6.94	1.6
6.95-7.71	12.5
7.72-8.48	6.25
8.49-9.25	3.13

Growth pattern. Based on the results of the study, the growth patterns of tiger shrimp from the three stations showed negative allometric growth properties (value b < 3) (Figure 3). Station 1 with a coefficient value of b = 2.131 is the highest coefficient of any other station, while the smallest coefficient b value is at station 3 which is 1.1468. The linear equation stating the correlation between tiger shrimp's carapace length and weight can be seen in Table 2.

Table 2

Length-weight relationship of *P. monodon* in each station

Station	*Amount of tiger shrimp*	*Length-weight relationship equation*	R^2	*r*	*Growth pattern*
1	20	$W = 1.0623L^{2.131}$	0.6364	0.864	Negative allometric
2	31	$W = 1.318L^{1.5136}$	0.6294	0.718	Negative allometric
3	13	$W = 3.4959L^{1.1468}$	0.5884	0.794	Negative allometric

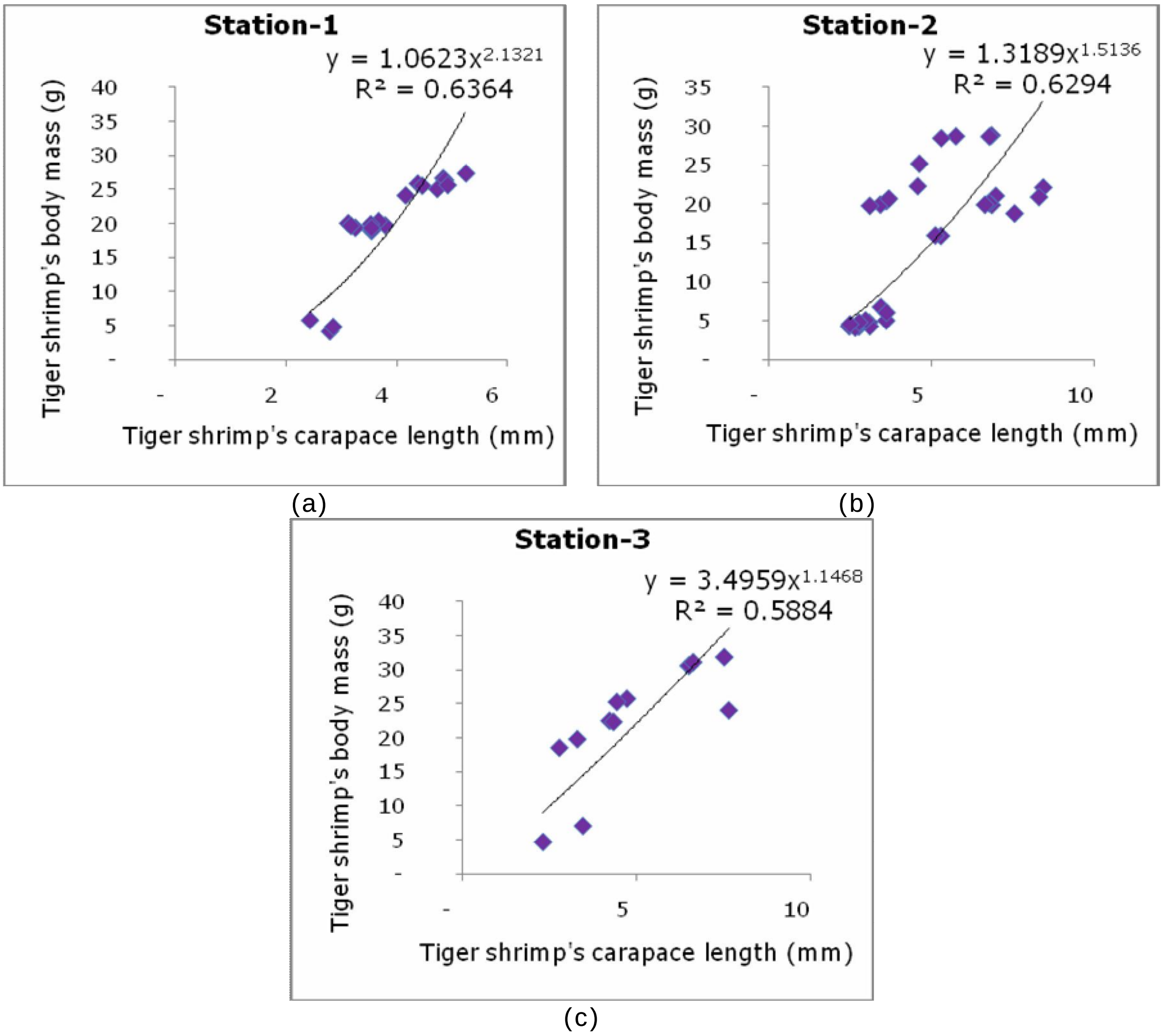

Figure 3. Tiger shrimp's growth pattern in each station.

Physico-chemical parameters of water in each station. The range of average values of physico-chemical parameters obtained during research at each station can be seen in Table 3.

Table 3

Range of average value of physico-chemical paramaters of water at each station

Parameter	*Station*		
	1	*2*	*3*
Physical			
Water temperature (^oC)	30-31	30.5-31	30-32
Water brightness (cm)	33-46	25-30	54-81
Water depth (m)	1.96-2.105	4.27-4.5	1.31-1.96
Current velocity (m s^{-1})	0.357-0.582	0.296-0.369	0.434-0.753
Substrate fraction (%)	Sand: 27 Silt: 38 Clay: 35	Sand: 17 Silt: 60 Clay: 23	Sand: 29 Silt: 33 Clay: 38
Chemical			
Water pH	4.33-4.54	4.96-5.53	5.57-6.59
Water salinity (‰)	12-25	16-27	12-18
Dissolved oxygen (mg L^{-1})	2.2-2.9	1.9-3.0	1.9-2.0
Biochemical oxygen demand (mg L^{-1})	0.4-1	0.7-2.1	0.1-2.0
Nitrate (mg L^{-1})	0.01-0.03	0.02-0.04	0.01-0.02
Phosphate (mg L^{-1})	0.03-0.1	0.04-0.2	0.03-0.1

The results of water temperature measurements obtained in the study area have a range between 30.0 and 32°C. The brightness of the water indicates a range between 25 and 81 cm. The depth of water has a range between 1.31 and 4.5 m. The result of substrate fraction in the estuary waters of Karang Gading shows that the waters are mostly dominated by silt (in station 1 and 2), and clay (in station 3). Current speeds in the research area have a range of 0.296 to 0.753 m s^{-1}. The pH measurements range from 4.33 to 6.59. The salinity of the water indicates a range of 12 to 27 ‰. DO in the study area had a range of 1.9 to 3 mg L^{-1}, while BOD_5 ranged from 0.1 to 2.1 mg L^{-1}. The results of nitrate measurements showed a range of 0.01 to 0.04 mg L^{-1}, while the phosphate levels ranged from 0.03 to 0.2 mg L^{-1}.

Correlation analysis. The results of the physico-chemical parameters correlation value (r) analysis showed that all parameters were negatively correlated (Table 4), where the values of water brightness, water salinity, current speed, water depth, BOD_5, water pH and nitrate had a very strong inversely proportional correlation to the density of tiger shrimp. DO values have a strong inversely proportional correlation to the density of tiger shrimp and water temperature values have a weak inversely proportional correlation to tiger shrimp density, and phosphate has a very weak inverse correlation to tiger shrimp density.

Table 4

Pearson's correlation values between tiger shrimp's density and physico-chemical parameters of water in research area

Physico-chemical water parameters	*Correlation value*
Temperature	- 0.385
Brightness	- 0.983
Salinity	- 0.911
Current velocity	- 0.867
Depth	- 0.961
Dissolved oxygen	- 0.691
Biochemical oxygen demand	- 0.999
pH	- 0.907
Nitrate	- 0.998
Phosphate	- 0.161

Discussion

Density of tiger shrimp. Station 2 with the highest density is a natural mangrove ecosystem area that leads to the offshores, mangroves at this station are dominated by cingam (*S. hydrophyllacea*) which has strong roots and has a lot of litter that causes shrimp to take refuge in this area. Sawida (2013) stated that the amount of litter in mangrove areas will increase the production of detritus that is used by aquatic organisms such as shrimp as a food source. Station 1 with the second highest density is a water area that is located adjacent to the community-owned encroachment area and is dominated by *A. marina*. Pane & Suman (2020) state that petroleum industry activities, ship traffic, palm plantations and other industries do not directly affect the shrimp life cycle. Station 3 with the lowest density is an area adjacent to palm plantations and is dominated by mangi-mangi (*R. apiculata*) which does not have strong roots and does not have litter that can be used by tiger shrimp as a source of food. Osmaleli et al (2014) reported that the conversion of mangrove ecosystem land as a place of settlement, industry, oil palm plantations and even cultivated land will negatively impact the availability of shrimp. Suroso et al (2014) stated that the availability of food has a huge potential for the survival of shrimp in the waters of the Mahakam Delta and the abundance of juveniles is determined by the total number of larvae.

Length-frequency distribution. The highest percentage of tiger shrimp size class is found in class hoses of 3.84 to 4.61 mm by 31.25%, while the lowest percentage of size classes is found in class hoses of 2.29 to 3.06 mm by 1.56%. The results of this study are almost the same as that conducted by Uddin et al (2016), who found tiger shrimp in the Bay of Bengal, India having a maximum carapace length of 9.5 mm and a minimum of 3.5 mm. Solanki et al (2020) also reported that tiger shrimp found in shrimp ponds of the Government of Gujarat, India had a maximum carapace length ranging from 14 to 16 mm and the minimum carapace length ranging from 3 to 8 mm.

The results of the frequency distribution of tiger shrimp length obtained during the study showed that shrimp caught in all stations on the Karang Gading estuary waters were classified into three size classes, namely small size with carapace length of 2.29 to 3.83 mm, medium size with carapace length of 3.84 to 6.94 mm and large size with carapace length of 6.95 to 9.25 mm. The three size classes were obtained from local fishermen who often group the size of shrimp to be sold in the local market. From the results of the length frequency distribution of tiger shrimp obtained during the study, most of the tiger shrimp population was dominated by medium size, so that the three research stations can be said to be feeding areas and nursery ground. The difference in the number or frequency of tiger shrimp in all class hoses of catchment might be due to the influence of environmental conditions and mangrove types around the research area.

The three size classes of caught tiger shrimp (Table 1) are also not much different from those found by Dimenta & Arismen (2017) who got three classes of tiger shrimp size in the intertidal area of Belawan, namely small (carapace range 2.20 to 4.44 mm), medium (carapace range 4.45 to 6.69 mm) and large (carapace more than 6.69 mm). Furthermore, Rosle & Ibrahim (2017) divided tiger shrimp found in the Kelantan Delta, Malaysia into three size classes ranging from small (< 15 mm) and medium (25 to 30 mm) to large (35 to 40 mm).

Growth pattern. The value of b obtained from the three research stations illustrates that the increase in the length of tiger shrimp carapace is faster than the increase in weight, so that at all three research stations found tiger shrimp that have a slender body.

Tiger shrimp obtained in all stations in the Karang Gading estuary waters had a variety of sizes, ranging from small to large. The smaller the shrimp, the faster the carapace increases, but the weight increase is slow. Conversely, the larger the shrimp, the increase in carapace slows down and is replaced by a faster increase in weight. In this study, the growth pattern could be influenced by factors such as the age of the shrimp. Juvenile shrimps were abundant in the length frequency distribution chart, as supported by Mulya et al (2011) that shrimp that have a small to medium size experience a very fast increase in carapace length, but the weight increase is very slow, while shrimp that have a large size experience a decrease in length gain and increased weight gain.

Chatterji et al (2015) stated that photoperiods (dark and light) and turbidity levels can affect the juvenile growth patterns of tiger shrimp, where the value of b obtained in dark conditions and high turbidity was higher (b = 3.99) than light conditions (b = 1.52). Uddin et al (2016) stated that the growth pattern of tiger shrimp is strongly influenced by gender, age, maturity stage, food availability, fishing area and environmental conditions. Udoinyang et al (2016) stated that factors such as the type of season, environmental conditions and food availability greatly affect the growth pattern of tiger shrimp. Komi et al (2017) stated that the growth pattern of tiger shrimp in the Andoni river was allometric because it was influenced by competition and adaptation challenges. Siagian et al (2020) reported that the growth pattern of tiger shrimp in the Tukad Aya estuary was allometrically negative due to differences in the age of each individual, the number of shrimp samples measured and the condition of the waters, and Indarjo et al (2020) added a negative allometric growth pattern due to high food competition factors that make shrimp accelerate the molting process to grow.

Physico-chemical parameters of water in each station. The temperature range obtained by each station is still relatively normal and can be tolerated by tiger shrimp. Chaitanawisuti et al (2013) reported that the water temperature range of 29 to 30°C still supports postlarvae tiger shrimp to grow. Syukri & Ilham (2016) stated that postlarvae tiger shrimp experienced good growth in the water temperature range of 27 to 31°C. Amien et al (2020) found that the temperature of water in a river estuary that can be used for tiger shrimp cultivation ranged from 28.8 to 31.6°C. Suriadarma (2011) stated that the difference in temperature obtained is thought to be due to different times during temperature measurements and levels of organic and inorganic substances capable of increasing heat delivery.

Station 2 had the lowest brightness namely 25 cm and station 3 had the highest brightness namely 81 cm. The range illustrates that the waters of Karang Gading are classified as murky and tend to be favored by tiger shrimp. Herlina et al (2017) found that with a water brightness range of 20 to 72.5 cm tiger shrimp can still survive. Suriadarma (2011) stated that the higher the brightness level, the farther away from the beach, while the low brightness level is thought to be due to its proximity to the beach which causes many suspended particles to be carried away by the flow of the river.

Station 2 is the station with the highest water depth, which is 4.5 m deep, followed by station 1 as deep as 2.105 m, and the lowest at station 3 as deep as 1.31 m and the depth range obtained still supports the life of tiger shrimp. According to Herlina et al (2017) at a water depth with a range of 1.75 to 3.5 m can still be found tiger shrimp dominated by young tiger shrimp, then Dimenta & Arismen (2017) reported there are tiger shrimp that are small to medium in the water depth with a range of 2.63 to 4.94 m. Station 3 is the station with the lowest water depth allegedly because the location of this station is close to oil palm plantations that result in plantation waste entering the waters, thus making these waters shallower than other stations. Osmaleli et al (2014) stated that the conversion of mangrove ecosystem land as a place of settlement, industry, oil palm plantations and even cultivated land will negatively affect the availability of shrimp.

Based on the results of laboratory analysis, station 3 obtained the highest sand fraction value of 29%, while station 2 only obtained a fraction value of 17%, being the lowest. The highest silt fraction value obtained by station 2 was as much as 60%, while station 3 only had 33% of dust fraction and is classified as the lowest. Station 3 also obtained the highest clay fraction value which was as much as 38% and the lowest clay fraction obtained by station 2 was as much as 23%.

Station 2 obtained the slowest current speed value of 0.296 m s^{-1}, followed by faster current on station 1 by 0.357 m s^{-1} and the fastest current at station 3 which was 0.753 m s^{-1}. According to Wardana (2011), tiger shrimp can be found at current speeds between 0.5 and 0.8 m s^{-1} in the waters of Aceh Besar, then Petatan-Ramirez et al (2020) found that the presence of tiger shrimp in the Indo-Pacific region was found at a minimum current speed of 0.23 m s^{-1} and a maximum of 0.3 m s^{-1}. The current speed obtained during the research in the estuary waters of Karang Gading is relatively calm and good for the life of tiger shrimp.

Station 3 received the highest water pH value of 6.59, while station 1 obtained the lowest water pH value of 4.33. Li et al (2015) reported that tiger shrimp can live at pH 7.8 to 8.6, and Rosle & Ibrahim (2017) found that there were 163 tiger shrimp that survived in the pH range of 7.05 to 7.68. The range of water pH obtained during the study showed that the pH of water tends not to support the life of tiger shrimp allegedly due to organic and inorganic material wastes in the area that allow the tiger shrimp metabolism to be disrupted.

Station 2 had the highest salinity value of 27‰, then station 1 had 25‰ and station 3 had the lowest salinity value of 12‰. The salinity range obtained during the study showed that the salinity of the water in the research area was still in tolerance in favor of tiger shrimp life. This is in accordance with Syukri & Ilham (2016) who stated that the range of water salinity of 25 to 30‰ is good enough for tiger shrimp in making skin changes, then Usman & Rochmady (2017) stated that in the range of water salinity of 30 to 31‰ postlarvae tiger shrimp can still grow well.

Station 2 obtained the highest DO value of 3 mg L^{-1}, then 2.2 mg L^{-1} was obtained at station 1 and station 3 obtained the lowest DO value of 1.9 mg L^{-1}. DO >5 value is the standard of DO quality according to the Decree of Minister of Environment No. 51 of 2004 (KepMenLH). Almadi et al (2013) reported that the availability of DO in traditional ponds in the Mahakam Delta for the growth of tiger shrimp ranged from 6.9 to 7.2 mg L mg L^{-1} and Hidayat (2017) stated the optimum value of DO content for the maintenance of tiger shrimp ranged from 4.27 to 5.26 mg L mg L^{-1}.

Station 2 has the highest BOD_5 content of 2.1 mg L mg L^{-1}, while station 3 has the lowest BOD_5 content of 0.1 mg L mg L^{-1}. The difference in BOD_5 value obtained from the three stations is suspected due to the influence of differences in organic matter waste that has been mixed in the mouth of the river. According to Silaen & Mulya (2018) the difference in BOD_5 value is due to the different amounts of organic matter at each research station.

Station 3 had the nitrate content of 0.02 mg L mg L^{-1} and station 2 has nitrate levels of 0.04 mg L^{-1}. The highest phosphate content found at stations 1 and 3 was 0.1 mg L mg L^{-1}, while the lowest phosphate content was at station 1 and 3 which was 0.03 mg L mg L^{-1}. Barus (2004) stated that the high nitrate levels supported by the availability of nutrients in an ocean can stimulate the growth and development of the biota.

Correlation analysis. The correlation values in opposite directions or negatives generated in all parameters in this study indicate that the higher the correlation value of each parameter, the lower the density of tiger shrimp obtained. The correlation value between temperature and density of tiger shrimp is worth -0.385. This means that if there is an increase in water temperature, then there is a decrease in the density of tiger shrimp. Temperature will affect the metabolic process of tiger shrimp, where the higher the temperature of the waters, the faster the metabolic process. This is supported by Verawati (2016) that rising water temperatures will increase the metabolic rate and growth rate of aquatic biota and oxygen consumption which also increases. Ropiah & Mahyuddin (2000) stated that when there is an increase in temperature of 10°C will result in an acceleration of chemical reactions almost 2 times in the metabolic process.

The correlation between the brightness and density of tiger shrimp is very strong and is inversely proportional, with the value of -0.983. If the brightness of the water is high, then the density of tiger shrimp decreases, conversely with low water brightness predators will have difficulties to prey on tiger shrimp because of a decrease in visibility. Mulya & Yunasfi (2018) stated that when the brightness level is high, predators will more easily prey on shrimp and conversely when the brightness level is low, the visibility of predators will be disturbed to get prey.

The correlation between water salinity and tiger shrimp density is very strong and was negatively valued (-0.911). If there is an increase in salinity, then the density of tiger shrimp decreases, where the optimum salinity for shrimp life is 20 to 30 ‰ and in salinity conditions more than 40 ‰ shrimp growth will stop (Boyd & Fast 1992). This is also supported by research of Syukri & Ilham (2016) who stated that the range of water salinity of 25 to 30 ‰ is good enough for tiger shrimp in doing skin turnover.

The correlation of current speed with shrimp density is negative and very strongly correlated (-0.867). These results indicate that the faster the current, the faster the density of shrimp will decrease resulting in disruption of tiger shrimp's life. Mulya & Yunasfi (2018) found that when the current speed calms down, many shrimp do foraging activities, conversely when the current speed increases, shrimp will choose to immerse themselves in the substrate.

The correlation between water depth and tiger shrimp density shows the value of -0.961 which means it is a very strong negative correlation which means that the density of tiger shrimp will decrease as the water depth increases. According to Herlina et al (2017) at the depth of water with a range of 1.75 to 3.5 m it can still be found tiger shrimp dominated by medium-sized individuals.

The correlation value between pH and shrimp density is -0.907. This indicates that if there is an increase in pH, then there is a decrease in the density of tiger shrimp. The low pH value of water at all three stations is due to the large waste of organic and inorganic materials in the region, which caused shrimp's metabolism to be disrupted due to the waste accumulation. Fajrilian (2018) stated that the low pH of water can cause shrimp to become stressed and interfere with the molting process so that shrimp carapace becomes mushy.

The correlation between DO and tiger shrimp density is negative and strong (-0.691), meaning that when DO increases, the density of tiger shrimp also decreases. The range of DO values in the research area was between 1.9 and 3 mg L^{-1}, where the DO results are not in accordance with the value of DO > 5 which is the standard of DO amount according to The Minister of Environment Decision No. 51 of 2004.

The correlation between BOD_5 and shrimp density is strong and negatively valued (-0.999). If there is an increase in BOD_5, then the density of tiger shrimp decreases. The same result is also found by Silaen & Mulya (2018) who stated that the correlation between BOD_5 and shrimp density is worth -0.984, where the high value of BOD_5 can be used as a bioindicator of the number of organic compounds that enter a water. The greater the BOD_5 value of water, the lower the DO content. Hatta (2014) reported that the more organic matter in water, the greater the value of BOD_5, and vice versa.

The correlation between nitrate content and the density of tiger shrimp shows a negative value of -0.998 which means that the correlation is very strong, which means that the density of tiger shrimp will decrease if there is an increase in nitrate content, while the correlation between the content of phosphate and the density of tiger shrimp shows the negative value of -0.161 which means that the correlation is very weak, which means that the density of tiger shrimp will increase as the phosphate content decreases.

Conclusions. The highest tiger shrimp population density was found at station 2 which was 5 ind m^{-2} and the lowest was at station 3 which was 2 ind m^{-2}. The distribution of length frequency of tiger shrimp was dominated by young shrimp, namely at a class interval of 3.84 to 4.61 mm with a percentage of 31.25%. The growth pattern of tiger shrimp at all stations was allometrically negative (value b < 3), where the highest b value is at station 1 (2.131) and the lowest at station 3 (1.1468). The values of brightness, salinity, current speed, depth, BOD_5, pH and nitrate are negative and very strongly correlated with the density of tiger shrimp. DO has a strong negative correlation, while temperature has a weak negative correlation to the density of tiger shrimp and phosphate negatively correlates very weakly to the density of tiger shrimp. The research data obtained can be used to establish reccomendations for local fishermen community on the eligibility of tiger shrimp fishing based on certain body length.

Acknowledgements. We are particularly grateful to the head manager of Natural Resource Management (PSDAL) Laboratory of Faculty of Mathematics and Natural Sciences, Universitas Sumatera Utara for the research supporting facility. We also give credits to all involved patrons for the constructive suggestions and comments for improving the manuscript.

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

References

Almadi I. F., Supriharyono, Bambang A. N., 2013 Dissolved oxygen availability on traditional pond using silvofishery pattern in Mahakam Delta. International Journal of Science and Engineering 5(1):35-41.

Amien M., Widiatmaka, Nirmala K., Pertiwi S., Ambarwulan W., 2020 Analysis of water quality in the river estuary as source water for tiger shrimp farming in ponds in Bulungan Regency, Province of North Kalimantan, Indonesia. AACL Bioflux 13(2): 618-626.

Barus T. A., 2004 Pengantar limnologi studi tentang ekosistem air daratan. USU Press, Medan, Indonesia, pp. 68-69. [in Indonesian]

Boyd C. E., Fast A. V., 1992 Pond monitoring and management. In: Marine shrimp culture: principles and practices. Fast A. W., Lester L. J. (eds), Elsevier Science Publisher Amsterdam, Netherlands, pp. 497-513.
CABI, Invasive Species Compendium, 2019 *Penaeus monodon* (giant tiger shrimp). Available at: https://www.cabi.org/isc/datasheet/71093. Accessed: March, 2021.
Chaitanawisuti N., Santhaweesuk W., Wattayakorn G., 2013 The combined effects of temperature and salinity on survival of postlarvae tiger prawn (*Penaeus monodon*) under laboratory conditions. Agricultural Sciences 4(6):53-56.
Chatterji A., Pati S., Dash B. P., 2015 A study on the growth of juveniles of tiger prawn, *Penaeus monodon* (Fabricius) under different photoperiods. Journal of Aquaculture Research and Development 6:12.
Dimenta R. H., Arismen S., 2017 [Spatial distribution and abundance of tiger shrimp populations (*Penaeus monodon*) in Belawan Mangrove waters]. Jurnal Nukleus 3(1):30-34. [in Indonesian]
Effendie M. I., 1997 [Fisheries biology]. Yayasan Pustaka Nusantara, Yogyakarta, Indonesia, 163 pp. [in Indonesian]
Effendie M. I., 2002 [Fisheries biology]. Yayasan Pustaka Nusantara, Yogyakarta, Indonesia, pp. 68-69. [in Indonesian]
Fajrilian B., 2018 [Analysis of lobster abundance (*Macrobrachium rosenbergii*) in Menduk River Bangka Regency]. Akuatik: Jurnal Sumberdaya Perairan 12(2):1-8. [in Indonesian]
Hatta M., 2014 Hubungan antara parameter oseanografi dengan kandungan klorofil-a pada musim timur di perairan Utara Papua. Jurnal Ilmu Kelautan dan Perikanan 24(3):29-39. [in Indonesian]
Herlina, Pangerang U. K., Farid Y., 2017 [Abundance, size composition and growth of tiger prawn (*Penaeus monodon*) in Kambu River, Southeast Sulawesi]. Jurnal Manajemen Sumber Daya Perairan 2(3):197-205. [in Indonesian]
Hidayat R., 2017 [Efficiency of feed utilization and growth of tiger shrimp (*Penaeus monodon*) in biofloc media with different C/N ratios]. Jurnal Sains Teknologi Akuakultur 1(1):11-20. [in Indonesian]
Indarjo A., Salim G., Nugraeni C. D., Prakoso L. Y., Soejarwo P. A., Rukisah, Pham Y. T. H., Daengs A. G. S., Hariyadi, Jabarsyah A., 2020 Analysis model of giant prawns population (*Macrobrachium rosenbergii*) in estuary edge of Sembakung waters, Nunukan, Indonesia. Jurnal Ilmiah Perikanan dan Kelautan 12(2):236-249.
Khafage A. R., Taha S. M., Attallah M. A., 2019 Presence of tiger shrimp *Penaeus monodon* Fabricius, 1798 (Penaeidae) in the Egyptian commercial shrimp catch, Alexandria, Egypt. The Egyptian Journal of Aquatic Research 45(2):183-187.
KepMenLH, 2004 [Decree of the State Minister of the Environment No.51 of 2004 regarding standard quality of seawater]. 10 pp. [in Indonesian]
KKP, Ministry of Marine Affairs and Fisheries, BKIPM Statistics, 2019 [Operational export volume of fishery products]. Available at: http://bkipm.kkp.go.id/bkipmnew/?r =stats/#_ops_volume_table/E/Kg/d/5/2019//nm_umum////total/desc/10/0/10. Accessed: April, 2021. [In Indonesian]
Komi G. W., Francis A., 2017 Length-weight relationship, condition factor and aspects of growth parameters of the black tiger shrimp (*Penaeus monodon*) in the Andoni River system, Niger Delta, Nigeria. Global Journals of Science Frontier Research: Agriculture and Veterinary 17(2):9-18.
Li Y. D., Jiang S. G., Huang J. H., Ma Z. H., Zhou F. L., 2015 Growth and survival variations of *Penaeus monodon* from six breeding families. International Journal of Aquaculture 5(39):1-9.
Michael P., 1995 [Ecological methods for field and laboratory investigation]. UI-Press, Jakarta, Indonesia, 616 pp. [in Indonesian]
Mohan M. M., Srinivasu K., 2015 Analysis of the nutritive composition of wild and farmed tiger shrimp *Penaeus monodon* Fabricius. International Journal of Advanced Research 3(9):711-716.
Mulya M. B., Arlen H. J., 2018 Production of litter and detritus related to the density of mangrove. IOP Conference Series: Earth and Environmental Science 130:012033.

Mulya M. B., Yunasfi, 2018 Abundance and ponderal index of white shrimp (*Penaeus merguiensis*) in estuary water. IOP Conference Series: Journal of Physics: Conference Series 1116:052042.
Mulya M. B., Bengen D. G., Kaswadji R. F., Etty R., 2011 [Distribution and growth pattern of white shrimp (*Penaeus merguiensis* de Man) in mangrove ecosystem Percut Sei Tuan North Sumatra]. Jurnal Omni Akuatika 1(13):49-56. [in Indonesian]
Osmaleli O., Kusumastanto T., Ekayani M., 2014 [Economic analysis of the linkage of mangrove ecosystems with shrimp resources]. Jurnal Ekonomi Pertanian Sumberdaya dan Lingkungan 1(1):61-70. [in Indonesian]
Pane A. R. P, Suman A., 2020 [Spawning season and size worthy of catching jerbung shrimp (*Penaeus merguiensis*) in Dumai waters and surrounding areas, Riau]. Dinamika Lingkungan Indonesia 7(2):81-88. [in Indonesian]
Perez Farfante I., Kensley B., 1997 Penaeoid and Sergestoid shrimps and prawns of the world: keys and diagnoses for the families and genera. Memories Du Museum National D'Historie Naturelle, Paris, vol 175, 233 pp.
Petatan-Ramírez D., Hernandez L., Becerril-Garcia E., Berumen-Solorzano P., Auliz-Ortiz D., Reyes-Bonilla H., 2020 Potential distribution of the tiger shrimp *Penaeus monodon* (Decapoda: Penaeidae), an invasive species in the Atlantic Ocean. Revista de Biologia Tropical 68(1):156-166.
Ropiah S., Mahyuddin K., 2000 [Water quality management]. Grafika, Jakarta, Indonesia, 77 pp. [in Indonesian]
Rosle S., Ibrahim S., 2017 Habitat preferences of shrimp (*Penaeus monodon*) in Kelantan Delta, Malaysia. International Journal of Fisheries and Aquatic Studies 5(6):326-330.
Sarwono J., Budiono H., 2012 [Applied statistics: applications for thesis research, thesis, and dissertation research using SPSS, AMOS, and Excel]. Elex Media Komputindo, Jakarta, Indonesia, 354 pp. [in Indonesian]
Sawida S., 2013 [Mangrove forest density relationship to paneid shrimp density in Laguna Mangguang in Pariaman City]. Eksakta 1:19-26. [in Indonesian]
Siagian J., Arthana I. W., Pebriani D. A. A., Saraswati S. A., 2020 The composition, size distribution and growth patterns of *Penaeus monodon* and *Penaeus merguiensis* at the estuary of Tukad Aya, Jembrana Bali. Advances in Tropical Biodiversity and Environmental Sciences 4(2):15-20.
Silaen S. N., Mulya M. B., 2018 Density and white shrimp growth pattern (*Penaeus merguiensis*) in Kampung Nipah waters of Perbaungan North Sumatera. IOP Conference Series: Earth and Environmental Science 130:012044.
Soetomo M. J. A., 2000 [Tiger shrimp farming technique (*P. monodon*)]. Kanisius, Yogyakarta, Indonesia, 78 pp. [in Indonesian]
Solanki H. G, Ujjania N. C., Gopal C., Pillai S. M., 2020 Length-weight relationship, condition factor and length-frequency analysis of tiger shrimp (*Penaeus monodon* Fabricius, 1798). International Journal of Fauna and Biological Studies 7(4):191-195.
Suriadarma A., 2011 [Impact of several parameters of chemical physical factors on environmental quality of coastal waters of Karawang, West Java]. Riset Geologi dan Pertambangan 21(1):21-36. [In Indonesian]
Suroso B., Hutabarat J., Afiati N., 2014 The potential of tiger prawn fry from Delta Mahakam, East Kalimantan Indonesia. International Journal of Science and Engineering 6(1):43-46.
Syam Z., Yunasfi, Dalimunthe M., 2014 [The effect of mangrove forests for tiger shrimp production (*Penaeus monodon*) in silvofishery pond in Tanjung Ibus village Sub-District Secanggang District of Langkat]. Jurnal Aquacostmarine 2(1):107-117. [in Indonesian]
Syukri M., Ilham M., 2016 [The influence of salinity to the survival and growth of the larvae of tiger shrimp (*Penaeus monodon*)]. Jurnal Galung Tropika 5(2):86-96. [in Indonesian]

Uddin S. K. N., Gosh S., Maity J., 2016 Length weight relationship and condition factor of *Penaeus monodon* (Fabricius, 1798) from Digha coast, West Bengal, India. International Journal of Fisheries and Aquatic Studies 4(3):168-172.
Usman A., Rochmady, 2017 [Growth and survival of post larvae of tiger shrimp (*Penaeus monodon* Fabr.) through the administration of probiotics with different doses]. Jurnal Akuakultur 1(1):19-26. [in Indonesian]
Udoinyang E. P., Amali O., Iheukwumere C. C., Ukpatu J. E., 2016 Length-weight relationship and condition factor of seven shrimp species in the artisanal shrimp fishery of Iko river estuary, southeastern Nigeria. International Journal of Fisheries and Aquatic Studies 4(2):109-114.
Venkateswarlu V., 2019 Comparative analysis of the biochemical composition of wild caught penaeid shrimps (*Penaeus indicus*, *Penaeus monodon* and *Penaeus vannamei*) in Nellore, Andhra Pradesh. International Journal of Fisheries and Aquatic Studies 7(5):410-413.
Verawati, 2016 [Analysis of sea water quality in Lampung Bay]. MSc thesis, Program Pascasarjana Magister Teknik Sipil, Universitas Lampung, Bandar Lampung, 167 pp. [in Indonesian]
Verdian A. H., Witoko P., Aziz R., 2020 [Chemical composition of white shrimp (*Litopenaeus vanamei*) and tiger shrimp (*Penaeus monodon*) meats cultivated in floating net cage]. Jurnal Perikanan Terapan 1:1-4. [in Indonesian]
Wardana M. Y., 2011 [The prospect of tiger prawn mother in Aceh Besar coastal area]. Agrisep 12(1):1-9. [in Indonesian]

Received: 10 January 2022. Accepted: 09 March 2022. Published online: 18 June 2022.
Authors:
Nurul Fauziah, Department of Biology, Faculty of Mathematics and Natural Science, Universitas Sumatera Utara, Jl. Bioteknologi No. 1 Kampus USU, Padang Bulan, Medan Baru, Medan, North Sumatera, Indonesia, 20155, e-mail: nurulahmady@gmail.com
Miswar Budi Mulya, Department of Biology, Faculty of Mathematics and Natural Science, Universitas Sumatera Utara, Jl. Bioteknologi No. 1 Kampus USU, Padang Bulan, Medan Baru, Medan, North Sumatera, Indonesia, 20155, e-mail: miswarbm_bio@usu.ac.id
Ternala Alexander Barus, Department of Biology, Faculty of Mathematics and Natural Science, Universitas Sumatera Utara, Jl. Bioteknologi No. 1 Kampus USU, Padang Bulan, Medan Baru, Medan, North Sumatera, Indonesia, 20155, e-mail: ternala@usu.ac.id

How to cite this article:
Fauziah N., Mulya M. B., Barus T. A., 2022 Density, length-frequency distribution and growth pattern of *Penaeus monodon* in Karang Gading estuary. AACL Bioflux 15(3):1422-1434.