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Length-weight relationship, sex ratio, mortality and growth condition of natural stock of *Macrobrachium rosenbergii* from the estuarine systems of North Kalimantan, Indonesia

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Abstract. Indarjo A, Salim G, Nugraeni CD, Zein M, Ransangan J, Prakoso LY, Suhirwan, Anggoro S. 2021. Length-weight relationship, sex ratio, mortality and growth condition of natural stock of *Macrobrachium rosenbergii* from the estuarine systems of North Kalimantan, Indonesia. *Biodiversitas* 22: 846-857. Giant prawns (*Macrobrachium rosenbergii*) in North Kalimantan Province, Indonesia are commonly found inhabiting estuarine areas: Salimbatu Village (Bulungan District), Tepian Village (Nunukan District) and Buong Baru and Sesayap Villages (Tana Tidung District). The present study was conducted to analyze the relationship between length and weight, sex ratio, mortality, and growth condition index of the naturally occurring giant prawns in three districts namely Bulungan, Nunukan, and Tana Tidung in the North Kalimantan Province, Indonesia. The samplings were carried out for a period of seven months beginning April to November 2020. The results revealed that the giant prawns in Buong Baru Village, Sesayap Village, and Salimbatu Village were characterized to have negative allometric growth patterns. Interestingly, the male giant prawns in Tepian Village were observed to exhibit positive allometric growth pattern. The ratio sex analysis of the giant prawns in the four villages indicated that female prawns were more than male. In terms of size distribution, Salimbatu Village exhibited 60.1% of prawns measured at 14.02-17.74cm (size range of 10.3-47.5 cm). In Tepian Village, 32.9% of the prawns were observed to measure between 11.20-12.80 cm (size range of 8.0-24.0 cm). In Buong Baru Village, it was observed 18.5% of the prawns measured 22.0-25.5 cm and 29.0-32.5 cm (size range of 15.0-50.0 cm), respectively. Finally, 28.3% of the prawns in Sesayap Village was observed to measure at 12.19-14.02 cm from the overall size distribution between 6.7-25.0 cm. Relative condition factor of giant prawns found in the waters of Salimbatu Village, Tepian Village, and Buong Baru Village waters and Sesayap Village waters was characterized by thin body shape. The maximum length of male prawns was higher than female prawns in Salimbatu Village, Desa Tepian and Sesayap Village, except in Buong Baru Village where female was longer than male. The exploitation rate and fishing mortalities of prawns were higher in Buong Baru Village, Tana Tidung District. Giant prawn fishery contributes to the socio-economic development of the people in North Kalimantan. Hence, sustainable fishery management of this species, particularly in Buong Baru Village is urgently needed so that it can continue to provide livelihoods to the fishermen in the area.

Keywords: Growth condition of natural giant prawn, length-weight relationship, *Macrobrachium rosenbergii*, mortality, sex ratio

INTRODUCTION

Estuarine ecosystems of Indonesia are rich in biodiversity (Suwartiningsih et al. 2017). Many of these biodiversities are exploited for economic development including giant prawns (Indarjo et al. 2020e). The giant prawns (*Macrobrachium rosenbergii*) are commercially important species and are highly exploited due to their large size (Khasani 2008) and high nutrition contents (Nandlal and Pickering 2005). Giant prawn is indigenous to south and southeast Asian as well as in the northern Oceania and Western Pacific islands, but research activities and commercial purposes have made its distribution

expanded throughout the tropical and subtropical regions of the world (Holthuis 1980; New 2002). It occurs in various types of coastal systems including rivers, swamps, lakes, irrigation as well as estuarine systems throughout Indonesia (New 2005). There are several natural populations of the prawn in Indonesia including Musi (South Sumatra), Kalipucang, Tajung Air (West Java) (Hadie et al. 2004), Makassar (South Sulawesi), Banjarmasin (South Kalimantan), Jambi (central Sumatra), and Barito (Kalimantan) (Hadie et al. 2005).

The price of *M. rosenbergii* varies according to places. Indarjo et al. (2020) reported that moderate size of giant prawn in Tepian Village, Nunukan District, is sold at

Rp.80,000 (USD 5.6)/kg while big sized prawn is sold at Rp.100,000 (USD 7.07)/kg. In Salimbatu Village, Bulungan District the moderate size prawn is sold at Rp.40,000 (USD 2.8)/kg while large-sized *M. rosenbergii* costs at Rp.65,000 (USD 4.6)/kg. In the Buong Baru Village and Sesayap Village, both in Tana District, the price of *M. rosenbergii* is also determined by size. Moderate size prawn is normally sold at Rp.80,000 (USD 5.6)/kg whereas large-sized prawn is sold at Rp.100,000 (USD 7.07)/kg, respectively. In Kalimantan Province, Indonesia, giant prawn is an important fishery resource because it provides income to coastal community (Samuel and Aida 2008). The market price of the prawn in Kalimantan Province ranges from Rp.140,000 (USD 9.9) to 200,000 (USD 14.13) per kilogram depending on sizes (Sukarli 2017).

According to Indarjo et al. (2020d), giant prawn in Tepian Village has huge potential for capture fishery but over-exploitation of the resource can affect its natural population. Unfortunately, no study has been conducted to assess the population dynamics of the prawn in the area. Sofian dan Sari (2018) suggested that the abundance of giant prawns can be affected by excessive exploitation of the resource. Indarjo et al. (2020e) also explained that high market demand of the giant prawn has increased fishing intensity using different gears. Such activity could alter size distribution, condition factor, and the overall population health of the species.

Hossain et al. (2012) reported that *M. rosenbergii* is one of the fast-growing prawns. Giant prawn was reported to grow up to 250 mm (female) and 320 mm (male) and weighed more than 300 grams (Wowor and Ng 2007; Holthuis and Ng 2010). Sofian and Sari (2018) reported male *M. rosenbergii* can attain between 7.6-27 cm in length and from 3 to 297 grams in weight. Likewise, female prawn was reported to achieve between 8.5-18.2 cm in length and between 5-53 gram in weight. However, Indarjo et al. (2020) suggested that the length of *M. rosenbergii* may vary. The authors reported that male and female prawns can grow up to 14.55±6.55 cm and 12.4±4.6 cm, respectively. *M. rosenbergii* is an euryhaline species and able to survive in estuarine areas (Ali and Waluyo 2015) with different levels of salinities. According to Indarjo et al. (2020), giant prawn can survive in 6-7 ppt salinity levels whereas New (2002) observed that giant prawn survive in 15 to 20 ppt salinity levels.

Due to attractive pricing, the number of fishermen fishing for the prawn in several villages within the three districts on the North Kalimantan Province especially in Balungan, Nunukan, and Tana Tidung has drastically increased. In addition, many fishing gears (e.g. *langgian* (scoop net), *tuguk* (filtering device), *jala* (cast nets), *empang lulung* (barrier trap), *bengkirai bilah* (poot traps) and *pancing* (hook and lines), *rawai udang* (long lines), *rompong* and *pukat rantau* (fish aggregating devices)) have also been invented to effectively catch the prawns. In recent years, *stroom* (electrical fishing) has also been practiced in some areas.

The high number of fishermen involved in fishing using various fishing gears can have negative impact on the

natural stock of the prawn and may lead to overfishing. In fact, there is already sign of stock reduction being experienced by the fishermen in this province, especially in the Tana Tidung District (Hanifah 2019). Unfortunately, the effects of fishing activity on the natural stocks of giant prawns in the three districts of North Kalimantan Province are difficult to evaluate due to no thorough studies were conducted on the status of natural stocks of the prawn in those areas. Such situation makes it difficult for the relevant agencies to implement sustainable management of the giant prawn resource. Hence, the present study was conducted to examine the status of length-weight relationship, sex ratio, mortality, and growth condition of the giant prawns in the three districts (Bulungan, Nunukan, and Tana Tidung) in the North Kalimantan Province, Indonesia.

MATERIALS AND METHODS

Sampling

Sampling sites and study period

The study of the giant prawn was conducted in the coastal waters of three districts (Bulungan, Nunukan and Tana Tidung) in the North Kalimantan, Indonesia (Figure 1). Samples of the prawn were collected from four villages namely Salimbatu Village (Tanjung Palas Tengah Subdistrict, Bulungan District), Tepian Village (Sembakung Subdistrict, Nunukan District), Buong Baru Village (Batayau Subdistrict, Tana Tidung District), and Sesayap Village (Sesayap Hilir Subdistrict, Tana Tidung District). The study was conducted for seven months from April 2020 to November 2020.

Sample collection

The collection of giant prawn (*M. rosenbergii*) specimens was done in the fields following the fishermen fishing technique unique to the study sites. The sampling of the prawn in Salimbatu was achieved by using prawn trap called *bubu* made of high-density polyethylene (HDPE) netting (Figure 2.A). Sample collection in Buong Baru was done by using *bubu* or prawn trap made of bamboo (Figure 2.B). The sample collection in Tepian was achieved by using casting net, called *jala* by the local peoples (Figure 2.C). Samples of prawns in Sesayap were collected using casting net (Figure 2.D). Then, the prawns were sorted out after capture and identified following Holthuis (1980) and Powell (1983).

Sample measurement

The total length (TL), carapace length (CL), total body weight (BW) and sexes of all specimens of the giant prawn were recorded and determined, respectively. A total of 404 prawn specimens were collected using prawn trap in Salimbatu; 621 specimens of prawn from Tepian; 81 specimens from Buong Baru and 53 specimens from Sesayap. The total length of all the prawns were assigned into 10 length classes interval (Tables 3-6).

Sex determination

The male and female giant prawns were distinguished following Aflalo et al. (2006). Briefly, the four main differences of the male and female prawns were specifically examined in order to assign the sex of the prawn specimens. It was noted that the 2nd pereopods (chelipeds) of the male prawn is longer than the female prawn. The abdomen of male prawn is slimmer than the abdomen of female prawn. The carapace of the male prawn is larger than the female prawn. The sex of the prawns was determined based on the location of the sex organ (gonophores). The gonophores of the male prawn are located on the 5th pereopods whereas the gonophores of female prawn are located on the 3rd pereopods.

Physicochemical parameters

The physicochemical parameters including temperature, salinity, pH, and dissolved oxygen were recorded in the sampling sites (Salimbatu, Tepian and Sesayap) except for Buong Baru due to Covid-19. The location of each

sampling site was recorded using the Global Positioning System (GPS). The temperature, salinity and pH were directly measured in the field (in situ) whereas the dissolved oxygen was measured ex-situ at the Water Quality Laboratory of the Faculty of Fisheries and Marine Sciences, University of Borneo Tarakan, Indonesia.

Data analysis

Sex ratio

Sex ratio (male: female) was calculated by dividing the number of male/female specimens with the total number of specimens analyzed. Then, sex ratios were then tabulated according to its sampling site. The sex determination was done following sex identification guidelines suggested by Aflalo et al. (2006).

Length-weight relationship

Regression analysis was performed on the length-weight measurement according to the following model (Pauly 1984).

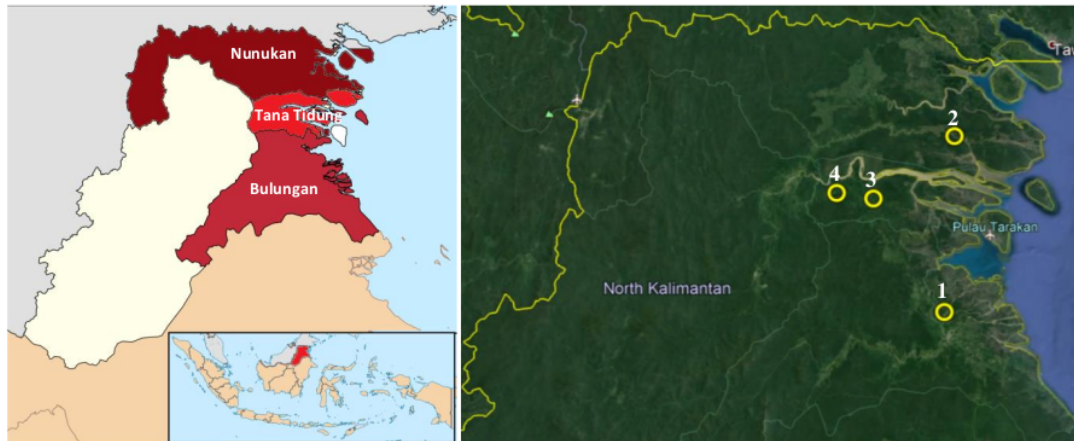


Figure 1. Study sites in the three districts (Bulungan, Nunukan and Tana Tidung) on the North Kalimantan Province, Indonesia. 1. Salimbatu Village, 2. Tepian Village, 3. Buong Baru Village 4. Sesayap Village



Figure 2. Fishing techniques used by fishermen in different sampling sites. A. Prawn traps, *bubu* (Salimbatu Village); B. Prawn trap, *bubu* (Buong Baru Village); C. Casting net (Tepian Village); D. Casting net (Sesayap Village)

$$W=aL^b$$

Where, W is body wet weight (g), L is total length (cm), a and b are parameters of the power equation.

The linearized equation of the model was expressed in the following equation (Effendie 2002).

$$\log_{10} W = \log_{10} a + b \log_{10} L$$

Where, W: total weight (gram); L: total length (mm); a: intercept and b: slope (growth exponent).

Condition factor

Relative condition factor 'Kn' introduced by Le Cren (1985) was estimated by the following formula:

$$Kn = \frac{W}{\hat{W}}$$

Where, W: actual weight of fish (g); \hat{W} : expected weight of fish (g). The \hat{W} was estimated from the logarithmic transformed of the allometric growth formula:

$$\log W = \log a + b \log L$$

Condition index of the fish was categorized into five categories i.e. very thin (Kn=0.01-0.50), thin (Kn=0.51-0.99), ideal (kn=1.0), fat (kn=1.01-1.50), and very fat (kn>1.50) (Firdaus and Salim 2011; Salim 2013; Salim 2015; Firdaus et al. 2018; Firdaus et al. 2020; Indarjo et al. 2020a; Indarjo et al. 2020b; Indarjo et al. 2020c).

Absolute growth

The absolute growth of prawns in different sampling sites was estimated using the Von Bertalanffy Growth Function (Sparre and Venema 1999) as follow:

$$L_t = L_\infty (1 - e^{-k(t-t_0)})$$

Where, L_t : length of *M. rosenbergii* at age t (unit time); L_∞ : maximum length (asymptotic length) of *M. rosenbergii*; K: growth coefficient *M. rosenbergii* (per unit time); t_0 : hypothetical age of the *M. rosenbergii* at length equals to zero.

Age structure

Age structure parameters estimated using the mode class shift method associated with the Von Bertalanffy Growth Function (Sparre et al. 1999) as follow:

$$\frac{\Delta L}{\Delta t} = \frac{(L_2 - L_1)}{(t_2 - t_1)}$$

$$L_{(t)} = (L_2 + L_1)$$

Where, $\Delta L/\Delta t$: Relative growth of *M. rosenbergii*; ΔL : Length of *M. rosenbergii*; Δt : Time difference in sampling of *M. rosenbergii*; $L_{(t)}$: Mean length at age t.

Then, by plotting $L_{(t)}$ and $(\Delta L/\Delta t)$, a linear equation can be derived as follow:

$$Y = a + bx$$

Where, $a = ((\sum y/n) - (b (\sum x/n)))$; $b = (n \sum (xy) - (\sum x)(\sum y)) / (n \sum x^2 - (\sum x)^2)$

The linear regression equation can be used to calculate the asymptotic length (L_∞), namely a/b , and the growth coefficient (K), namely $-b$.

The theoretical age of *M. rosenbergii* when the length is equal to zero can be estimated separately using empirical equations (Pauly 1984) as follows:

$$\log_{10} (-t_0) = -0.3922 - 0.275 (\log_{10} L_\infty - 1.038 (\log_{10} K))$$

Where, L_∞ : Asymptotic length of *M. rosenbergii* (cm); K: Growth coefficient of *M. rosenbergii*; t_0 : hypothetical age of *M. rosenbergii* at length equals to zero (year).

Mortality

Natural mortality (M) of *M. rosenbergii* was estimated using Pauly's empirical formula (1980) as follows:

$$\log M = -0.0066 - 0.279 \log L_\infty + 0.6543 \log K + 0.4634 \log T$$

Total mortality (Z) of *M. rosenbergii* was estimated using Beverton and Holt formula (Sparre and Venema 1998), Sparre et al. (1999) as follows:

$$Z = K \cdot \left[\frac{L_\infty - \bar{L}}{\bar{L} - L'} \right]$$

Fishing mortality (F) of *M. rosenbergii* as follows:

$$F = Z - M$$

The exploitation rate (E) of *M. rosenbergii* was estimated following Gulland (1965) as follows:

$$E = F / (F + M)$$

Where, E: Exploitation rate of *M. rosenbergii*; Z: Total mortality of *M. rosenbergii*; F: Fishing mortality of *M. rosenbergii*; M: Natural mortality of *M. rosenbergii*.

Statistical analyses

All the statistical analyses were conducted using the SPSS Windows Statistical Package (Version 26, Chicago, USA). The regression analysis was employed to analyze the length-weight relationship, while Chi-square test was used to analyze the differences in the frequency distributions of fish length and fattiness.

RESULTS AND DISCUSSION

Sex ratio

Sex ratio of the giant prawns (*M. rosenbergii*) in each sampling site analyzed in the current study is presented in Table 1. It was noted that the proportion of male and female prawns is consistent across sampling sites and districts whereby females are generally more than males except in Sesayap whereby the proportion of male and

female prawns almost equal is 1 : 1.03. The proportion of female prawns in Tepian was found 4.45 times higher than that of males. This is not surprising observation as New Kutty (2010) had reported that the proportion of female *M. rosenbergii* is commonly higher than male. The published proportion of female to male of *M. rosenbergii* in Indonesia ranged from 1.88 times (Sofian and Sari 2018) to 3.67 times (Indarjo et al. 2020e).

Knowledge of sex proportion of naturally occurring *M. rosenbergii* is important because it allows estimation of differential prawn fishing in different periods of the year and the various size groups (Bahuguna 2013). It can also provide information about the abundance of the sex ratio at different times of the year such as during breeding season. In this study, it was observed that the number of female specimens was higher than males. This sex ratio is very similar to that in *M. felicinum* (Ukagwu and Deekae 2016), *M. hetreochirus* and *M. carcinus* (Mejia-Ortiz et al. 2001), *M. brasiliense* (Mantellato and Barbosa 2005), *M. dux* (Arimoro and Meye 2007), *M. macrobrachion* and *M. vollenhovenii* (Lawal-Are and Owolabi 2012). This indicates that the natural stocks of the giant prawn (*Macrobrachium* spp) are generally dominated by females. Hence, the findings of the present study showed that the natural stocks of the giant prawns in the estuarine systems of North Kalimantan Province are still not over-exploited and no sign of fishing preference over one particular sex. However, the observation in Sesayap Village could be a concern for sustainable fishery management but more studies are needed to examine what factors could remove more females in the area before management strategies can be designed and implemented.

Length and weight relationship

The present study revealed that the total length (TL), carapace length (CL) and body weight (BW) of male prawns in the three sampling sites (Tepian, Salimbatu, and Sesayap) were recorded higher than that of female prawns (Table 2). One exception to this observation was in Buong Baru whereby male prawns were observed to have bigger size (TL, CL and BW) compared to female prawns (Table 2). In terms of total length distribution, it was observed that all prawns in all sampling sites were distributed into the 10 length classes with no significant differences ($p > 0.05$) in frequency between male and female specimens (Table 3).

The prawns in Salimbatu were found to have TL that ranged from 10.3-47.5 cm and CL ranged 4.5-14 cm and BW ranged from 3.05 to 193 grams, respectively. Meanwhile, the prawns in Tepian observed to have TL and CL that ranged from 8.0-24 cm and 2.0-12.5 cm with BW of 2.37-181.8 grams. The prawns caught in Buong Baru and Sesayap were observed to have TL that ranged from 15.0-50 cm (CL: 5.5-13 cm) and 6.7-25 cm (CL: 2.0-13.0 cm) with BW of 9.67-214.47 grams and 3.84-141.09 grams, respectively (Table 2). The present observations on the TL of the giant prawns in the four villages were in agreement with the observations by the previous studies. New Kutty (2010) observed that *M. rosenbergii* can reach TL of 9.9-19.3 cm with BW of 10.86-69.86 grams. Sofian

and Sari (2018) also reported *M. rosenbergii* is able to reach TL between 7.6-27 cm with BW of 3-297 grams. Indarjo et al. (2020d) and (2020e) reported that *M. rosenbergii* can reach TL of 7.8-21.1 cm and 9.9-19.3 cm, respectively. Regardless of sex, the giant prawns caught in Salimbatu recorded CL that ranged between 2-14 cm. This seems to be an advantage to the prawn population in the area as Hadie and Hadie (2012) reported that prawns with shorter CL would have greater meat proportion.

The present study also examined the size (length) distribution of the naturally occurring prawns in the four selected villages on the North Kalimantan Province. Table 3 shows the TL distribution of giant prawns. In Salimbatu, it was observed that the male prawns ($n = 182$ samples), females ($n = 222$) and overall ($n = 404$) were mostly found within the 14.02 and 17.74 cm length class. In Tepian, it was observed that male prawns ($n = 114$) were mostly within the 17.6-19.2 cm length class while the female prawns ($n = 507$) and overall specimens ($n = 621$) were found mostly within the 11.2-12.8 cm length class. In Buong Baru, it was observed that majority of the male prawns ($n = 20$) were found within the 36-39.5 cm length class. As for female prawns ($n=61$), majority of them were within the 22.0-25.5 cm length class. However, overall specimens ($n = 81$) were observed to be distributed within the two length classes (22.0-25.5 cm and 29.0-32.5 cm). In Sesayap, the male prawns ($n = 26$) were found mostly distributed within the 19.51-21.34 cm length class while female prawns ($n=27$) and overall specimens ($n = 53$) were mostly distributed within the 12.19-14.02 cm length class. From this study, it was evident that most of the giant prawns caught in the four villages were dominated by young prawns (Sofian and Sari 2018). This shows that the fishermen in the villages may have limited knowledge of the sustainable exploitation of fishery resources.

The calculated exponents of the length-weight (L-W) relationship of the prawns in all sampling sites are given in Table 4. Overall, the L-W relationship of the prawns both male and female from different sampling sites showed negative allometric growth pattern ($b < 3.0$). Overall and regardless of sex, the prawn stocks in the four villages (Salimbatu, Tepian, Buong Baru, and Sesayap) showed negative allometric growth pattern. Only male prawns from the Tepian showed allometric positive growth pattern ($b > 3.0$).

The relationship between weight and length for crustaceans is usually described by the expression $W = aL^b$. The organism is growing isometrically if $b=3$, and when the b parameter is not equal to 3, the growth is said to be allometric (Wootton 1992; Enin 1994). Ricker (1975) stated that allometric growth can either be positive ($b > 3$) or negative ($b < 3$). Wootton (1992) reported if the animal gets relatively thinner, then the b value would be less than 3.0 but if it gets plump, the b value would be greater than 3.0. All the overall values of the growth exponent, b in this study were less than 3 (Gayanilo and Pauly 1997) indicating that the prawns are exhibiting negative allometric growth fashion.

Table 1. The proportion of male and female prawn according to sampling site

Sampling site	Male		Female		Total	Ratio M:F
	N	Proportion	N	Proportion		
Salimbatu Village (Bulungan District)	182	45.05%	222	54.95%	404	1:1.22
Tepian Village (Nunukan District)	114	18.36%	507	81.64%	621	1:4.45
Buong Baru Village (Tana Tidung District)	20	24.69%	61	75.31%	81	1:3.05
Sesayap Village (Tana Tidung District)	26	49.06%	27	50.94%	53	1:1.03

Note: N: number of specimens

Table 2. Length and weight distributions of the *Macrobrachium rosenbergii* specimens collected from North Kalimantan, Indonesia

Parameter	Male	Female	Overall
Salimbatu Village (Bulungan District)			
Total length (cm)	10.3-47.5 (18.94±6.50)	13.2-44.8 (19.45±6.11)	10.3-47.5 (19.22±6.29)
Carapace (cm)	5.0-14.0 (7.51±1.71)	4.5-10.5 (7.19±0.99)	4.5-14.0 (7.34±1.37)
Weight (g)	3.05-193.0 (47.78±34.42)	14.6-106.0 (41.34±12.77)	3.05-193.0 (44.24±25.13)
	35.75	39.28	38.14
Tepian Village (Nunukan District)			
Total length (cm)	8.5-24.0 (16.49±3.22)	8.0-21.0 (13.42±1.77)	8.0-24.0 (13.98±2.42)
Carapace (cm)	2.0-12.5 (6.60±2.42)	2.0-10.5 (4.65±2.00)	2.0-12.5 (5.10±2.69)
Weight (g)	5.95-181.80 (53.27±37.32)	2.37-75.89 (26.31±9.64)	2.37-181.80 (31.26±20.94)
	42.43	24.46	24.90
Buong Baru Village (Tana Tidung District)			
Total length (cm)	26.5-45.0 (36.14±4.98)	15.0-50.0 (29.76±7.08)	15.0-50.0 (31.34±7.15)
Carapace (cm)	7.50-13.0 (11.02±1.45)	5.5-13.0 (8.73±1.71)	5.5-13.0 (9.3±1.92)
Weight (g)	26.65-154.49 (106.86±37.28)	9.67-214.47 (53.57±37.76)	9.67-214.47 (66.73±43.98)
	112.78	42.18	52.33
Sesayap Village (Tana Tidung District)			
Total length (cm)	14.5-25.0 (20.97±3.11)	6.7-23.2 (14.48±3.83)	6.7-25.0 (17.66±4.76)
Carapace (cm)	6.0-13.0 (10.52±2.13)	2.0-12.5 (7.04±2.42)	2.0-13.0 (8.75±2.86)
Weight (g)	25.78-141.09 (88.95±37.91)	3.84-110.23 (35.31±29.56)	3.84-141.09 (61.63±43.14)
	93.43	22.52	39.53

Table 3. Length class distribution of the *Macrobrachium rosenbergii* specimens from North Kalimantan, Indonesia

Length class	Size range (cm)	Male	Female	Overall
Salimbatu Village (Bulungan District)				
1	10.30-14.02	19	8	27
2	14.02-17.74	103*	140*	243*
3	17.74-21.46	10	13	23
4	21.46-25.18	23	14	37
5	25.18-28.90	11	23	34
6	28.90-32.62	6	14	20
7	32.62-36.34	7	6	13
8	36.34-40.06	0	3	3
9	40.06-43.78	1	0	1
10	43.78-47.50	2	1	3
	Total**	182 ^a	222 ^a	404 ^a
Tepian Village (Nunukan District)				
1	8.00-9.60	1	3	4
2	9.60-11.20	3	18	21
3	11.20-12.80	12	192*	204*
4	12.80-14.40	17	161	178
5	14.40-16.00	17	93	110
6	16.00-17.60	18	26	44
7	17.60-19.20	26*	11	37
8	19.20-20.80	8	2	10
9	20.80-22.40	9	1	10
10	22.40-24.00	3	0	3
	Total**	114 ^a	507 ^a	621 ^a
Buong Baru Village (Tana Tidung District)				
1	15.0-18.5	0	2	2
2	18.5-22.0	0	4	4
3	22.0-25.5	0	15*	15*
4	25.5-29.0	2	8	10
5	29.0-32.5	2	13	15*
6	32.5-36.0	5	8	13
7	36.0-39.5	7*	6	13
8	39.5-43.0	2	2	4
9	43.0-46.5	2	2	4
10	46.5-50.0	0	1	1
	Total**	20 ^a	61 ^a	81 ^a
Sesayap Village (Tana Tidung District)				
1	6.70-8.53	0	1	1
2	8.53-10.36	0	1	1
3	10.36-12.19	0	2	2
4	12.19-14.02	0	15*	15*
5	14.02-15.85	3	2	5
6	15.85-17.68	1	1	2
7	17.68-19.51	2	2	4
8	19.51-21.34	8*	0	8
9	21.34-23.17	6	2	8
10	23.17-25.00	6	1	7
	Total**	26 ^a	27 ^a	53 ^a

Notes: *the length class in which the median value is recorded; **different letters indicate significant differences in terms of frequency distributions.

Table 4 shows the L-W relationships of the giant prawns in the four villages in North Kalimantan Province. It was observed that the prawns in three villages exhibited negative Y-intercept of the linear regression between weight and length. Whether or not these values have significant biological consequences to the prawns in the areas is something very interesting but with the limited amount of data gathered in the present study, interpretation of this observation cannot be accurately done. It was reported that the L-W relationships of *M. rosenbergii* are affected by the age of the animal (Ming et al. 2016). Growth pattern for *M. rosenbergii* varies according to life stages (Primavera et al. 1998; Kurup et al. 2000; Lalrinsanga et al. 2012).

Such growth pattern is always referred to as the "leapfrog" growth pattern (Karplus et al. 1991). The values of the allometry coefficient (b) of the prawns in the present values were in agreement with previous studies in terms of all showed negative allometric growth (Table 5) except for the prawn stock in Salimbatu. The allometry coefficient of the *M. rosenbergii* in the North Kalimantan tends to have similar growth characteristics with the prawn stocks in Sarawak, Malaysia (Khairul Adha et al. 2016). This may be explained by the close relatedness of the prawns since Sarawak and North Kalimantan are adjacent.

In the present study, the allometry coefficient of the prawn in Sesayap BW-TL was less than 3 ($b=2.7$) which may indicate that the increase in weight of the prawns in the area is relatively slower than the length (Effendie 2002). Such observation was in accordance with the finding of Sofian and Sari (2018) who found lower allometry coefficient value ($b<3.0$) of the giant prawns in the Ogan River, Ogan Ilir District. However, the male prawns caught in Tepian exhibited higher allometry coefficient ($b = 3.1$) which indicates that weight gain is faster than the length. This is not a surprising finding as Murni (2004) also reported high allometry coefficient

($b>3.0$) of giant prawns in Kapuas Pontianak, West Kalimantan. The differences in allometry coefficient were reported to influence by food abundance and availability, water conditions and analytical methods (Raswin et al. 1981). Furthermore, the growth of any organism depends on the intrinsic factors (genetic makeup) as well as the extrinsic (environmental) factors acting on the individual throughout its ontogenetic development. According to Hartnoll (1982), the exogenous factors that mostly influence the growth of crustaceans are temperature and food availability.

Condition index

Analysis of the condition index of the giant prawn specimens revealed little variations in terms of body shape among the prawns collected from different sampling sites (Table 6). Different values of the condition index imply different body shapes of the prawns (Lagler 1961). The prawn specimens collected from Salimbatu exhibited 4 different body shapes which are very thin, thin, fat and very fat. The male prawn specimens in this sampling site seemed to have a wide distribution of body shape compared to the female prawns. More than half (51.8%) of the female prawns in Salimbatu consisted of thin specimens. In contrast, the male prawns in this area showed to have fat body shape (37.4%), but small letters overall explained that 44.8% of body shape is thin. The prawns in Tepian were noted to have similar body shapes to the one in Salimbatu, however more than half male prawns (57.9%); females (57.8% and overall (57.8%) have a thin body shape. This is the same as the shrimp found in Sesayap where more than half male prawns (69.2%); female (51.9%) and overall (60.4%) have a thin body shape. And that the prawns in Buong Baru in the Tana Tidung District were mostly exhibited thin body shape for male (65%); female (44.3%) and overall (49.4%).

Table 4. Estimated parameters of length-weight relationships ($W = aL^b$) of male, female and overall *Macrobrachium rosenbergii* specimens collected from North Kalimantan Province, Indonesia

Sampling site	Male	Female	Overall
Salimbatu Village (Bulungan District)	$W=0.0822L^{1.2075}$ $b=1.2$ Allometric negative	$W=1.1714L^{0.335}$ $b=0.3$ Allometric negative	$W=0.6488L^{0.7509}$ $b=0.7$ Allometric negative
Tepian Village (Nunukan District)	$W=-2.2417L^{3.196}$ $b=3.1$ Allometric positive	$W=-1.0623L^{2.1864}$ $b=2.1$ Allometric negative	$W=-1.5028L^{2.5797}$ $b=2.5$ Allometric negative
Buong Baru Village (Tana Tidung District)	$W=-1.6425L^{2.3374}$ $b=2.3$ Allometric negative	$W=-1.5413L^{2.1738}$ $b=2.1$ Allometric negative	$W=-1.8953L^{2.4377}$ $b=2.4$ Allometric negative
Sesayap Village (Tana Tidung District)	$W=-1.6248L^{2.6778}$ $b=2.7$ Allometric negative	$W=-1.6976L^{2.7301}$ $b=2.7$ Allometric negative	$W=-1.6997L^{2.7334}$ $b=2.7$ Allometric negative

Note: BW: body weight; TL: total length; b: growth exponent

Table 5. Comparison of length-weight relationship of the *Macrobrachium rosenbergii* in North Kalimantan Province, Indonesia with other studies

Study	Location	L-W relationship (W=aL ^b)	Coefficient of determinants	Number of samples
Present study	Salimbatu Village (Bulungan District, North Kalimantan Province, Indonesia)	W=0.6488L ^{0.7509}	0.2254	404
Present study	Tepian Village (Nunukan District, North Kalimantan Province, Indonesia)	W=-1.5028L ^{2.5795}	0.7699	621
Present study	Buong Baru Village (Tana Tidung District, North Kalimantan Province, Indonesia)	W=-1.8953L ^{2.4377}	0.6593	81
Present study	Sesayap Village (Tana Tidung District, North Kalimantan Province, Indonesia)	W=-1.6997L ^{2.7334}	0.9257	53
Ming et al. (2016)	Shanghai, China	W=5×10 ⁻⁶ (TL) ^{3.1205}	0.9935	456
Khairul Adha et al. (2016)	Kayan River, Sarawak	W=6.350L ^{1.172}	0.607	20
	Kerang River, Sarawak	W=7.320L ^{0.792}	0.626	30
	Samarahan River, Sarawak	W=6.256L ^{1.151}	0.573	16
Rao (1967)	Hooghly Estuary, India	W=7.222×10 ⁻⁵ L ^{3.19346}	0.99013	873
Wang (1985)	Hawaii, USA	W=3.2×10 ⁻⁴ (OL) ^{3.2615}	0.978	503
Sain et al. (1987)	Telula River, Bangladesh	W=0.00303L ^{3.4011}	0.96	500
Sampaio and Valenti (1996)	Sao Paulo, Brazil	W=1.21×10 ⁻⁶ L ^{3.43}	-	-
Kunda et al. (2008)	Mymensingh, Bangladesh	W=0.008875L ^{3.075}	0.99	100
Lalrinsanga et al. (2012)	Orissa, India	W=0.087694L ^{3.3893}	0.9478	733

Table 6. Distribution of fish condition factor (K_n) or body shape

Sampling site	Condition factor (body shape)	Male	Female	Overall
Salimbatu	Very Thin (K _n <0.5)	11.5%	0.9%	5.7%
	Thin (0.5≤K _n <1)	36.3%	51.8%*	44.8%*
	Ideal (K _n =1)	-	-	-
	Fat (1<K _n ≤1.5)	37.4%*	38.3%	37.9%
	Very Fat (K _n >1.5)	14.8%	9.0%	11.6%
Tepian	Very Thin (K _n <0.5)	-	-	-
	Thin (0.5≤K _n <1)	57.9%*	57.8%*	57.8%*
	Ideal (K _n =1)	-	-	-
	Fat (1<K _n ≤1.5)	37.7%	40.6%	40.1%
	Very Fat (K _n >1.5)	4.4%	1.6%	2.1%
Buong Baru	Very Thin (K _n <0.5)	5.0%	3.3%	3.7%
	Thin (0.5≤K _n <1)	65.0%*	44.3%*	49.4%*
	Ideal (K _n =1)	-	-	-
	Fat (1<K _n ≤1.5)	30.0%	32.8%	32.1%
	Very Fat (K _n >1.5)	-	19.7%	14.8%
Sesayap	Very Thin (K _n <0.5)	-	-	-
	Thin (0.5≤K _n <1)	69.2%*	51.9%*	60.4%*
	Ideal (K _n =1)	-	-	-
	Fat (1<K _n ≤1.5)	23.1%	48.1%	35.8%
	Very Fat (K _n >1.5)	7.7%	-	3.8%

Note: *the length class in which the median value is recorded; **different letters indicate significant differences in term of frequency distributions

The condition factor, K, is widely used in fisheries and fish biology studies as a measure of the degree of robustness of fish. K is used as an index to reflect fish's

physical and biological conditions, and K=1 is the baseline between slender and robust conditions of the organism. If K >1, it means that the animal is stout indicating better condition of robustness of the organism. In the current study, the mean K value ranged from 0.50 to 1.5 in the wild stocks of *M. rosenbergii* in the North Kalimantan Province, Indonesia. Similar results of K were observed in *M. rosenbergii* cultured in rice fields which varied from 0.97~1.17 (Kunda et al. 2008). The fluctuation in the K value in the entire period, for *M. rosenbergii* was similar to the study reported by Lalrinsanga et al. (2012) where the K value ranged from 0.79 in nursery animals to 1.0 to 1.14 in adult broodstock. Judging from the K values of the prawns in different sampling sites in the present study, majority of the prawn specimens in Sesayap, Salimbatu and Tepian are having total lengths (TL) of <22 cm which is considered young. Only prawns in Buong Baru were observed to have bigger size (TL>36 cm) (Table 3). The condition indexes recorded in this study indicate that the prawns in the sampling sites are normal and healthy condition.

17 Von Bertalanffy Growth Function

The Von Bertalanffy Growth Function (VBGF) analysis estimated the asymptotic (maximum) total length (TL) of the male prawns in Salimbatu to be at 74.757 cm which can be attained within 557 days of age and growth coefficient of 0.0206 cm/day with the t₀ value of -1.6271. For female prawns, the maximum TL was estimated at 57.172 cm which attainable within 419 days of age at growth coefficient of 0.0297cm /day and with the t₀ value of -1.4942. The maximum TL of male prawns in Tepian was estimated at 28.215 cm which can be attained at 336 days of age with growth coefficient of 0.0354 cm/day and with

the t_0 value of -1.4995. The female prawns were estimated to have maximum TL of 25.623 cm at the age of 410 days with growth coefficient of 0.026cm/day and with a t_0 value of -1.6501. The male prawns in Buong Baru was estimated to have maximum TL of 46.649cm at 210 days of age at the growth coefficient of 0.0519 cm/day and with the t_0 value of -1.2668 while female prawns were estimated to attain maximum TL of 52.113 cm at the age of 319 days achievable at the growth coefficient of 0.0344 cm/day and the t_0 value of -1.439. The estimated maximum TL of male prawns in Sesayap was at 25.969 cm that is achievable within 216 days of age at growth coefficient of 0.0514 cm/day and with t_0 value of -1.3412. As for female prawns, the maximum TL was estimated at 24.514 cm at the age of 375 days with a growth coefficient of 0.0331 cm/day and t_0 value of -1.5465.

Based on this estimation, it is suggested that the maximum TL of male shrimp in Salimbatu, Tepian and Sesayap was larger than that of female populations in the respective fishing grounds. This is in accordance with the finding of Sofian and Sari (2018) who reported that the maximum TL (28.74 cm) of male prawns was larger than that of female prawns (19.08 cm). Murni (2004) also reported the maximum TL (29.3 cm) of male prawns in Kapuas River Estuary in Pontianak, West Kalimantan was larger than that in female prawns (25 cm). The current study observed that the female prawns in Buong Baru exhibited larger maximum TL than that in male prawns. According to Sofian and Sari (2018), growth differences among different sexes of *M. rosenbergii* could be influenced by the habitat characteristics particularly water quality. However, due to lack of information, the effect of water quality on the estimated maximum growth (TL) of *M. rosenbergii* in the present study, cannot be determined.

Estimated mortality and exploitation rate

The estimated mortalities of the prawns in each of the four villages is given in Table 7. It was observed that the male (118.7%) and female (117.9%) prawns in Sesayap recorded the highest total mortality (Z). The highest fishing mortality (F) of male (64.1%) and female (49%) prawns were recorded in Buong Baru. The male prawns (80.5%) in Salimbatu and female prawns (99.6%) in Tepian recorded the highest natural mortality (M). As for exploitation rate (E), the male (54.5%) and female (41.9%) prawns in Buong Baru were observed to be highly exploited. According to Indarjo (2020a), exploitation rate exceeds 50% can indicate that the fishery resource is experiencing overfishing. Yudiati et al. (2020) suggested one of the reasons for over-exploitation is high market demand and attractive pricing. This is particularly true in Buong Baru where prawns are sold at Rp 80,000.00 (USD 5.6) to Rp 100,000.00 (USD 7.07)/kg.

Physicochemical parameters

The results of the measurement of the physicochemical parameter are given in Table 8. It was noted that the

physicochemical properties of the water in the three sampling sites (fishing grounds) were not much different and within the suitable range for *M. rosenbergii* (Hadie and Supriyatna 1985; Murtidjo 1992; Ali 2009; Waluyo et al. 2018).

Generally, the giant prawn populations in the four fishing grounds (Salimbatu, Tepian, Sesayap and Buong Baru) are dominated by female prawns. In terms of size distribution, most prawns caught in the fishing grounds are considered young having total length that ranged from 11-25 cm. The length-weight relationship of the prawns in all fishing grounds was characterized by negative allometric growth pattern which indicates that the weight gain is slower than the length increment. As for condition index (body shape), majority of the prawns in the fishing grounds were thin. Based on the VBGF analysis, the prawns in the fishing grounds have shown to have different asymptotic (estimated maximum) lengths and expected to be achieved in different time periods. Interestingly, the prawns in the four fishing grounds exhibited different levels of mortality and exploitation rates. The giant prawns in two fishing grounds namely Tepian and Sesayap were observed to experience high natural and total mortality, respectively. However, situation in Buong Baru was particularly interesting because the prawns in the area were shown to experience high fishing mortality and high exploitation rate, a worrisome situation that requires more attention and immediate conservation efforts to prevent further exploitation of the prawns in area.

Table 7. Estimated parameters of mortality of male and female *Macrobrachium rosenbergii* specimens collected from North Kalimantan Province, Indonesia

Sampling site	Parameters of mortality	Male	Female
Salimbatu Village (Bulungan District)	Total	109.1%	110.6%
	Catch	28.6%	42.3%
	Natural	80.5%*	68.3%
	Exploitation rate	26.2%	38.2%
Tepian Village (Nunukan District)	Total	117.1%	110.6%
	Catch	37.9%	11.0%
	Natural	79.2%	99.6%*
	Exploitation rate	32.4%	9.9%
Buong Baru Village (Tana Tidung District)	Total	117.7%	117%
	Catch	64.1%*	49%*
	Natural	53.6%	68%
	Exploitation rate	54.5%*	41.9%*
Sesayap Village (Tana Tidung District)	Total	118.7%*	117.9%*
	Catch	55.2%	31.8%
	Natural	63.5%	86.1%
	Exploitation rate	46.5%	27%

Note: *the length class in which the median value is recorded

Table 8. Estimated average parameters of habits of *Macrobrachium rosenbergii* specimens collected from North Kalimantan, Indonesia

Sampling site	Water quality parameters recorded during sampling	Water quality parameters reported suitable for <i>M. rosenbergii</i>
Salimbatu Village (Bulungan District)	pH	5.70-6.30 (5.90)
	Dissolved oxygen (mg/L)	3.74-7.50 (6.19)
	Salinity (ppt)	2
	Temperature (°C)	27.0-28.0 (27.6)
Tepian Village (Nunukan District)	pH	5.60-6.20 (5.90)
	Dissolved oxygen (mg/L)	2.23-6.36 (3.9)
	Salinity (ppt)	1
	Temperature (°C)	23.8-24.1 (24.0)
Buong Baru Village* (Tana Tidung District)	pH	-
	Dissolved oxygen (mg/L)	-
	Salinity (ppt)	-
	Temperature (°C)	-
Sesayap Village (Tana Tidung District)	pH	6.2-6.9 (6.3)
	Dissolved oxygen (mg/L)	4.77-7.66 (6.1)
	Salinity (ppt)	1
	Temperature (°C)	24.0-24.4 (24.2)

Note: *Covid-19 incidents; No travel is allowed in April 2020

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