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Original Article

Growth patterns and relative condition factor of *Macrobrachium* species from Sungai Batang River, Indonesia

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Abstract

The present study provides the first reference for the growth patterns and relative condition factor of *Macrobrachium* species from Sungai Batang River, Indonesia. A total of 328 specimens, caught by using wire-stage trap, consisted of 83 males (25%) and 245 females (75%) with the sex ratio of 1:3. *Macrobrachium* species showed a negative allometric growth pattern (*b* = 1.94-2.14). The highest percentage of catch falls between 90-94 mm TL (38.55%) and weighted between 9-10 g (46.99%). The average total length and body weight of male were 1.1 and 1.4 times greater than those of female computed by comparing the said body sizes of shrimp. Male had total length, carapace length, abdominal length and chelae length longer than female. The mean relative condition factor values ranged of 0.96 ± 0.17 and 1.01 ± 0.16, reflecting well-being of the species. Outcome of research could be useful for sustainable fisheries management and conservation measures for *Macrobrachium* species in this river. In addition, a new fishing method was also introduced to improve fishing efficiency.

Keywords: *Macrobrachium* species, growth pattern, relative condition factor, wire-stage trap, Sungai Batang River

1. Introduction

In all parts of the world, the length-weight relationships and condition factors of shrimps have been well-documented not only for marine species such as *Acetes japonicus* (Wong, Ong, & Khoo, 2015), *Penaeus monodon* (Uddin, Ghosh, & Maity, 2016) and *Plesionika ensis* (Sousaa *et al*., 2019), but also for freshwater species like *Macrobrachium rosenbergii* (Lalrinsanga *et al*., 2015), *M. macrobrachion* (Kingdom, Hart, Erondu, & Kwen, 2014), *M. lamarrei* (Ara, Nobi, Ahmed, & Fatema, 2014), *M. hainanense* (Mantel & Dudgeon, 2004), *M. malcolmsonii* (Hossain *et al*., 2012) and *M. assamense peninsulare* (Kumar, Kotnala, & Rana, 2014). Penaeid shrimp and Palaemonid prawns support beneficially aquaculture, capture fishery and shrimp processing industries in countries all over the world, including Indonesia. The shrimp species are being caught by various fishing gears such as trawl nets (Wong, Ong, & Khoo, 2015), cast nets (Sethi, Ram, & Venkatesan, 2012), gillnet (Pravin & Ravindran, 2011), trammel nets (Ahmadi & Kristina, 2017), fyke-nets (Farias, Pereira-Júnior, Domingos, & Dantas, 2019), electrofishing (Ng, 2017), basket traps (Kingdom, Hart, Erondu, & Kwen, 2014), bottom and floating traps (Sousaa *et al*., 2019), and light traps (Ahmadi, 2018*a*).

The length-weight relationship has important implication in fisheries management and aquaculture practice (Klassen, Gawlik, & Botson, 2014). It is applicable for estimating growth rates, age structure and other aspect of shrimp population dynamics (Tsoumani *et al*., 2006), calculating the standing stock biomass (Enin, 1994) and determining condition factor (Li *et al*., 2016). The length-weight regressions often used to estimate weight from length due to the technical constraint in the field. Morphometric traits have been reported to give an accurate estimate of body weight and it can serve as a useful tool for selecting

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broodstock on weight basis (Daud & Ang, 1995). Variability in the length-weight relationship, as an indicator of condition in marine fishes and crustaceans, is a feature that can reflect fluctuations in the uptake and allocation of energy. These morphometric variations can be affected by many factors such as reproductive cycle (Chu, Chen, Huang, & Wong, 1995), genetic differences (Cadrin, 2000) and environment factors such as water temperature, nutrient supply (Castilho *et al*., 2007) and also interspecific characteristic between species (Bissaro, Gomes-Jr, & Beneditto, 2013). Fulton's condition factor (K) is often used to quantify an animal's physical wellbeing and thought to be a useful complement to growth estimates of crustaceans. Information on the length-weight relationship and condition factor are useful for fish farmers in selecting suitable species or varieties of faster growth rate for culture and estimating its duration for producing marketable size of the shrimps (Piratheepa, Edrisinghe, & Chitravadivelu, 2013).

Like other freshwater bodies, Sungai Batang River in South Kalimantan Province also plays important role particularly for fisheries and aquaculture. A great attention has been devoted to describe the morphometric characteristic of some endemic fish species such as snakehead (Ahmadi, 2018*b*), *mystus nigriceps* (Ahmadi, 2018*c*), and three spot gourami (Aminah & Ahmadi, 2018); whereas *Macrobrachium* species, locally called **"***udang sapit***"** is still poorly studied (Ahmadi & Rizani, 2012). It can be distinguished clearly from other shrimp species in term of cheliped traits, which are longer than its body length (Figure 1). To more understand the biological aspect and its implication for fisheries management, we investigated the length-weight relationship, growth patterns and condition factor of this species, as well as provided some recommendation for future research in this area of study.

2. Materials and Methods

2.1 Study site

Field survey was carried out in Sungai Batang River, South Kalimantan (Figure 2), located on 03°22'36 S and 114°49'29 E determined by GPS 60 (Garmin Co. Ltd., Taiwan). *Macrobrachium* species were caught by fishermen using the wire stage-trap (heart-shaped, 65 cm high and 45 cm wide with 4 cm wide opening of entrance slit, and a piece of coconut used as bait). The traps were deployed at shallow water along the riverbank before sunset and retrieve the next morning. According to fishermen, the number of daily catch was low (1-3 shrimp per trap). Sampling activity was conducted on February to March 2019.

2.2 Data collection and statistical analysis

A total of 328 individuals of *Macrobrachium* species consisted of 83 males (25%) and 245 females (75%) with the sex ratio of 1:3 were investigated. Male has a pair of long second pereiopods (chelipeds) that were rather dark in color with a pair of the small movable fingers of the leg. Male had chelae about 1.5 times longer than female in the same length size. Rostrum was over half of total carapace length and bent in the middle with 11 dorsal teeth and 8 ventral teeth. The upper eyes of male were parallel with the maximum

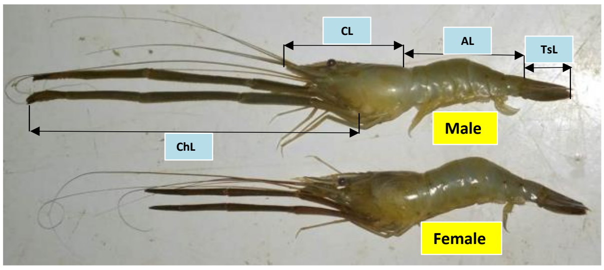

Figure 1. *Macrobrachium* species from Sungai Batang River, Indonesia. CL = carapace length, AL = abdominal length, TsL = telson length, ChL = chelae length

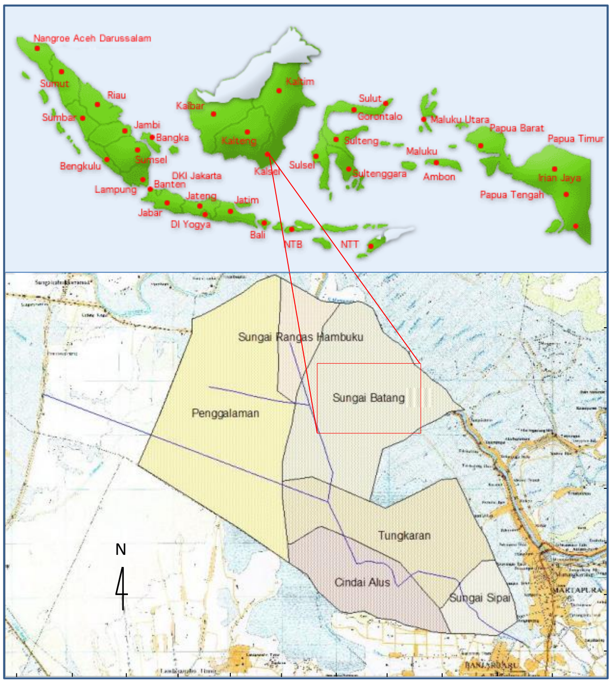

Figure 2. Map showing the location of sampling site in Sungai Batang River, Indonesia

height of rostrum, while those of female were slightly beneath the rostrum lines. Male and female had a pair of second antenna about 1.2 and 1.7 times longer than its chelae measured at 90 mm TL. The genital pores of the male were situated at the base of the fifth walking legs, while those female were at the base of the third walking legs. Distinct black bands located on the dorsal side at the junctions of the fifth abdominal segments. The tip of its telson reaches distinctly beyond the posterior spines of the telson. The catches were counted, identified and measured for total length (TL), carapace length (CL), abdominal length (AL), telson length (TsL), chelae length (ChL), and weight (W). Total length was measured from the tip of the rostrum to the tip of the telson to the nearest mm, keeping the abdomen fully stretched. Carapace length was measured from the anterior tip of the rostrum to the posterior edge of the carapace; Abdominal length (AL) was measured from the anterior margin of the first abdominals somite to tip of the telson; Telson length (TsL) was measured from the posterior end of the carapace to the base of the telson; Chelae length was from the base of the first pair of walking legs to the anterior tip the pincers. The body weight was measured by Digital balance with precision of 0.01 g (Dretec KS-233, Japan). The sexes were determined by visual examination of chelae second pereopods or chelipeds. The size distribution of catch was set at class interval of 5 mm length and of 2 g weight, and the number of catch was stated in percentage. The length-weight relationship of shrimp was expressed in the allometric form (Li *at al*., 2016):

$$W = aL^b \quad (1)$$

The length-weight relationship of shrimp can also be represented in logarithmic equation:

$$\text{Log } W = \text{Log } a + b \text{ Log } L \quad (2)$$

where W is the weight (g), L is the total length (mm), *a* is the constant showing the initial growth index, and *b* is the slope showing growth coefficient. If shrimp retains the same shape, it grows isometrically ($b = 3$). When weight increases more than length ($b > 3$), it shows positively allometric. When the length increases more than weight ($b < 3$), it indicates negatively allometric (Li *et al*., 2016). The proper fit of the growth model was given by determination coefficient (R^2). The regression coefficient (r) of morphological variables between male and female was figured by the square regression. The class interval for each 5 mm total length and 2 g weight was also computed regardless the sex. The previous length-weight relationship data were used for calculating the Fulton's condition factor of shrimp by using the following formula (Gayanilo & Pauly, 1997):

$$K = 100(W/L^3) \quad (3)$$

where K is the Fulton's condition factor, L is total length (cm), and W is weight (g). The factor of 100 is used to bring K close to a value of one. Relative condition factor (Kn) was further estimated by following Le Cren (1951) formula:

$$Kn = W/\hat{}W \quad (4)$$

where Kn is relative condition factor reflecting 'Condition', 'fatness' or well-being of shrimp, W is the observed weight and ^W is the calculated weight derived from length-weight relationship. The metric indicates that the higher the Kn value the better the condition of shrimp. The t-test was applied for comparing the body sizes and condition factor between male and female. All tests were analyzed at the 0.05 level of significance using SPSS-16 software.

3. Results

The body sizes, growth patterns, and condition factors of *Macrobrachium* species from Sungai Batang River were presented in Table 1. There was significantly difference between male and female ($P<0.05$). The size of male ranged from 71 to 100 mm (88.28 ± 5.87) TL and from 4 to 12 g (8.40 ± 1.56) weight; while the size of female ranged from 60 to 100 mm (82.96 ± 6.41) TL and from 2 to 10 g (6.17 ± 1.46) weight. The pooled mean and standard deviation were 84.30 ± 6.68 mm TL and 6.73 ± 1.78 g weight. Total length, carapace length, abdominal length, and chelae length of male were considerably longer than those of female ($P<0.001$) as described in Table 2. The mean total length of male (88.28 ± 5.87 mm) was significantly higher than that of female (82.96 ± 6.41 mm). The carapace length of male varied from 30 to 50 mm (38.48 ± 3.12); while the carapace length of female ranged from 25 to 45 mm (35.59 ± 3.26). Male had abdomen slightly longer than female. The mean abdominal length of male and female were 36.19 ± 7.11 mm (20-53 mm) and 33.74 ± 4.47 mm (16-52 mm) respectively. There was no significant difference in the telson length between male and female ($P>0.05$). Male had chelae about 1.5 times longer than female of the same size. The chelae length of male ranged from 75 to 148 mm (98.60 ± 15.41); while the chelae length of female ranged from 35 to 95 mm (63.26 ± 13.19). During sampling period, we also collected 26 females carrying the eggs (77.27 ± 6.37 mm TL and 5.11 ± 1.66 g weights) and they are also incorporated in statistical analysis as the whole.

Values of observed length and corresponding weight of *Macrobrachium* species are plotted in Figure 3A. The slopes (*b*) of the regressions were less than three for both the sexes, hence growth of the individual sex in river was found to be negative allometric, even for the pooled data, which means that the length increases more than weight. The estimated *b* values given in the allometric equations were 1.94 for male ($W = 0.0014TL^{1.9379}$) and 2.14 for female ($W = 0.0005TL^{2.1408}$); with R^2 value falls between 0.435 and 0.449, respectively. The correlation coefficient (r) of male and

Table 1. Body sizes, growth patterns, and condition factors of *Macrobrachium* species sampled from Sungai Batang River.

Sex	n	Total length (mm)			Weight (g)			Allometric equations	a	b	R^2	r	Growth pattern	K	Kn
		Min	Max	Mean ± SD	Min	Max	Mean ± SD							Mean ± SD	Mean ± SD
Male	83	71	100	88.28 ± 5.87	4	12	8.40 ± 1.56	$y = 0.0014x^{1.9379}$	0.0014	1.938	0.435	0.659	A-	1.22 ± 0.24	1.01 ± 0.16
Female	245	60	100	82.96 ± 6.41	2	10	6.17 ± 1.46	$y = 0.0005x^{2.1408}$	0.0005	2.141	0.449	0.670	A-	1.08 ± 0.21	0.96 ± 0.17
Pooled	328	60	100	84.30 ± 6.68	2	12	6.73 ± 1.78	$y = 0.0001x^{2.4433}$	0.0001	2.443	0.509	0.714	A-	1.12 ± 0.23	0.97 ± 0.16

a = constant, b = exponent, R^2 = coefficient of determination, r = coefficient of correlation, A = allometric, K = Fulton's condition factor, Kn = relative condition factor

Table 2. Statistical parameters of main body parts observed for *Macrobrachium* species from Sungai Batang River.

Sex	Statistical Parameter	TL	W	CL	AL	TsL	ChL	K	Kn
Male	N	83	83	83	83	83	83	83	83
	Minimum	71	4	30	20	10	75	0.88	0.68
	Maximum	100	12	50	53	18	148	2.51	1.66
	Mean	88.28	8.40	38.48	36.19	13.65	98.60	1.22	1.01
	Std. Deviation	5.87	1.56	3.12	7.11	1.88	15.41	0.24	0.16
	Std. Error Mean	0.64	0.17	0.34	0.78	0.21	1.69	0.03	0.02
Female	N	245	245	245	245	245	245	245	245
	Minimum	60	2	25	16	10	35	0.29	0.27
	Maximum	100	10	45	52	20	95	2.31	1.58
	Mean	82.96	6.17	35.60	33.74	13.62	63.26	1.08	0.96
	Std. Deviation	6.41	1.46	3.26	4.47	1.83	13.19	0.21	0.17
	Std. Error Mean	0.41	0.09	0.21	0.28	0.12	0.84	0.01	0.01
P	Sig. (2-tailed)	0.0000	0.0000	0.0000	0.0003	0.9114	0.0000	0.0000	0.0058

TL = total length, W = weight, CL = carapace length, AL = abdominal length, TsL = telson length, ChL = chelae length, K = Fulton's condition factor, Kn = relative condition factor

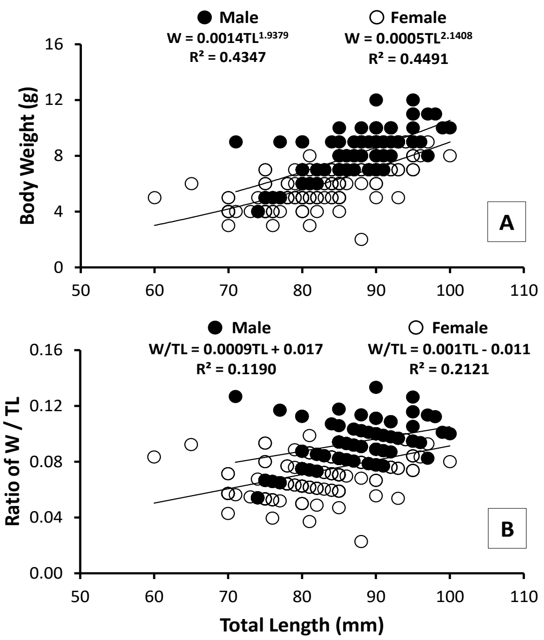

Figure 3. Length-weight relationship [A] and the length-ratio of W/TL [B] of male and female *Macrobrachium* species.

female was 0.659 and 0.670, found to be higher than 0.5, showing the length-weight relationship was positively correlated. The value of b = 2.44 for the pooled also departs significantly from isometry (W = $0.0001TL^{2.4433}$, R^2 = 0.509). Data on the length-weight relationship were presented in Table 1. Further analysis showed that male had the W/TL ratio significantly higher than female (P<0.001). The relationship between total length and W/TL ratio was plotted in Fig. 3B. The W/TL ratio of male ranged from 0.054 to 0.133 (0.09 ± 0.02) and that of female ranged from 0.023 to 0.113 (0.07 ± 0.01). The CL/TL ratio of male ranged from 0.378 to 0.549 (0.44 ± 0.03), while the CL/TL ratio of female varied from 0.295 to 0.533 (0.43 ± 0.02). Morphologically carapace length of male was longer than that of female, however, the CL/TL ratios between the sexes were not statistically significant difference (P>0.05). Both male and female being equal in the ratio of abdominal length to the total length was observed (P>0.05). The AL/TL ratio of male ranged from 0.288 to 0.494 (0.41 ± 0.04), while the AL/TL ratio of female ranged from 0.246 to 0.591 (0.41 ± 0.04). Apparently male's telson length was equal to female has; however, the ratio of telson length to total length (TsL/TL) between the sexes was dimensionally differ. The mean TsL/TL ratios of male and female were 0.15 ± 0.02 (0.108 - 0.200) and 0.16 ± 0.02 (0.114 - 0.231) respectively. Male had the ChL/TL ratio greater than female (P<0.001). The ChL/TL ratio of male ranged from 0.825 to 1.648 (1.12 ± 0.17), while the ChL/TL ratio of female ranged from 0.452 to 1.188 (0.76 ± 0.13). Those comparative values of body size ratios can be seen in Table 3.

The regression plots of the transformed data on the length of body parts (CL, AL, TsL, ChL) and total length relationship for the sexes indicated a linear relationship between the two variables (Figures. 4A-D). There was a variation in the intercept (a) and slope (b) of model-fitting with linear regression; a values varied between -3.328 and 1.056, while b values fallen between 0.479 and 2.141. The R^2 values obtained from these relationships ranged from 0.051 to 0.497, and the respective logarithmic equations and its attributes given for each relationship were presented in Table 3.

The mean Fulton's condition factor (K) of male was significantly higher than that of female (P<0.001). The K values of male ranged from 1.175 to 1.276 (1.22 ± 0.23), while the K values of female ranged from 1.052 to 1.107 (1.08 ± 0.21). Male also had the relative condition factor (Kn) greater than female (P<0.01). The Kn values of male ranged from 0.981 to 1.049 (1.01 ± 0.16), while the K values of female ranged from 0.934 to 0.978 (0.96 ± 0.17). In other words, the condition factor of *Macrobrachium* species was statistically significant increase corresponding to length classes. The detail estimated parameters (the main body sizes and its aspect ratios, Fulton's condition factor and relative condition factor), as well as the significance test for the said parameters between male and female were described in Table 4.

Table 3. Descriptive statistical and estimated parameters of length-weight and length-length relationships of *Macrobrachium* species from Sungai Batang River

Sex	n	Total length (mm)			Weight (g)			Logarithmic equations	a	b	R^2	r	Range of W/TL	Mean±SD W/TL
		Min	Max	log TL	Min	Max	Log W							
Male	83	71	100	1.94 ± 0.03	4	12	0.93 ± 0.09	y = 1.9379x - 2.8530	-2.853	1.938	0.435	0.659	0.054 - 0.133	0.09 ± 0.02
Female	245	60	100	1.92 ± 0.03	2	10	0.78 ± 0.11	y = 2.1408x - 3.3278	-3.328	2.141	0.449	0.670	0.023 - 0.113	0.07 ± 0.01
Sex	**n**	**Total length (mm)**			**Carapace length (mm)**			**Logarithmic equations**	**a**	**b**	**R^2**	**r**	**Range of CL/TL**	**Mean±SD CL/TL**
		Min	Max	log TL	Min	Max	Log CL							
Male	83	71	100	1.94 ± 0.03	30	50	1.58 ± 0.04	y = 0.7455x + 0.1340	0.134	0.745	0.392	0.626	0.378 - 0.549	0.44 ± 0.03
Female	245	60	100	1.92 ± 0.03	25	45	1.55 ± 0.04	y = 0.8398x - 0.0609	-0.061	0.840	0.496	0.704	0.295 - 0.533	0.43 ± 0.03
Sex	**n**	**Total length (mm)**			**Abdominal length (mm)**			**Logarithmic equations**	**a**	**b**	**R^2**	**r**	**Range of AL/TL**	**Mean±SD AL/TL**
		Min	Max	log TL	Min	Max	Log AL							
Male	83	71	100	1.94 ± 0.03	20	53	1.55 ± 0.06	y = 1.4209x - 1.2096	-1.209	1.421	0.467	0.684	0.282 - 0.494	0.41 ± 0.04
Female	245	60	100	1.92 ± 0.03	16	52	1.52 ± 0.06	y = 1.2664x - 0.9044	-0.904	1.266	0.497	0.705	0.246 - 0.591	0.41 ± 0.04
Sex	**n**	**Total length (mm)**			**Telson length (mm)**			**Logarithmic equations**	**a**	**b**	**R^2**	**r**	**Range of TsL/TL**	**Mean±SD TsL/TL**
		Min	Max	log TL	Min	Max	Log TsL							
Male	83	71	100	1.94 ± 0.03	10	18	1.13 ± 0.06	y = 0.7675x - 0.3618	-0.362	0.767	0.138	0.371	0.108 - 0.200	0.15 ± 0.02
Female	245	60	100	1.92 ± 0.03	10	20	1.13 ± 0.06	y = 0.8995x - 0.5945	-0.594	0.899	0.260	0.510	0.114 - 0.231	0.16 ± 0.02
Sex	**n**	**Total length (mm)**			**Chelae length (mm)**			**Logarithmic equations**	**a**	**b**	**R^2**	**r**	**Range of ChL/TL**	**Mean±SD ChL/TL**
		Min	Max	log TL	Min	Max	Log ChL							
Male	83	71	100	1.94 ± 0.03	75	148	1.99 ± 0.06	y = 0.4795x + 1.0565	1.056	0.479	0.051	0.225	0.825 - 1.648	1.12 ± 0.17
Female	245	60	100	1.92 ± 0.03	35	95	1.79 ± 0.09	y = 1.7759x - 1.6142	-1.614	1.776	0.411	0.641	0.452 - 1.188	0.76 ± 0.13

a = constant, b = exponent, R^2 = coefficient of determination, r = coefficient of correlation

Table 4. Estimated parameters and significance test for LWR and its ratios of *Macrobrachium* species from Sungai Batang River

Estimated parameters	Levene's test for equality of variances		t-test for equality of means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% Confidence interval of the difference	
								Lower	Upper
Total Length (TL)	1.510	0.220	6.671	326	0.000	5.3179	0.7972	3.7496	6.8862
Weight (W)	0.428	0.513	11.800	326	0.000	2.2302	0.1890	1.8584	2.6021
Carapace length (CL)	0.018	0.893	7.039	326	0.000	2.8860	0.4100	2.0794	3.6926
Abdominal length (AL)	34.015	0.000	3.675	326	0.000	2.4540	0.6678	1.1403	3.7677
Telson length (TsL)	0.007	0.934	0.111	326	0.911	0.0261	0.2344	-0.4350	0.4872
Chelae length (ChL)	0.024	0.876	20.192	326	0.000	35.3412	1.7502	31.8980	38.7844
Fulton's condition factor	0.011	0.918	5.252	326	0.000	0.1462	0.0278	0.0914	0.2009
Relative condition factor	0.271	0.603	2.775	326	0.006	0.0584	0.0211	0.0170	0.0999
W/TL	0.287	0.593	11.434	326	0.000	0.0209	0.0018	0.0173	0.0246
CL/TL	0.426	0.514	1.890	326	0.060	0.0069	0.0037	-0.0003	0.0141
AL/TL	0.771	0.381	0.509	326	0.611	0.0026	0.0051	-0.0075	0.0127
TsL/TL	1.068	0.302	-3.892	326	0.000	-0.0096	0.0025	-0.0144	-0.0047
ChL/TL	5.626	0.018	19.688	326	0.000	0.3603	0.0183	0.3243	0.3963

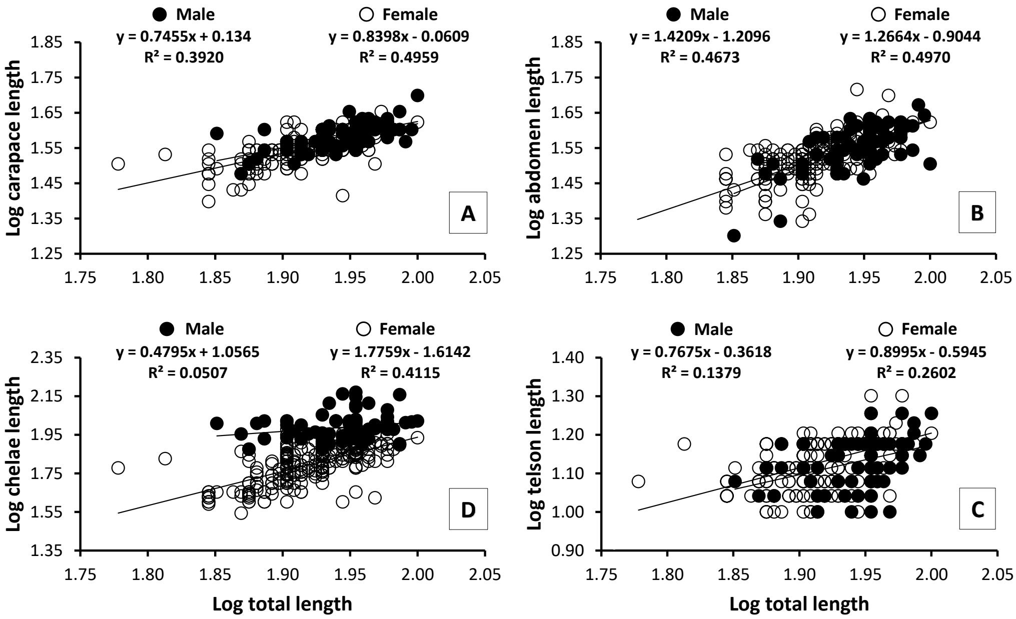

Figure 4. Relationship between the body sizes and total length of male and female *Macrobrachium* species

From fishing point of view, the highest number of catch was found between 90-94 mm TL (38.55%) for male and between 80-84 mm TL (32.24%) for female (Figure 5A). To facilitate the largest amount of shrimp caught, weight was recorded at the interval class of 9-10 g (46.99%) for male and of 5-6 g (45.71%) for female (Figure 5B). None of shrimp catch over 104 mm TL and 12 g weight was observed. The other way, we found no male was captured at the size of less than 70 mm TL or between 1-2 g weights. On the other hand, *Macrobrachium* species in the present study was mostly caught by the wire stage-trap in the middle size classes compared to lower or higher classes. The t-test analysis showed that there was no significant difference in individual class interval of length-weight size range between male and female (P>0.05), except for class interval of 11-12 g weight represented by male (P<0.0001).

4. Discussion

There was sexual dimorphism in the sizes of male and female. In present study, male *Macrobrachium* species was significantly larger and heavier than female. Male with larger chelae win competitive interactions for shelter and food (Capelli & Munjal, 1982). Meanwhile the size of individual species had a significant effect on energy utilization efficiency on a linear basis (Glencross, 2008). On the other side, the female ratio was three times higher than male caught in the investigated area, indicating that female was more active than male in term of spawning migration during wet season. Although the traps are female-biased gear, male ratio in catch would increase when population density decreases and competitive interaction are often. The similar results were also documented for *M. malcolmsonii* in Indus River, Pakistan (Soomro *et al.*, 2012) or *M. felicinium* in the lower Taylor Creek, Nigeria (Kingdom, Hart, Erondu, & Kwen, 2014). In contrast, no significant difference between the sexes observed for *M. lar* in the stream of Andaman and Nicobar Islands (Sethi, Ram, & Venkatesan, 2012) and *Metapenaeus dobsoni* in the Vishakhapatnam coast (Murthy & Ramaseshaiah, 1996).

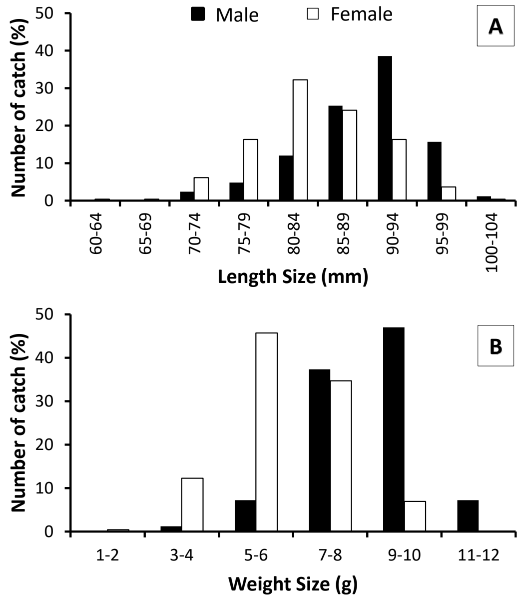

Figure 5. Number of catch, length size [A], and weight size [B] distribution of male and female *Macrobrachium* species

The most important result of this study was that *Macrobrachium* species from Sungai Batang River grew negatively allometric, where the *b* values (1.94–2.14) were significantly lower than the critical isometric value ($b < 3$). Females have a greater regression slope than males. A negative allometric growth condition in the present study was also reported for female *M. lamarrei* (Ara, Nobi, Ahmed, & Fatema, 2014), *M. dux* (Arimoro & Meye, 2007), female *M. malcolmsonii* (Hossain *et al.*, 2012), *M. lar* (Sethi, Ram, &

Venkatesan, 2012) or *P. monodon* (Komi, Wilson, & Francis, 2017). It was contrary to *M. vollenhovenii* (Nwosu & Wolfi, 2006), *M. rosenbergii* (Lalrinsanga *et al*., 2012) or *Litopenaeus vannamei* (Gautam *et al*., 2014) that grew positively allometric, as well as *M. felicinium* (Okayi & Iorkyaa, 2004) or male *Acetes japonicas* (Wong, Ong, & Khoo, 2015) that displayed isometric growth pattern (Table 5). Although male had the mean carapace size substantially greater than female, however, it was found not to be correlated with the growth pattern since both male and female grew negatively isometric. According to Li *et al.* (2016), the big carapace was not conducive to effective growth.

Table 5. Comparative parameters of length-weight relationship and condition factors of *Macrobrachium* species from Sungai Batang River and other shrimp species from different geographical areas

Species	Country	n	Sex	W/TL	a	b	R^2	K	Growth Type	References
Macrobrachium sp.	Indonesia	83	M	0.952	0.001	1.938	0.435	1.22	A-	Present study
Macrobrachium sp.	Indonesia	245	F	0.744	0.001	2.141	0.449	1.08	A-	Present study
Macrobrachium sp.	Indonesia	161	M	0.710	0.000	3.210	0.975	1.39	A+	Ahmadi, 2018
Macrobrachium sp.	Indonesia	175	F	0.322	0.000	2.734	0.937	1.14	A-	Ahmadi, 2018
M. lamarrei	Bangladesh	1018	P	...	0.000	2.924	0.970	-	A-	Ara, Nobi, Ahmed & Fatema, 2014
M. malcolmsonii	Pakistan	62	M	5.464	0.003	2.97	0.97	0.61	A-	Soomro *et al*., 2012
M. malcolmsonii	Pakistan	47	F	2.779	0.009	3.04	0.94	0.86	I	Soomro *et al*., 2012
M. felicinium	Nigeria	55	P	1.043	0.002	3.003	0.998	2.03	I	Okayi & Iorkyaa, 2004
M. felicinium	Nigeria	132	M	0.372	0.009	3.23	0.92	1.23	A+	Kingdom, Hart, Erondu & Kwen, 2014
M. felicinium	Nigeria	726	F	0.308	0.010	2.12	0.75	1.23	A-	Kingdom, Hart, Erondu & Kwen, 2014
M. vollenhovenii	Nigeria	246	M	0.820	0.007	3.29	0.98	1.26	A+	Kingdom, Hart, Erondu & Kwen, 2014
M. vollenhovenii	Nigeria	94	F	0.605	0.007	3.25	0.98	1.26	A+	Kingdom, Hart, Erondu & Kwen, 2014
M. vollenhovenii	Nigeria	1070	M	...	0.000	3.483	0.993	1.24	A+	Nwosu & Wolfi, 2006
M. vollenhovenii	Nigeria	1358	F	...	0.000	3.329	0.990	1.25	A+	Nwosu & Wolfi, 2006
M. macrobrachion	Nigeria	352	P	0.299	0.006	3.280	0.968	1.13	A+	Enin, 1994
M. macrobrachion	Nigeria	36	M	0.240	0.014	2.71	0.84	1.06	A-	Kingdom, Hart, Erondu & Kwen, 2014
M. macrobrachion	Nigeria	61	F	0.420	0.011	2.96	0.98	1.06	A-	Kingdom, Hart, Erondu & Kwen, 2014
M. macrobrachion	Nigeria	27	P	...	-1.797	1.443	0.730	0.68	A-	Olawusi-Peters Olamide *et al*., 2014
M. dux	Nigeria	138	M	0.990	0.769	0.839	0.706	2.37	A-	Arimoro & Meye, 2007
M. dux	Nigeria	166	F	0.971	0.708	0.861	0.739	1.43	A-	Arimoro & Meye, 2007
M. rosenbergii	India	273	M	9.046	-2.718	3.550	0.958	1.14	A+	Lalrinsanga *et al*., 2012
M. rosenbergii	India	460	F	11.260	-2.273	3.244	0.969	1.05	A+	Lalrinsanga *et al*., 2012
M. lar	India	110	M	2.083	0.000	2.453	0.769	-	A-	Sethi, Ram & Venkatesan, 2012
M. lar	India	128	F	1.971	0.000	2.622	0.839	-	A-	Sethi, Ram & Venkatesan, 2012
Penaeus monodon	India	242	M	7.661	0.077	2.409	0.778	1.38	A-	Uddin, Ghosh & Maity, 2016
P. monodon	India	391	F	5.256	0.091	2.388	0.847	1.48	A-	Uddin, Ghosh & Maity, 2016
P. monodon	Sri Langka	98	M	1.202	0.006	3.016	0.958	-	I	Piratheepa, Edrisinghe & Chitravadivelu, 2013

Table 5. Continued

Species	Country	n	Sex	W/TL	a	b	R^2	K	Growth Type	References
P. monodon	Sri Langka	153	F	1.317	0.005	3.075	0.963	-	I	Piratheepa, Edrisinghe & Chitravadivelu, 2013
P. monodon	South China Sea	210	M	2.308	0.023	2.803	0.901	2.71	A-	Li *et al*., 2016
P. monodon	South China Sea	202	F	2.313	0.026	2.764	0.892	2.42	A-	Li *et al*., 2016
P. monodon	Africa	190	M	2.151	0.019	2.911	0.911	2.49	A-	Li *et al*., 2016
P. monodon	Africa	168	F	2.174	0.023	2.795	0.901	1.83	A-	Li *et al*., 2016
P. monodon	Nigeria	376	P	2.528	-0.157	1.460	0.957	0.69	A-	Komi, Wilson & Francis, 2017
P. notialis	Nigeria	413	M	1.714	0.539	0.619	0.302	1.38	A-	Lawal-Are &Akinjogunla, 2012
P. notialis	Nigeria	187	F	1.788	0.397	0.817	0.394	1.34	A-	Lawal-Are & Akinjogunla, 2012
Pandalus borealis	West Greenland	1225	P	0.313	0.000	3.057	0.972	-	I	Wieland, 2002
Plesionika ensis	Portugal	81	P	3.679	0.053	2.609	0.950	-	A-	Sousaa *et al*., 2019
Acetes japonicas	Malaysia	25	M	5.486	0.002	3.153	0.659	-	I	Wong, Ong & Khoo, 2015
A. japonicas	Malaysia	49	F	2.810	0.017	2.432	0.798	-	A-	Wong, Ong & Khoo, 2015
Acetes indicus	Malaysia	264	M	1.197	0.010	2.694	0.907	-	A-	Wong, Ong & Khoo, 2015
A. indicus	Malaysia	340	F	0.886	0.008	2.778	0.917	-	A-	Wong, Ong & Khoo, 2015
Metapenaeus monoceros	India	190	M	1.426	0.009	2.924	0.907	1.80	A-	Dineshbabu, 2006
M. monoceros	India	173	F	5.269	0.003	3.292	0.972	2.00	A+	Dineshbabu, 2006
Litopenaeus vannamei	India	157	M	0.481	0.001	3.260	0.999	-	A+	Gautam *et al*., 2014
L. vannamei	India	156	F	2.839	0.000	3.654	0.998	-	A+	Gautam *et al*., 2014
L. vannamei	Iran	634	P	0.758	0.011	2.694	0.889	0.56	A-	Khademzadeh & Haghi, 2017

a = constant, b = exponent, R^2 = coefficient of determination, A+ = positive allometric, A- = negative allometric, I = isometric, K = Fulton's condition factor

The sizes of *Macrobrachium* species collected from the Sungai Batang River was also similar to *M. hainanense* in Chinese streams (Mantel & Dudgeon, 2004) and *M. Lamarrei* in Nepal rivers (Sharma & Subba, 2005), but it was smaller than *Macrobrachium* species in Barito River (Ahmadi & Rizani, 2012). The W/TL ratio of *Macrobrachium* species in the present study was higher than *M. vollenhovenii* (Kingdom, Hart, Erondu, & Kwen, 2014), *M. macrobrachion* (Enin, 1994), *Pandalus borealis* (Wieland, 2002), or *Litopenaeus vannamei* (Khademzadeh & Haghi, 2017), but it was lower than *M. lar* (Sethi, Ram, & Venkatesan, 2012), *P. monodon* (Komi, Wilson, & Francis, 2017) or *Acetes japonicas* (Wong, Ong, & Khoo, 2015). The weight-length relationships are not constant over the entire year and vary according to factors such as food availability, feeding rate, gonad development and spawning period, fecundity, temperature, salinity, and inherited body shape (Li *et al*., 2016).

The values of Fulton's condition factor (K = 1.08-1.22) of *Macrobrachium* species in the present study agreed favorably with the values recorded for other shrimp species from different geographical areas (Table 4). The K values were greater than *M. malcolmsonii* from Pakistan (Soomro *et al*., 2012), *M. macrobrachion* from Nigeria (Kingdom, Hart, Erondu, & Kwen, 2014) or *Litopenaeus vannamei* from Iran (Khademzadeh & Haghi, 2017), but those were lower than *M. felicinium* from Nigeria (Okayi & Iorkyaa, 2004) or *P. monodon* from South China Sea (Li *et al*., 2016). The K value greater than 1 indicating *Macrobrachium* species in Sungai Batang River were in good condition (Le-Cren, 1951), suggested that the result of this study was valid. Our sampling period coincided with the reproductive period of this species that was between February and March indicated by female carrying the eggs caught by the traps. It was also consistent with our previous work in Barito River (Ahmadi, 2018*a*). Variation in the value of the mean K may be attributed to the biological interaction involving intraspecific competition for food and space (Arimoro & Meye, 2007) between species including sex, stages of maturity, condition of the stomach contents and availability of food (Komi, Wilson, & Francis, 2017; Uddin, Ghosh, & Maity, 2016).

It is interested to note that *Macrobrachium* species caught by the wire stage-trap from Sungai Batang River were identical to those captured by the lighted traps from Barito River (Ahmadi, 2018*a*). It is quite reasonable because both rivers were geographically connected one to another. For both species, the W/TL, CL/TL and ChL/TL ratios of males were considerably higher than those of females. The principal differences were found in the total length, chelae length and body color. The mean body sizes of male and female *Macrobrachium* species from Sungai Batang River were 88.28 ± 5.87 mm TL and 82.96 ± 6.41 g weight; while those of Barito River were 66.2 ± 14.17 mm TL and 49.7 ± 11.68 g weight. Males *Macrobrachium* species from Sungai Batang River had chelae about 1.5 times longer than females; while those of Barito River had chelae about 1.3 times longer than females of the same size. Moreover, the body color of *Macrobrachium* species from Sungai Batang River was much brighter than *Macrobrachium* species from Barito River with high turbid water due to sedimentation. Recording of individual length and weight data of *Macrobrachium* species from Sungai Batang River should be continued to provide more detailed statistical analysis on possible differences in the length-weight and the length-length relationships, and also condition factor at different developmental stages. This study presents the first reference for growth patterns and relative condition factor of *Macrobrachium* species sampled from Sungai Batang River. From fishing practices point of view, the local fishermen were still unsatisfied with the current number of shrimp catch collected by the baited wire stage-trap, therefore it is recommended to use the lighted traps for catching *Macrobrachium* species as they were successfully applied in Barito River, and the results are still open for discussion.

5. Conclusions

Macrobrachium species in Sungai Barito River grew negatively allometric and were in good condition; males were significantly larger and heavier than females. The *b* values were generally in good agreement with the results obtained from other geographical areas. This study provides a useful method in assessing the well-being and growth performance, as well as conservation and management measures for this species.

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