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Length-length, Length-weight Relationships and Condition Factor of the Giant Freshwater Prawn *Macrobrachium rosenbergii* (de Man 1879) Cultured in Earthen Pond at High Density

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Abstract

Length-length and length-weight relationships of *Macrobrachium rosenbergii* (de Man 1879) cultured at high density in earthen pond were investigated. The results revealed that the relationships among various length measurements: rostrum length (*RL*), carapace length (*CL*), head length (*HL*), abdominal length (*AL*), body length (*BL*) and total length (*TL*) showed significant linear correlations through regression analysis ($P<0.001$). The values obtained from the length-weight relationship showed that there was a significant correlation between body weight (*BW*) and *RL*, *CL*, *HL*, *AL*, *BL* and *TL* ($P<0.001$). Their regression equation confirmed a power function relationship: $BW=1.5\times10^{-2}RL^{2.6572}$, $BW=9\times10^{-3}CL^{2.9433}$, $BW=1\times10^{-3}HL^{2.8676}$, $BW=2\times10^{-5}AL^{3.3475}$, $BW=9\times10^{-6}BL^{3.2277}$, and $BW=5\times10^{-6}TL^{3.1205}$. All the values of *b* obtained in the current study were significantly different from the isometric value ($b=3$). Low slopes (*b*) were observed in *BW-RL*, *BW-CL* and *BW-HL*, while high slopes (*b*) were observed in *BW-AL*, *BW-BL* and *BW-TL*. The growth type in *BW-RL*, *BW-CL* and *BW-HL* was negative-allometric growth ($b<3$) while growth type in *BW-AL*, *BW-BL* and *BW-TL* was postive-allometric growth ($b>3$). The values of Fulton's condition factor *K* obtained in the present study varied from 0.70 to 1.05. A high value of *K* (>1) was obtained at harvest time indicating that prawns cultured at high intensive condition were stout showing a good condition of robustness.

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Introduction

The giant freshwater prawn *Macrobrachium rosenbergii* (de Man 1879), is one of the largest species of the genus *Macrobrachium*, which is among the most commercially cultured crustaceans in the world (Ling 1969; New 2002). It was commonly known as "big head prawn" in China due to its huge cephalothorax. Freshwater prawn farming is very popular in many regions in China especially in the Yangtze River Delta. According to the China Fishery Statistical Yearbook 2015 (Bureau of Fisheries, Ministry of Aquaculture 2015), Chinese farmed production of *M. rosenbergii* reached 127,204 tonnes in 2014, with over 50% production of total farmed *M. rosenbergii* originating from Jiangsu Province especially from Gaoyou City, the biggest *M. rosenbergii* culture area in the country.

Morphometric relationship has been widely used in studies in genetic breeding (Daud and Ang 1995), population research (Kurup et al. 1992), shrimp stock assessment (Rao et al.1993), life history traits (Hossain et al. 2012) and comparing the difference in inter-species growth rate (Cheng and Chen 1990). At present, there are many reports regarding length-weight relationship in penaeid shrimp (Hutchins et al. 1979; Primavera et al. 1998), crayfish (Rhodes and Holdich 1984; Wang et al. 2011), spiny lobster (Senevirathna et al. 2014) and *Macrobrachium* species (Sethi and Venkatesan 2013; Abohweyere and Williams 2008; Soomro et al. 2012). In addition, length-length relationship was often used to predict one length parameter from another in penaeid shrimp (Fontaine and Neal 1968; Brusher 1972). However, reports on morphometric relationship of length-length of *M. rosenbergii* are limited. The length-weight relationships of *M. rosenbergii* in natural populations (Rao 1967; Hossain et al. 1987) or in culture conditions at lower stocking density (Sampaio and Valenti 1996; Weng and Zhao 1988) have been reported. In eastern China, especially in Jiangsu Province and Shanghai, monoculture model with high density was applied by local farmers. High density as 60×10^4 postlarvae (PL)·ha^{-1} or even higher was stocked into earthen ponds. However, no studies have been conducted on the morphometric relationship of length-length, length-weight of *M. rosenbergii* cultured at high density.

This study investigated the length-length, length-weight relationships and condition factor of the giant freshwater prawn cultured in earthen pond at intensive conditions. Detailed knowledge of morphometric relationships can be used to predict weight at a given length and help in the adjustment of feeding rates for different sizes of *M. rosenbergii*. The results would be useful for culturists to better manage culture production of *M. rosenbergii* when raised in intensive conditions.

Materials and Methods

A rectangular earthen culture pond of 4000 m^2 and a depth of 1.8 m used in this experiment was located at a commercial farm belonging to the Shanghai Shencao Special Fisheries Development Company. Prior to stocking with PLs, the pond was filled with freshwater from a nearby river, to approximately 90 cm in depth and the water was chlorinated to achieve a concentration of 10 $mg{\cdot}L^{-1}$ active chlorine.

After 7 days, the water was dechlorinated by aeration. Newly metamorphosed PLs of *M. rosenbergii* were reared in indoor cement nursery ponds for a period of 15 days. After the nursery phase, PLs with an average weight of 0.0193±0.0116 g were directly stocked at a density of $60.m^{-2}$ in the experimental pond. After stocking, PLs were provided with pelleted commercial feed containing 40% crude protein. For the first 30 days the shrimp were fed three times daily and six times per day after that. The feeding rate was adjusted according to the observed feed consumption and the residual feed during different growing phases.

Two paddle wheel aerators (0.75 KW) were installed at a distance of 3 m away from the side of the pool. Dissolved oxygen (DO) levels (measured by a YSI Model ProODO, Yellow Springs, Ohio, USA) were maintained at ≥ 4 $mg{\cdot}L^{-1}$. The culture period was 148 days during 20 May to 14 October, 2015. Water quality in the pond was maintained by partially changing 30% of water when necessary.

Shrimps were sampled biweekly starting from the second day after stocking. Samples were collected randomly (30~60 individuals per sample time) throughout the 5-months grow-out period. For the first 100 days specimens were collected by a trawl net and after that a casting net was used to catch the larger shrimp. Length parameters were measured with a digital vernier caliper to the nearest 0.01 mm. Each prawn was blotted dry and its body weight was measured with an analytical balance to the nearest 0.0001 g when individual prawn weighed ≤ 0.1 g; specimens heavier than 0.1 g were measured with an electronic balance to the nearest 0.01 g.

Newly molted animals and those without chelipeds or rostrum were excluded from consideration. All the specimens used for analysis were in intermolt condition in this experiment. A total of 456 specimens were examined using seven morphometric measurements indicated in Table 1.

Table 1. Measurement description of morphometric parameters of *Macrobrachium rosenbergii*.

Morphometric parameter	Abbreviation	Measurement description
rostrum length	*RL*	Distance from the tip of the rostrum to the postorbital margin of the carapace
carapace length	*CL*	Distance from posterior orbital margin to the posterior edge of the carapace along the mid-dorsal line
head length	*HL*	Distance from the tip of the rostrum to the midpoint of the posterior margin of the carapace
abdominal length	*AL*	Distance from the anterior margin of the first abdominals somite to tip of the telson
body length	*BL*	Distance from posterior orbital margin of the carapace to the tip of the telson
total length	*TL*	Distance from rostrum tip to the tip of the telson with shrimp stretched out
body weight	*BW*	Body wet weight

Regression analyses were performed among length–length and length–weight measurements according to the following models:

$$Y=a+bX$$

where Y represents one length parameter (mm), X is a random rest length parameter (mm), and a (intercept) and b (slope) are parameters of the linear equation.

$$W=aL^b$$

where W is body wet weight (g), L is length parameter such as rostrum length, carapace length, head length, abdominal length, body length or total length (mm), a and b are parameters of the power equation. The exponents (b) of length-weight relationships were tested for departure from isometry (b=3) using a t statistic function given in Pauly (1984). All analysis was carried out at 95 % confidence level.

Fulton's condition factor (K) was calculated in accordance with Lalrinsanga et al. (2012) by using the following formula: $K=W/L^3\times100$, where W is the body weight (g), and L is the total length (TL, cm). The results are presented as the means ± standard deviation (means ± SD). Data of K were analysed using one-way ANOVA procedure in SPSS 21.0 (IBM Corp., New York, USA). Significant differences among different culture days were evaluated using Duncan's multiple range test. Significant differences were considered when $P<0.05$. Regression relationships of length-length and length-weight were determined using Curve Estimation procedure in SPSS 21.0.

Results

Length-length relationship

It was found that body length parameters have a straight line relationship. Linear functions provided a better fit for morphometric relationship of length-length. The fitness of the linear regression equations were determined based on coefficient of determination (R^2) and the Residual Sum of Squares (*RSS*). The regression functions are shown in Table 2. Results in Table 2 showed that the coefficient of determination between two random body size parameters was more than 0.91 in all the groups (ranging from 0.9192~0.9958) indicating significant correlations between two measurements. Different slopes of linear regressions among body length dimensions were observed. Slope <1 (negative allometry) was only found in *AL* versus *HL* (0.9353) and *RL* versus *CL* (0.9846) while slopes were all above 1 (positive allometry) among other groups (1.3447~3.8593). These relationships indicated allometric growth in different parts of the body.

Table 2. Linear regression among length morphometric parameters of *Macrobrachium rosenbergii*.

Length-length relationship	Coefficient of determination (R^2)	Residual sum of squares
TL=1.3447(*BL*)+0.3219	0.9958	2539.954
TL=1.9353(*HL*)+3.6521	0.9956	2611.784
TL=2.0495(*AL*)-3.1360	0.9951	2930.719
TL=3.7244(*RL*)+2.5901	0.9665	20074.004
TL=3.8593(*CL*)+7.8359	0.9840	9611.072
BL=1.4285(*HL*)+2.8810	0.9851	4916.928
BL=1.5228(*AL*)-2.5197	0.9976	789.175
BL=2.7244(*RL*)+2.5901	0.9392	20074.004
BL=2.8747(*CL*)+5.5027	0.9914	2829.934
AL=0.9353(*HL*)+3.6521	0.9816	2611.784
AL=1.7909(*RL*)+3.3200	0.9433	8050.517
AL=1.8747(*CL*)+5.5027	0.9801	2829.934
HL=1.9336(*RL*)-0.7299	0.9799	3200.931
HL=1.9846(*CL*)+2.3332	0.9788	3375.907
RL=0.9846(*CL*)+2.3332	0.9192	3375.907

(*TL*: total length, *BL*: body length, *AL*: abdominal length, *RL*: rostrum length, *CL*: carapace length, *HL*: head length.)

Length-weight relationship

Regression analysis of various measurements of body size (*RL*, *CL*, *HL*, *AL*, *BL* and *TL*) versus *BW* and the estimated coefficients of length-weight relationship are given in Table 3.

Table 3. Regression relationship of different length parameters versus body weight of *Macrobrachium rosenbergii*.

Length-weight relationship	Coefficient of determination (R^2)	Residual sum of squares	Value $\hat{t}$	Growth type
$BW=1.5\times10^{-2}(RL)^{2.6572}$	0.9402	108.328	10.99	–allometry
$BW=9\times10^{-3}(CL)^{2.9433}$	0.9939	11.022	5.16	–allometry
$BW=1\times10^{-3}(HL)^{2.8676}$	0.9855	26.354	8.08	–allometry
$BW=2\times10^{-5}(AL)^{3.3475}$	0.9938	11.208	28.10	+ allometry
$BW=9\times10^{-6}(BL)^{3.2277}$	0.9977	4.234	31.39	+ allometry
$BW=5\times10^{-6}(TL)^{3.1205}$	0.9935	11.774	10.24	+ allometry

Note: "–" represents negative-allometric growth; "+" represents postive-allometric growth. $t(\alpha=0.05, n=454)=1.960$. (*TL*: total length, *BL*: body length, *AL*: abdominal length, *RL*: rostrum length, *CL*: carapace length, *HL*: head length.)

Coefficients of determination were found to be very highly significant ($P<0.001$) in all length-weight groups which indicate good correlation between length and weight. The exponential values of *b* estimated for regression coefficients of various body dimension-weight relationship were tested against the isometric value of 3 and the results are also shown in Table 3. The *b* value among *BW-RL*, *BW-CL* and *BW-HL* were below the value of isometric growth and were also found significantly different from the isometric value. In contrast, *b* values for *BW-AL*, *BW-BL* and *BW-TL* were well above the value of isometric growth and were found significantly different from the isometric value. Regression coefficient appeared lowest in *BW-RL* in contrast to the highest in *BW-BL*.

Length-weight regression analysis when body length exceeds 9 cm

Results from the current study found that coefficient of determination in the linear equation were higher than power regression. Linear equation fitted better than power equation through regression analysis between *BL* and *BW* of *M. rosenbergii* when body length exceeded 9 cm (Fig. 1).

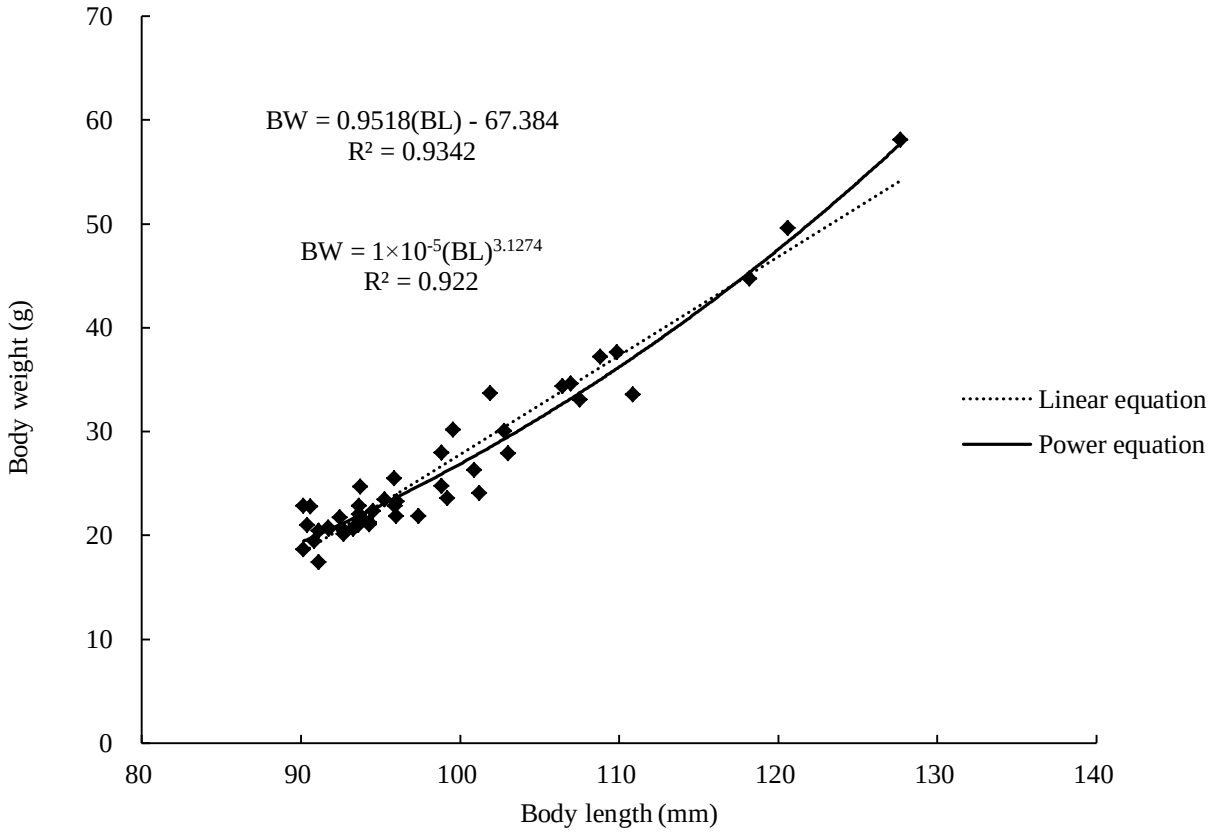

Fig. 1. Regression equations between body length and body weight of *Macrobrachium rosenbergii* when shrimp body length exceed 9 cm.

Fulton's condition factor

The results of the Fulton's condition factor (*K*) determined for *M. rosenbergii* in the current study are shown in Table 4. The *K* value ranges from 0.70 to 1.05 with mean value 0.91±0.11. The *K* value gradually decreased in the first 60 days of culture and rose gradually to the highest value of 1.05 in 140 days. The results of one-way ANOVA analysis showed significant difference between *K* values at 5% level (F=54.81>$F_{0.05\ (10,443)}$ =1.85). *K* value for 56 days of culture was significantly lower than that in 14, 84, 98, 112, 126, 140 and 147 days of culture (P<0.05). *K* values in 14, 84, 98, 112, 126, 140 and 147 days of culture were significantly higher than in 42 days of culture (P<0.05). *K* value for 70 days of culture was significantly lower than that in 14, 98, 112, 126, 140 and 147 days of culture (P<0.05). *K* values for 14, 98, 126, 140 and 147 days of culture were significantly higher compared to 28 days (P<0.05). *K* value for 140 and 147 days were significantly higher compared to 84 days (P<0.05).

Table 4. Condition factor (*K*) of *Macrobrachium rosenbergii* during culture period.

Culture period (days)	Condition factor (*K*)
14	0.98±0.16
28	0.82±0.07
42	0.76±0.07
56	0.70±0.04
70	0.79±0.09
84	0.86±0.17
98	0.98±0.10
112	0.97±0.12
126	1.02±0.11
140	1.05±0.12
147	1.04±0.13

Discussion

The morphometric relationships of length-length are usually described with a linear regression model (Fontaine and Neal 1968; Brusher 1972; Dall et al. 1990). In general, there is a lack of information on the length-length relationship of *RL*, *HL* and *AL* as compared to *CL*, *BL* or *TL* which are the measurement most commonly used in morphometric studies of crustaceans (Anger and Moreira 1998; Chu et al. 1995). In the current study the relationship between *AL* and *TL* was determined so that measurements obtained from beheaded shrimp could be converted to total length conveniently as headless shrimps were often sold as bait shrimp in supermarket. Relationships of *RL* and *TL*, *HL* and *TL* were also studied. In fact, length measurements are easier to obtain than weight measurements. Rostrum length or head length can be easily measured with a ruler, so total length can be obtained through *TL*-*RL* and *HL*-*TL* relationships.

The length-weight relationships of *M. rosenbergii* in earlier studies are shown in Table 5. Some of the equations reported in published studies used *TL* (as the present study) and other length parameters, e.g. orbit length. The parameter (*b*) of length-weight relationships estimated in the current study (*b*=3.1205) was within the values (2.9604~3.5932) previously reported for *M. rosenbergii*.

Table 5. Relationship between weight and length of *Macrobrachium rosenbergii* reported in various studies.

Study	Length-weight relationship	Coefficient of determination	Number of samples
Present study	$W=5\times10^{-6}(TL)^{3.1205}$	0.9935	456
Rao (1967)	$W=7.222\times10^{-5}L^{3.19346}$	0.99013	873
Wang (1985)	$W=3.2\times10^{-4}(OL)^{3.2615}$	0.978	503
Hossain, et al. (1987)	$W=0.00303L^{3.4011}$	0.96	500
Weng and Zhao. (1988)	$W=0.0347L^{2.9604}$	-	1160
Haq and Quddus. (1995)	$W=1.8\times10^{-3}(TL)^{3.5932}$	-	200
Sampaio and Valenti. (1996)	$W=1.21\times10^{-6}L^{3.43}$	-	-
Kunda et al. (2008)	$W=0.008875L^{3.075}$	0.99	100
Lalrinsanga et al. (2012)	$W=0.087694L^{3.3893}$	0.9478	733

The relationship between weight and length for fish or 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 growth is allometric (Wootton 1992; Enin 1994). Ricker (1975) stated that allometric growth can be either positive ($b>3$) or negative ($b<3$). Wootton (1992) reported if the fish gets relatively thinner, b is less than 3.0, if it gets plump, b is greater than 3.0. Similar reports were observed in *Penaeus vannamei* Boone 1931 (Araneda et al. 2008) as well as several other species including *Penaeus duorarum* Burkenroad 1939 (Diaz et al. 2001), *Nematopalaemon hastatus* (Aurivillius 1898) (Enin 1994), *Macrobrachium macrobrachion* (Herklots 1851) (Abohweyere and Williams 2008), *Macrobrachium malcolmsonii malcolmsonii* (H. Milne Edwards, 1844) (Soomro et al. 2012) and *M. rosenbergii* (Kurup et al. 2000; Sampaio and Valenti 1996; Lalrinsanga et al. 2012). Isometric growth ($b=3.07$) of *M. rosenbergii* cultured in rice field was reported by Kunda et al. (2008).

Similarly, Sampaio and Valenti (1996) observed higher b value of 3.43 for *M. rosenbergii* raised at a density of 1.5 animals·m^{-2} in 0.02 ha earthen ponds, Kurup et al. (2000) obtained different b values varying from 1.53 to 3.50 in various male morphotypes of *M. rosenbergii*. In the present study, significantly higher b value was observed in *BW-AL* ($b=3.3475$), *BW-BL* ($b=3.2277$) and *BW-TL* ($b=3.1205$) relationships which means positive allometric growth indicating the weight increase to be more than cube of *AL*, *BL* and *TL* in contrast to the negative allometric growth in *BW-RL* ($b=2.6572$), *BW-CL* ($b=2.9433$) and *BW-HL* ($b=2.8676$) meaning the weight increase to be less than cube of *RL*, *CL* and *HL*.

Shrimp growth follows a sigmoidal pattern during its whole life history (Dall et al. 1990). However, linear function was also used to describe growth for juvenile size in *Penaeus monodon* Fabricius 1798 (Primavera et al. 1998), *Penaeus setiferus* (Linnaeus 1767) (Lindner and Anderson 1956), broodstock in *Penaeus penicillatus* Alcock 1905 (Wu et al. 1990) and *M. rosenbergii* (Chen et al. 1996). Growth pattern for shrimps varied in different life stage (Primavera et al. 1998; Kurup et al. 2000; Lalrinsanga et al. 2012). *Macrobrachium rosenbergii* was found to exhibit a "leapfrog" growth pattern (Karplus et al. 1991); the relationship between weight and length at different life stage should therefore be described in different biological regression equations. The correlation equation of length-weight relationship in *P. penicilatus* broodstock (*BL*=10.2092±0.0321cm, *BW*=14.0696±0.1273g) was described as *BW*=3.1414(*BL*)-18.0016. In *M. rosenbergii,* similar linear equation was also obtained between length and weight over broodstock size (*BL*=11.040±0.122cm, *BW*=42.258±1.740g) as *BW*=13.056(*BL*)-102.019.

Fulton's condition factor, *K*, is widely used in fisheries and fish biology studies as a measure indicating the degree of robustness of fish. *K* was used as an index to reflect fish's physical and biological conditions, and *K*=1 is the baseline between slender and robust condition 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 0.70 to 1.05 in *M. rosenbergii* cultured at high density (60.m^{-2}). The *K* value decreased gradually before 60 days of culture due to the fact that freshwater prawns grew faster in body length than body weight in earlier culture phase. However, *K* increased stepwise during 60~100 days of culture and rose perpendicularly in the late culture period in accordance with faster growth rate of body weight. Condition factor was >1 after 126 days during the later culture period indicating the prawns were above the average condition with good health. 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 mean *K*-value was lowest at 56 days of culture (0.70±0.04) and highest at 140 days (1.05±0.12). The fluctuation in the *K* value in the entire period, for *M. rosenbergii* was similar with the study reported by Lalrinsanga (2012) where the *K* value ranged from 0.79 in nursery animals to 1.0 to 1.14 in adult broodstock.

Conclusion

The results in this study revealed that length-length relationship exhibited a linear regression and length-weight relationship showed a significant power correlation. All the values of *b* from length-weight regression obtained in the current study were significantly different from the isometric value (*b*=3).

The growth type in *BW-RL*, *BW-CL* and *BW-HL* was negative-allometric growth (b<3) while growth type in *BW-AL*, *BW-BL* and *BW-TL* was postive-allometric growth (b>3). The mean condition factor value ranged from 0.70 to 1.05 in *M. rosenbergii* cultured at high density (60.m^{-2}) during entire culture period. Lower value of condition factor (K<1) was observed between 14-112 d, while higher value (K>1) after 126 d during the late culture period indicating the prawns were above the average condition with good health.

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References

Abohweyere, P.O. and A.B. Williams. 2008. Length–weight relationship and condition factor of *Macrobrachium macrobrachion* in the Lagos-Lekki Lagoon system, Nigeria. Research Journal of Biological Sciences 3:1333-1336.

Anger, K. and G.S. Moreira. 1998. Morphometric and reproductive traits of tropical Caridean shrimps. Journal of Crustacean Biology 18:823-838.

Araneda, M.E., P. Pérez and E. Gasca-Leyva. 2008. White shrimp *Penaeus vannamei* culture in freshwater at three densities: Condition state based on length and weight. Aquaculture 283:13-18.

Brusher, H.A. 1972. Tail length-total length relation for the commercially important prawn, *Penaeus indicus*. Indian Journal of Fisheries 19:180-182.

Bureau of Fisheries, Ministry of Aquaculture. 2015. China Fishery Statistical Yearbook 2015. China Agriculture Press, Beijing. 155 pp.

Chen, G., H.J. Chai and X.W. Lin. 1996. Primary analysis in genetic parameters of *Macrobrachium rosenbergii*. Journal of Zhanjiang Fisheries College 16:25-30.

Cheng, C.S. and L.C. Chen. 1990. Growth characteristics and relationships among body length, body weight and tail weight of *Penaeus monodon* from a culture environment in Taiwan. Aquaculture 91: 253-263.

Chu, K.H., Q.C. Chen, L.M. Huang and C.K. Wong. 1995. Morphometric analysis of commercially important penaeid shrimps from the Zhujiang estuary, China. Fisheries Research 23: 83-93.

Dall, W., B.J. Hill, P.C. Rothlisberg and D.J. Sharples. 1990. The biology of the Penaeidae. Academic Press, London. 489 pp.

Daud, S.K. and K.J. Ang. 1995. Selection of broodstock of tiger prawn, *Penaeus monodon* Fabricius, on the basis of morphometric traits. Pertanika Journal of Tropical Agricultural Science 18:15-20.

Diaz, G.A., S.G. Smith, J.E. Serafy and J.S. Ault. 2001. Allometry of the growth of pink shrimp *Farfantepenaeu sduorarum*in a subtropical bay. Transactions of the American Fisheries Society 130:328-335.

Enin, U. 1994. Length–weight parameters and condition factor of two West African prawns. Revista de Biología Tropical 27:121-127.

Fontaine, C.T. and R.A. Neal. 1968. Relation between tail length and total length for three commercially important species of penaeid shrimp. Fishery Bulletin 67:125-126.

Haq, M.E. and M.A. Quddus. 1995. Meat yield to total weight in freshwater giant prawn *Macrobrachium rosenbergii*. Indian Journal of Fisheries 40:231-233.

Hossain, M.A., M.A. Ali, M.S. Islam, M. Sahabuddin and S. Dewan.1987. Length-weight relationship and condition factor of *Macrobrachium rosenbergii* (De Man) of Tetulia River. Bangladesh Journal of Fisheries 10:89-95.

Hossain, M.Y., J. Ohtomi, A. Jaman, S. Jasmine and R.L.V. Jr. 2012. Life history traits of the Monsoon River prawn *Macrobrachium malcolmsonii* (Milne-Edwards, 1844) (Palaemonidae) in the Ganges (Padma) River, northwestern Bangladesh. Journal of Freshwater Ecology 27:131-142.

Hutchins, D.L., G.W. Chamberlain and J.C. Parker. 1979. Length-weight relations for several species of penaeid shrimp cultured in ponds near Corpus Christi, Texas. Proceedings of the World Mariculture Society 10:565-570.

IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, New York: IBM Corp.

Karplus, I., A. Barki, Y. Israel and S. Cohen. 1991. Social control of growth in *Macrobrachium rosenbergii*. II. The "leapfrog" growth pattern. Aquaculture 96:353-365.

Kunda, M., S. Dewan, M.J. Uddin, M. Karim, S. Kabir and M.S. Uddin. 2008. Length-weight relationship, condition factor and relative condition factor of *Macrobrachium rosenbergii* in rice fields. Asian Fisheries Science 21:451-456.

Kurup, B.M., M. Harikrishnan and S. Sureshkumar. 2000. Length-weight relationship of male morphotypes of *Macrobrachium rosenbergii* (de Man) as a valid index for differentiating their developmental pathway and growth phases. Indian Journal of Fisheries, 47:283-290.

Kurup, B.M., T.M. Sankaran, P. Rabindranath and M.J. Sebastian. 1992. Growth and population dynamics of *Macrobrachium rosenbergii* (de Man) and *M. idella* (Hilgendore) in the Vembanad Lake. In: Freshwater Prawns (ed. E.G. Silas), pp. 90-98. Kerala Agricultural University.

Lalrinsanga, P.L, B.R. Pillai, G. Patra, S. Mohanty, N.K. Naik and S. Sahu. 2012. Length weight relationship and condition factor of giant freshwater prawn *Macrobrachium rosenbergii* (De Man, 1879) based on developmental stages, culture stages and sex. Turkish Journal of Fisheries and Aquatic Sciences 12:917-924.

Lindner, M.J. and W.W. Anderson. 1956. Growth, migrations, spawning and size distribution of shrimp *Penaeus setiferus*. Fishery Bulletin 56:555-645.

Ling, S.W. 1969. The general biology and development of *Macrobrachium rosenbergii* (De Man). FAO Fisheries Report 57:589–606.

New, M.B. 2002. Farming freshwater prawns: A manual for the culture of the giant freshwater prawn (*Macrobrachium rosenbergii*). FAO Fisheries Technical Paper No. 428, Rome. 212 pp.

Pauly, D. 1984. Fish population dynamics in tropical waters: A manual for use with programmable calculators. International Center for Living Aquatic Resources Management, Manila. 325 pp.

Primavera, J.H., F.D. Parado-Estepa and J.L. Lebata. 1998. Morphometric relationship of length and weight of giant tiger prawn *Penaeus monodon* according to life stage, sex and source. Aquaculture 164:67-75.

Rao, G.S., V.T. Subramaniam, M. Rajamani, P.E.S Manickam and G. Maheswarudu.1993. Stock assessment of *Penaeus* spp. off the east of India. Indian Journal of Fisheries 40:1-19.

Rao, R.M. 1967. Studies on the biology of *Macrobrachium rosenbergii* (de Man) of the Hooghly Estuary with notes on its fishery. Proceedings of the National Institute of Sciences of India. Part B. Biological Sciences 33:252-279.

Rhodes, C.P. and D.M. Holdich. 1984. Length-weight relationship, muscle production and proximate composition of the freshwater crayfish *Austropotamobius pallipes* (Lereboullet). Aquaculture 37:107-123.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada, Ottawa. 382 pp.

Sampaio, C.M.S. and W.C. Valenti. 1996. Growth curves for *Macrobrachium rosenbergii* in semi-intensive culture in Brazil. Journal of the World Aquaculture Society 27:353-358.

Senevirathna, J.D.M., G.G.N. Thushari and D.H.N. Munasinghe. 2014. Length-weight relationship of spiny lobster, *Panulirus homarus* population inhabiting southern coastal region of Sri Lanka. International Journal of Science, Environment and Technology, 3: 607-614.

Sethi, S.N, N. Ram and V. Venkatesan. 2013. Morphometric relationships of the monkey river prawn *Macrobrachium lar* (Fabricius, 1798) (Decapoda, Palaemonidae) from the Andaman Islands. Indian Journal of Fisheries 60:157-161.

Soomro, A.N, W.A Baloch, T.J. Chandio, W.M. Achakzai and S. Saddozai. 2012. Condition factor and length-weight relationship of Monsoon River prawn *Macrobrachium malcolmsonii malcolmsonii* (H. Milne-Edwards, 1844) (Palaemonidae) in lower Indus River. Pakistan Journal of Zoology 44:1279-1283.

Wang, J.K. 1985. Weight and width relationship of freshwater prawn (*Macrobrachium rosenbergii*). Aquacultural Engineering, 4:21-32.

Wang, Q., J.X. Yang, G.Q. Zhou, Y.A. Zhu and H. Shan. 2011. Length–weight and chelae length-width relationships of the crayfish *Procambarus clarkii* under culture conditions. Journal of Freshwater Ecology 26:287-294.

Weng, S.J. and S.C. Zhao. 1988. Growth characteristic of *Macrobrachium rosenbergii*. Fujian Fisheries 2:32-35.

Wootton, R.J. 1992. Fish Ecology. Chapman & Hall, London. 212 pp.

Wu, Z.Q., F.Z. Xu and X.F. Zhou. 1990. Some genetic parameters in the body length and body weight of *Penaeus penicilatus*. Journal of Xiamen Fisheries College 12:5-14.

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