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Length Weight Relationship and Condition Factor of Giant Freshwater Prawn *Macrobrachium rosenbergii* (De Man, 1879) Based on Developmental Stages, Culture Stages and Sex

P.L. Lalrinsanga[1,*], Bindu R. Pillai[1], Gunamaya Patra[1], Swagatika Mohanty[1], Namita Kumari Naik[1], Sovan Sahu[1]

[1] Central Institute of Freshwater Aquaculture, Kausalyaganga, Bhubaneswar, Orissa -751002, India.

* Corresponding Author: Tel.: +91.674 2465446; Fax: +91.674 2465446;
E-mail: viensky2@gmail.com

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Abstract

Length-weight relationship and condition factor of *Macrobrachium rosenbergii* (De Man, 1879) were investigated for different culture phases, developmental stages and sexes in the present study. Regression lines differed among the culture phases, developmental stages as well as between sexes. Significant difference in the slope was observed among different culture phases with nursery animals showing significantly lower slope. The most significant variation in the slope was observed among different developmental stages. Sex wise comparison also exhibit highly significant variation between male and female. Therefore, separate interconversional equations were derived for different culture phases, developmental stages and sexes to simplify management during culture. Additionally, condition factor was also found to be varying significantly between different culture phases, developmental stages and between sexes.

Keywords: Length weight, condition factor, *Macrobrachium rosenbergii*, freshwater prawn

Introduction

Length-weight relationship has vital importance in fisheries science. It helps in establishing mathematical relationship between the two variables, enables conversion of one variable to other (Le Cren, 1951), to describe growth in the wild (Enin, 1994; Abohweyere and Williams, 2008; Deekae and Abowee, 2010), to determine possible differences among different stocks of the same species (Petrakis and Stergiou, 1995; King, 2007), delineate the stocks and comparative growth studies (Sampaio and Valenti, 1996; Primavera *et al*., 1998; Peixoto *et al*., 2004). Although shrimp body weight is commonly recorded for culture management purposes (e.g. estimations of growth rate, feed conversion ratio, harvest weight, and productivity), the application of morphometric relationships could be a simple alternative to estimate body weight from length measurements that are less variable and more easily measured in the field (Cheng and Chen, 1990; Primavera *et al*., 1998). Therefore, the use of morphometric measurements and mathematical models in aquaculture is highly encouraged because that is the most precise and complete way of analyzing growth data (Hopkins, 1992).

The condition factor (K) is an index reflecting interactions between biotic and abiotic factors in the physiological condition of the fishes. It shows the well-being of the population during various life cycle stages and assessments of fish condition based on weight at a given length are thought to be reliable indicators of the energetic condition or energy reserves in fish (Lambert and Dutil, 1997). Although condition factor indicates the general body condition but not the qualitative characteristics (protein, lipid, carbohydrates, etc.) of the body (Lalrinsanga *et al.*, 2012), the body condition could be a useful complement to expensive *in vitro* proximate composition analysis (Sutton *et al*. 2000).

Morphometric relationships of length and weight have been determined mainly in adult of several *Macrobrachium* species (Jayachandran and Joseph, 1988; Enin, 1994; Abohweyere and Williams, 2008; Deekae and Abowee, 2010). Relationships that allow interconversions among the various length and weight parameters are needed e.g., to compare growth parameters (Dall *et al*., 1990) especially for commercially important species like the giant freshwater prawn *Macrobrachium rosenbergii* (De Man, 1879). However report on morphometric analysis of *M. rosenbergii* is limited (Sampaio and Valenti, 1996; Kurup *et al*. 2000; Kunda *et al*. 2008). Further there is a need to investigate length–weight

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relationships at a wider size range, in order to determine how the relationships change with size or life stage and between sexes (Chow and Sandifer, 1991). Therefore, the present work was undertaken to analyze length-weight relationship and condition factor for separate sexes of *M. rosenbergii* of a wide size range, cultured in Central Institute of Freshwater Aquaculture (CIFA), Kausalyaganga, India under different conditions during nursery, growout, and broodstock production phases. The knowledge may provide a basis for the establishment of a practical conversion protocol to simplify management practices in the different culture phases of the species.

Materials and Methods

The length and weight data of *M. rosenbergii* samples individuals were obtained during stocking or termination of various studies conducted at the Central Institute of Freshwater Aquaculture (CIFA), Prawn breeding and culture unit, Kausalyaganga, Orissa, India from 2008 to 2010. Data were collected from three different culture phases: nursery (2 months), grow out (8-10 months), and broodstock production (>10 months). Total length (TL) was measured to the nearest 0.1 mm using a 30-cm ruler for nursery, growout and broodstock animals, as the distance from the tip of the rostrum to the tip of the telson. Analytical balances with precision of 0.01 g were used to record body weight (BW). Approximate size ranges were (a) nursery: 4-10 cm TL, (b). growout: 6–23 cm TL, and (c) broodstock: 11–29 cm TL.

Nursery animals were excluded and only grow-out and broodstock animals were considered for comparative analysis of developmental stages and sexes in order to enhance precision over manual segregation of sex and stages. Sex was determined by checking the external genital organs and ovarian maturation stages were evaluated according to the criteria proposed by Kuris *et al.* (1987) and Sagi and Ra'anan (1985). Males were segregated to four developmental morphotypes as blue claw (BC), orange claw (OC), small males (SM) and no claw (NC); while females were divided as berried, maturing and immatured. Animals of different sizes were taken at random for both males and females and considered for analysis.

The length–weight (log-transformed) relationships were determined by regression analysis and analysis of covariance was performed to determine variation in ‘*b*’ values within a given category (by developmental stages, culture stages and sex) following Snedecor and Cochran (1967). In order to test “b” value against the isometric value of “3”, student’s t-test was employed to predict any significant deviation. The t-statistic was calculated as follows:

$$t = (b-3)/Sb$$

where, Sb= Standard error of ‘b’ = Sb = “(1/(n-2))*[(Sy/Sx)2-b2], Sx and Sy are the standard deviations of x and y respectively.

Fulton’s condition factor (K) for each individual was calculated according to Htun-Han (1978) equation $K = 100\times(W/L^3)$, where W is the body weight (BW), and L, the total length (TL).

Results

The values for elevation (a*)* and slope (b*)* together with their corresponding regression coefficient (r^2*)* for the length–weight relationships in *M. rosenbergii* of different developmental stages, culture stages, sources and sexes are presented in Table 1. The relationships vary with developmental stages, culture stages and sexes such that different equations have to be used for purposes of interconversions.

Culture Phases

Nursery juveniles showed significantly lower values of b (Table 1), indicating lower weight gain relative to increase in length compared to growout and broodstock animals. The growth in nursery showed isometry where as it is positive allometry in growout as well as broodstock animals. Although the slope in growout is found higher than broodstock, no significant difference was observed between growout and broodstock animals. Scatter diagrams of length and weight for different culture phases exhibited curvilinear relationship are shown in Figure 1.

Developmental Stages

Comparative analysis of different developmental stages showed significant variation in the slope (Table 1). Among different stages of male developmental stages, highest slope was observed for OC male compared to NC, SM and BC, indicating higher weight gain relative to per unit changes in length. The slope in NC animals is however found higher, meaning a greater increase in weight per unit increase in length compared to SM and BC animals. The slope in OC and NC is significantly higher than critical isometric value indicating positive allometric growth whereas it is isometric in SM and BC. In the case of female, no significant variation was observed between different stages of life. However, immature females showed lowest slope, indicating lower weight gain relative to per unit increase in length compared to berried and maturing females.

Sex

Sex wise comparison was carried out by taking different size animals at random and segregating male and female from growout and broodstock animals. Scatter diagrams of length and weight for male,

Table 1. Length – weight relationship parameters, condition factor (K) and growth pattern of *M. rosenbergii* based on developmental stages, culture stages and sex

Particulars	*n*	*Log a*	a $CI_{95\%}$	*b*± SE	*b* $CI_{95\%}$	r^2	Condition factor (K)	Growth pattern
Culture stage								
Nursery	278	-2.0570	-2.1287 to -1.9610	2.9506±0.109[a]	2.8211 - 3.0313	0.7239	0.7973±0.1251[a]	Isometry
Growout	387	-2.3344	-2.3911 to -2.2776	3.2944±0.025[b]	3.2444 - 3.3443	0.9776	1.0049±0.1324[a]	+ allometry
Broodstock	342	-2.2855	-2.4602 to -2.1108	3.2667±0.071[b]	3.1270 - 3.4063	0.8602	1.1451±0.2657[a]	+ allometry
Developmental stages								
Female								
Berried	84	-2.2069	-2.4214 to -1.9922	3.2086±0.091[a]	3.0280 - 3.3891	0.9384	1.1060±0.1344[a]	+ allometry
Maturing	202	-2.2257	-2.3759 to -2.0754	3.2046±0.063[a]	3.0813 - 3.3278	0.9293	1.0639±0.1372[a]	+ allometry
Immatured	174	-2.2589	-2.3404 to -2.1774	3.1218±0.036[a]	3.1502 - 3.2933	0.9787	0.9989±0.1434[a]	+ allometry
Male								
Blue claw	70	-1.8079	-2.3543 to -1.2614	2.9551±0.214[a]	2.5287 - 3.3813	0.7378	1.4076±0.4583[a]	Isometry
Orange claw	95	-2.5427	-2.7849 to -2.3005	3.4809±0.099[b]	3.2828 - 3.6790	0.9290	1.1186±0.1533[b]	+ allometry
Small male	75	-2.1374	-2.3232 to -1.9515	3.0938±0.088[a]	2.9192 - 3.2683	0.9447	0.9224±0.1022[b]	Isometry
No Claw	33	-2.3185	-2.6445 to -1.9925	3.2774±0.134[b]	3.0036 - 3.5512	0.9506	1.0326±0.1140[b]	+ allometry
Sex								
Male	273	-2.6132	-2.7180 to -2.5076	3.5502±0.045[a]	3.4617 - 3.6386	0.9584	1.1435±0.3379[a]	+ allometry
Female	460	-2.2734	-2.3362 to -2.2106	3.2443±0.027[b]	3.1912 - 3.2973	0.9693	1.0470±0.1446[a]	+ allometry
Sex pooled	2.6132	-2.4339	-2.4923 to -2.3754	3.3893±0.025[b]	3.3401 - 3.4385	0.9615	1.0829±0.2402[a]	+ allometry

n: sample size; Log *a*: Log intercept; *b*±SE: slope±standard error; CI: confidence Interval; r^2: coefficient of determination.
Values with different superscripts in a column for culture stages, developmental stages and sex differ significantly (P < 0.05).

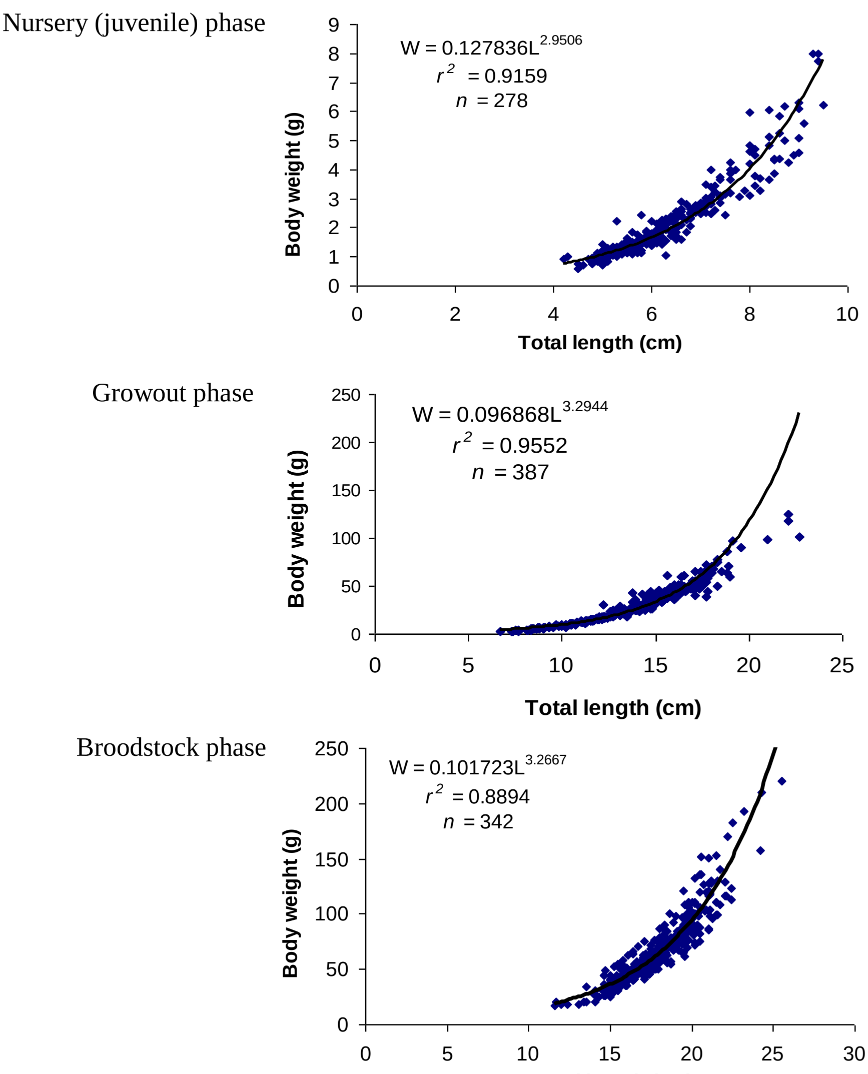

Figure 1. Scatter diagram showing length-weight relationship of *M. rosenbergii* during different culture phases.

female and pooled sexes exhibited curvilinear relationship are shown in Figure 2. Significantly higher slope was observed in male compared to female (Table 1). The slope was found to be significantly varying from critical isometric value indicating high positive allometric growth in male, female and pooled sex.

Condition Factor (K)

The condition factor obtained in the present study ranges from 0.79±0.13 in nursery animals to 1.41±0.46 in BC animals (Table 1). No significant variation was observed in K of different culture stages with broodstock animal showing the highest followed by growout animals and nursery animals.

Based on developmental stages, the K was found highest in BC compared to all other male morphotypes. The K in OC was also found to be higher than SM although it did not vary significantly. In case of female, K in immatured female was found to be lower compared to berried and maturing female (Table 1).

Sex wise comparison revealed no significant variation between male and female, although male was found to exhibit higher K than female.

Discussion

Generally shellfish maintains dimensional equality, the weight increase will be proportional to the cube of length increment while the slope value less than 3 indicates that the animal becomes slender as it increases in length whereas slope greater than 3 denotes stoutness indicating allometric growth

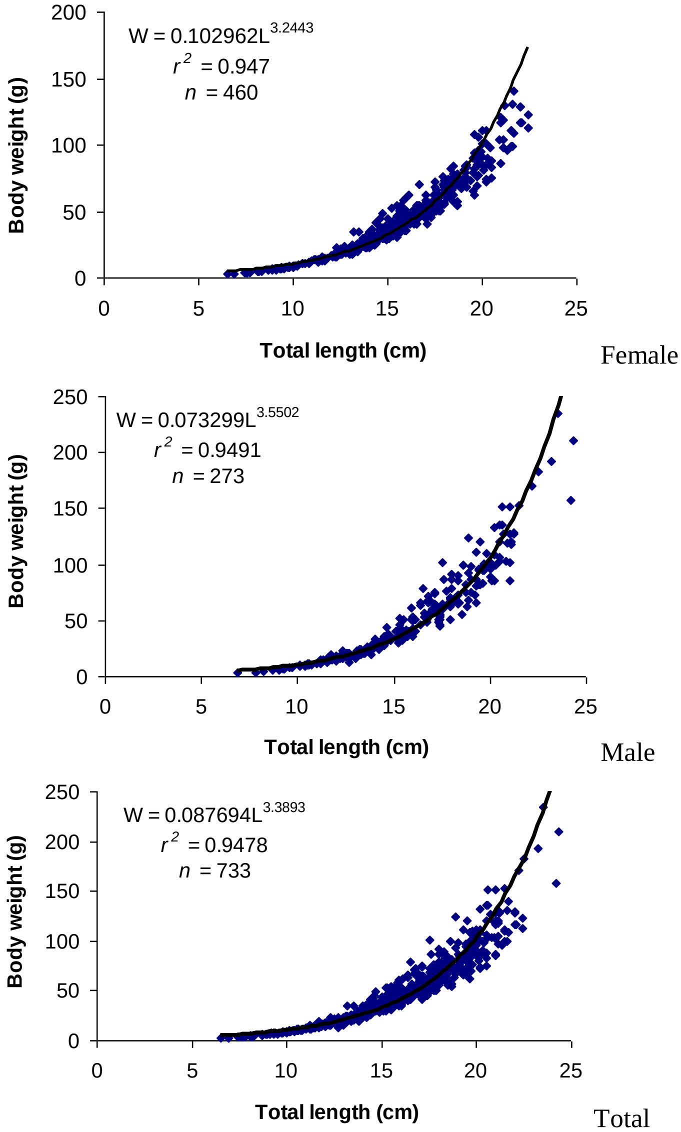

Figure 2. Scatter diagram showing sex wise length-weight relationship of *M. Rosenbergii.*

(Grover and Juliano, 1976; Kurup *et al*., 2000). Variations in the slope (b) value of regression have been reported in several *Macrobrachium* species under natural environment based on total length-body weight relationship (Enin, 1994; Abohweyere and Williams, 2008; Deekae and Abowei, 2010), which is attributed to sample size variation, life stages, and environmental factors. Nevertheless, few studies have dealt on how these relationships change with life stages, size and sex under culture conditions in *M. rosenbergii*.

The use of total length to determine length–weight morphometric relationships has been widely applied for wild and captive *Macrobrachium* species (Sampaio and Valenti, 1996; Anger and Moreira, 1998; Kunda *et al*. 2008) as well as other penaeids (Cheng and Chen, 1990; Chow and Sandifer, 1991; Chu *et al*., 1995; Primavera *et al*., 1998). Hence, total length is used to determine the length-weight relationship in the current study. The parameters of the length–weight relationships estimated in the present study are well within the ranges previously reported for several *Macrobrachium* species (Enin, 1994; Abohweyere and Williams, 2008; Deekae and Abowei, 2010). Kunda *et al*. (2008) reported isometric growth (b=3.075) of *M. rosenbergii* in rice field with co-efficient of determination (*r2*) of 0.99. Under culture environment, Sampaio and Valenti (1996) also observed high b value of 3.43 (positive allometry) for *M. rosenbergii,* indicating rapid growth of the species.

Culture Stages

The growth rate of animals varies widely depending on the culture stages and developmental stages such that younger and smaller nursery juveniles grow faster than older and bigger animals (Primavera *et al*., 1998). In contrast the slope of nursery animals, although follows isometric growth pattern, was found significantly lower compared to grow out and broodstock animals ($P<0.05$) in the present study. The higher slope of growout and broodstock animal may be due to the presence of maturing and berried females representing additional weight of ovaries and eggs (Peixoto *et al*., 2003; Tan-Fermin and Pudadera, 1989). Further, the higher slope in growout and broodstock may also be attributed to the presence and/or dominance of the male.

Developmental Stages

In the present study SM showed lowest regression coefficient followed by BC. Interestingly, significantly higher slope was observed in OC, which occupies the transition stage from SM to BC, compared to SM, BC and NC indicating very rapid weight gain relative to per unit increase in length. Kurup *et al*., (2000) also reported highest slope in OC with about 100% improvement of b value from SM. SM which occupies the initial stage of developmental hierarchy in the developmental pathway of male prawn (Kurup *et al*. 2000), possesses a well developed reproductive system characterized with intense sexual activity which is comparable with BC (Sagi and Ra'anan, 1988). Therefore a large part of its energy is spend towards mating; usually sneak mating behavior (Ra'anan and Sagi, 1985), resulting into slow growth rate. BC male which represent the terminal stage of male developmental pathway also spend most of its energy for maintaining dominance and courtship which results into infrequent moulting and reduced growth (Ra'anan and Sagi, 1985). In contrast, the somatic growth in OC male is reported to be very fast (Sagi and Ra'anan, 1988) and they spend only very little energy for reproduction and courtship, as the reproductive system is not well developed corresponding with ineffective reproductive behaviour (Kurup *et al*., 2000). The slope in NC males is higher than SM but lies between OC and BC which may be due to the possibility of the presence of both OC and BC males.

In case of female, no significant difference was observed between different stages of life, although berried and maturing females showed higher slope compared to immature females. Although little information is available on the effects of sexual maturation on the morphometry of *Macrobrachium* species, mature females are usually heavier than immature females of the same body length (Crocos and Kerr, 1983; Chu *et al*., 1995). Peixoto *et al*. (2003) reported that the additional weight of ovaries in female constitute up to 13% of total body weight in wild *Fenneropenaeus paulensis* while it is more than 8% of total body weight in wild *Penaues monodon* spawners (Tan-Fermin and Pudadera, 1989). Therefore, it is suggested that the additional weight of the ovaries and eggs in maturing and berried females life stages may partially explain the higher slope in berried and maturing females compared to immature female. Positive allometry in immatured female may be due to the representation of unvirgin spent female with high body weight in the population. Therefore, investigation when the animal attains its first maturity will help in illustrating concrete conclusion.

Sex

Sexual dimorphism in growth with larger sizes and faster growth rates in males compared to females has been documented for *M. rosenbergii* (Nagamine and Knight, 1980; Jayachandran and Joseph, 1988; Thanh *et al*., 2009; Lalrinsanga *et al.*, 2012), *M. malcolmsonii* (Rajaylaskhmi, 1980), *M. macrobrachion* (Abohweyere and Williams, 2008), *M. acanthurus* and *M. olfersii* (Anger and Moreira, 1998) as well as several other species including *Penaues semisulcatus*, *Metapenaues affinis* and *Parapeneopsis stylifera* (Farmer, 1986). In the present study, significantly higher slope was observed in male compared to female ($P<0.05$) indicating faster growth of male. Nwosu and Wolfi (2006) reported a higher 'b' value of 3.483 for males compared to 3.329 for females of *M. vollenhovenii*. Mossolin and Bueno (2003) and Fransozo *et al*. (2004) also observed that males reached a greater total length than females as a function of the differences in growth rates and patterns of population structure between sexes in *M. olfersi* and *M. iheringi* respectively. Bigger male sizes may be due to a greater weight increase per molt cycle leading to a faster growth rate (Hansford and Hewitt, 1994; Makinouchi and Hirata, 1995). Additionally, male in *M. rosenbergii* generally show higher weight gain as observed in the present study, which may be due to the development of long and robust chela which account for additional weight gain in the developmental pathway of the species. Mantelatto and Barbosa (2005) observed higher mean weight and carapace length in males of *M. brasiliense* compared to females and suggested larger size reached by males may be related to domination over females, as well pre-adult males, during the copulation process.

Separation of morphometric relationships for males and females may not be necessary for penaeids at certain life history stages (Cheng and Chen, 1990; Dall *et al*., 1990; Chu *et al*., 1995). Primavera *et al*. (1998) reported for *P. monodon* that morphometric dimorphism due to sex was observed only after the broodstock stage in captivity when females had a greater weight gain per unit length. The present study clearly indicated however the need for developing separate morphometric relationship for males and females of *M. rosenbergii* during growout and broodstock stage. Several authors have also presented separate length–weight relationships for males and females in other species (Chow and Sandifer, 1991; Primavera *et al*., 1998; Tzeng *et al*., 2001).

Condition Factor (K)

Information on condition factor (K) can be vital to culture system management because they provide the producer with information of the specific condition under which organisms are developing (Araneda *et al*., 2009). It reflects recent physical and biological circumstances, and fluctuates by interaction among feeding conditions, parasitic infections and physiological factors (Le Cren, 1951) and it is an indicator of the changes in food reserves and therefore an indicator of the general fish condition.

The K observed in the present study ranges from 0.79 in nursery animals to 1.41, indicating that the prawns are in good condition. Kunda *et al.* (2008) reported a condition factor and relative condition factor (Kn) of 1.09 and 1.00, respectively in *M. rosenbergii* under rice fields suggesting good condition of the prawn. Similar ranges of condition have also been reported in other species of *Macrobrachium* (Arimoro and Meye, 2007; Enin, 1994). Significantly higher K in growout and broodstock animals compared to nursery animals in the current study may be explained by due to attainment of maturity by the prawns (Rao, 1967; Deekae and Abowei, 2010) in growout and broodstock ponds. The K in berried and maturing animals were also higher compared to immatured animals in the current study.

The existence of social hierarchy among male morphotypes is clearly revealed in the present study with BC, the most dominating morphotypes showing highest K, while it was lowest in SM. Variation in the value of the mean K may be attributed to biological interaction involving intraspecific competition for food and space (Arimoro and Meye, 2007) and the difference in aggressive behaviour (Deekae and Abowei, 2010) between morphotypes. The lower K in SM compared to BC, OC and NC may be due to the less dominance of SM among male morphotypes, spending most of its energy on hiding and sneaking (Kurup *et al*., 2000). Sex wise comparison in the present study revealed higher K male compared to female. Abohweyere and Williams (2008) and Arimoro and Meye (2007) also reported higher condition factor in male of *M. macrobrachion* compared to female and suggested that males generally appear to have better mean condition factor than the females.

Conclusion

Although knowledge of the size structure at different culture stages is important for management decisions, body weight can be inferred from body length that is more readily measured which is considered a less variable and easier means to record compared to body weight in the field. Results from the current study found evidence that morphometric relationship of length and weight measurements can be used efficiently for separating different developmental stages, different culture stages and sexes of *M. rosenbergii*. Further the varying length–weight relationships in *M. rosenbergii* according to developmental stage, culture stage and sex require different equations for interconversions, which could simplify the management strategies and selection of appropriate broodstock size for reproduction purposes in culture of *M. rosenbergii* and . In addition, the present results revealed that condition factor of prawn may also be considered as a reliable indicator of different stages of prawn and management efforts in a culture system may be altered based on condition factor.

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