Sheik Istiak Md. Shahriar
Department of Aquaculture,
Hajee Mohammad Danesh
Science & Technology
University, Bangladesh

Muhammad Abdur Rouf
Fisheries and Marine Resource
Technology Discipline, Khulna
University, Bangladesh

Sex ratio, length-weight relationship, condition and relative condition factor of mud crab (*Scylla olivacea*) in Sunderban mangrove forest, Bangladesh

Sheik Istiak Md. Shahriar and Muhammad Abdur Rouf

Abstract
This study was attempted to determine the basic biological information on *Scylla olivacea* collected from Sunderban mangrove forest, Bangladesh during a period of May-October 2016. The average length of male and female crabs was 87.48 mm and 79.86 mm with an average weight of 173.15 g and 97.15 g, respectively. Although the sex ratio of this species remained uneven throughout the study, highest (male: female=1:3) was recorded in 70-79 mm size range. In length-weight relationship, the coefficient determinant (r^2) for male was 96.5%, for female was 98.2%, and for combined sexes was 93.9%. The value of exponential 'b' at 95% confidence interval was 3.222-3.45 in male, 2.618-2.748 in female and 3.06-3.261 in combined sexes. A strong positive correlation was observed in length-weight relationship of three different sexes. The value b observed in combined sexes resulted that the growth of these organisms was close to isometrics. The average condition factor (K) in male was 0.025 and in female was 0.019 and but the Kn of male was 0.0000057 and female was 0.00014. The obtained K value suggested, males were much heavier than female at the same length. However, this study will be helpful to understand the biological status of *Scylla olivacea* fishery in Sunderban mangrove forest, Bangladesh which ultimately could be used in the management of mud crab resources in this forest.

Keywords: Length-weight relationship, condition factor, *Scylla olivacea*, Sunderban, Bangladesh

1. Introduction
The mud crab, genus *Scylla* is extensively distributed in the muddy river, tributaries, canals and intertidal areas of mangrove wetlands in Indo-Pacific regions [13, 17]. In Bangladesh, after a long controversy on taxonomic classification on genus *Scylla*; recently, it has been confirmed that *S. olivacea* is the common mud crab species being caught from Sunderban mangrove forest [21] which was mistakenly addressed as *S. serrata* in earlier literature by many researchers [20]. Since, the taxonomic clarification of this species is stated; exploration for significant biological features of this species is now paramount in importance.

Length-weight relationship and condition factor provide useful information to understand the dynamics of a fishery in a given ecosystem. Moreover, data on length-weight relationship has significance in determining the actual dimension of a crustacean stock [3, 11] and it also helps to determine the growth performance; more explicitly present condition, maturity, feeding rate, spawning frequency, their suitability to environment and so on [6, 8, 22]. Condition factor is more suitable in comparing the physical condition of an organism to that of others. In addition, it refers to the assumption that the higher weight at the same length provides much better condition in terms of growth [19].

In recent years, capture of wild mud crab has been expanding because of its high export value in international market. Consequently, the wild population is being subjected to enhanced exploitation for last few decades to meet the increasing demand [2]. Due to its high economic value, several Bangladeshi researchers conducted studies dealing with morphology, general biology, taxonomy, molecular systematics, distribution, biochemical analysis, catch per unit effort, culture and marketing [1, 7, 10, 12, 20, 21]. However, the extensive information on population features of this species is lacking. This present investigation, therefore, aims to provide useful biological information regarding sex ratio, length-weight relationship, condition factor and relative condition factor of *Scylla olivacea* found in the Sunderban mangrove forest, Bangladesh.

Correspondence
Sheik Istiak Md. Shahriar
Department of Aquaculture,
Hajee Mohammad Danesh
Science & Technology
University, Bangladesh

2. Materials and Methods

A total of two hundred and fifty (N=250) wild individuals of mud crabs were collected from a commercial landing center of Shyamnagar upazilla, Shatkhira district, located near the Sunderban mangrove forest. Sampling was done monthly over the period of May-October 2016. Identification was performed on the sampling site to confirm *Scylla olivacea* based on morphological characteristics suggested by Keenan *et al.* 1998 [13]. Sexes were separated observing external morphology as well.

Fresh samples with all appendages were taken and washed completely to remove excess mud and other particles. Then the carapace length (CL) was measured from tip of the 1st later spine to the tip of 9th lateral spine using a digital vernier caliper (accuracy 0.01 mm) and the body weight (BW) was taken to the nearest 1g with the help of an electric balance, respectively.

Sex ratio was calculated dividing the number of female samples by the number of male samples in the same size range. The carapace length (CL) and body weight (BW) relationship of *S. olivacea* was estimated using the log transformed formula given by Bagenal and Tesch (1978) [5];
lnBW = a + b lnCL; where 'a' is a constant and 'b' is an exponent.

The strength of that relationship was estimated by correlation determinant (r^2) and exponential value b was tested at 95% confidence interval.

Condition factor (K) is calculated by using the following formula;
$K=100*(BW/CL^3)$ (Gayanilo *et al.* 1997) [9]
Relative condition factor (Kn) was determined using formula given by LeCren (1951) [16],
$Kn=BW/aCL^b$

3.0 Results and Discussions

3.1 Size range and sex ratio

The size range of *Scylla olivacea* with their sex ratio was presented in Table 1. The highest number of male (48) was found in 70-79 mm and the number of female was greatest (64) in the same size group. The frequency of both mud crabs was high in between 70-99 mm size range. In general, after size class 90-99 mm the number of mud crabs was gradually decreasing with the increase of size (Table 1).

The average sex ratio was recorded to be 1.0:0.97 (Table 1), while the maximum was found in 70-79 mm and the minimum was observed in 120-129 mm. Ali *et al.* 2004 [2] reported the overall sex ratio of mud crab collected from Khulna region of Bangladesh was 1:0.94 which comply with the results of the present study. In sex ratio, the number of female in *S. olivacea* is higher in comparison to *Scylla serrata* and *S. traquebarica*, because this species is mostly restricted to intertidal zone while other moves freely [11]. However, this ratio varies depending upon the size range of population, season [23] as well as exploitation of the stock.

Table 1: The size range (mm) of *S. olivacea* in correspondence with its sex ratio

Size range (mm)	No. of male	No. of female	Combined	Sex ratio (male : female)
~-3.9	-	-	-	-
40-49	02	03	05	1.0: 1.5
50-59	06	05	11	1.0: 0.83
60-69	15	15	30	1.0 : 1.0
70-79	16	48	64	1.0 : 3.0
80-89	24	26	50	1.0 : 1.08
90-99	31	14	45	1.0 : 0.45
100-109	19	09	28	1.0 : 0.47
110-119	11	05	16	1.0 : 0.45
120-129	1	0	1	1.0 : 0.0
130-139	-	-	-	-
Total	125	125	250	1.0 : 0.97 (average)

3.2 Carapace length (CL) and body weight (BW)

The measurements of carapace length (CL) and body weight (BW) of collected samples were shown in Table 2. The average CL of male and female crabs was 87.48 mm and 79.86 mm respectively. The maximum length recorded in this study was 122 mm for male and 119 mm for female samples. The average weight of male was 173.15 g and 97.15 g for female simultaneously. It was observed that both male and female reaches to equal maximum carapace length (Table 2), however, a marked discrepancy was seen in the weight of samples. Male sometimes attain double weight in compare to female in the same carapace length which might be due to the presence of their muscular chelate legs.

Table 2: Carapace length and body weight measurements of mud crabs

	Carapace length (mm)			Body weight (g)		
	Lowest	Highest	Average	Lowest	Highest	Average
Male	46	122	87.48	24	487	173.15
Female	45	119	79.86	22	296	97.15

3.3 Carapace length and body weight relationship

The results of length-weight relationship derived through regression analysis were exhibited in Table 3 and log transformed scatter plots of carapace length and body weight for the male, female and combined mud crab, *S. olivacea* were shown in Figure1, 2 and 3.The results revealed that the correlation coefficient (r) for female sample was 0.991 followed by male 0.982 and combined group 0.969 which is very close to 1. Subsequently, the value of correlation determinant (r^2) was 98.2% for male, 96.5% for female and 93.9% for combined sexes (Table 3). The value of r suggested the degree of correlation between CL and BW of *S. olivacea* is very high while r^2 revealed that in three sexes; most of the changes in body weight was due to the changes in carapace length.

Table 3: Length-weight relationship of *S. olivacea* (male, female and combined sexes) along with its condition factor and relative condition factor

Sex	n	Exponential b	r	r² (%)	95% confidence interval of b		Condition factor	Relative condition factor
					Lowest	Highest		
Male	125	3.336	0.982	96.5	3.222	3.450	0.025	0.0000057
Female	125	2.618	0.991	98.2	2.618	2.746	0.019	0.00014
Combined	250	3.16	0.969	93.9	3.060	3.261	0.022	0.0000017

The obtained exponential value (b) for female, male and combined was 2.618, 3.336 and 3.16 respectively (Table 3 and Figure 1, 2 and 3). This difference in b values clearly depicted the sexual dimorphism of this species [19]. According to Khan and Alam (1992) [12], higher b value in male mud crab is common in brachyuran crab species. The observed values revealed the male are much heavier than the female. Similar result was reported for *S. tranquebarica* collected from Indian waters [22]. However, the size of an organism is ideal with weight if the value of b is in between 2.5–4.0 [18]. In addition, more precisely the growth of an organism is said to be isometric especially when the value of b is 3 [14]. In this study, 95% confidence interval of slope b exhibited that the range of slope for male sample was above 3 (b>3.0) and female sample was below 3 (b<3.0) which meant there was a negative allometry exists [5] i.e. the male grow larger as the size increase and in contrary, the female become relatively less large as the size progress [8]. In the combined sexes, the lower interval of slope b (3.06) was close to the isometric growth value (b=3). Consequently, it is evident that the overall growth of combined group *S. olivacea* showed much positive allometry than the separate one. The variation observed in b value may be resulted from some biological aspects like size, age, feed availability, feeding behavior and metabolic rate [22].
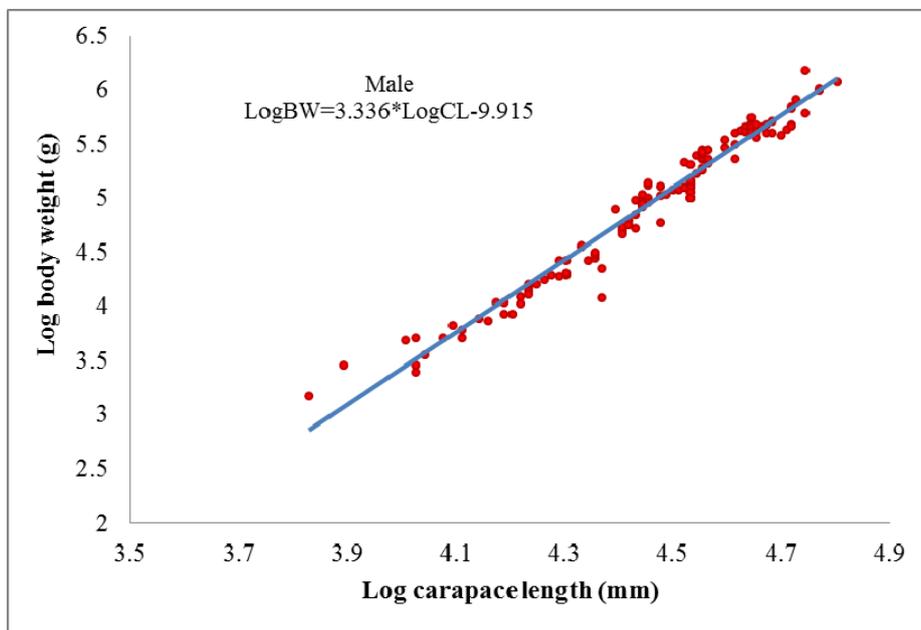

Fig 1: A scatter plot of log transformed carapace length and body weight for the male mud crab, *S. olivacea*
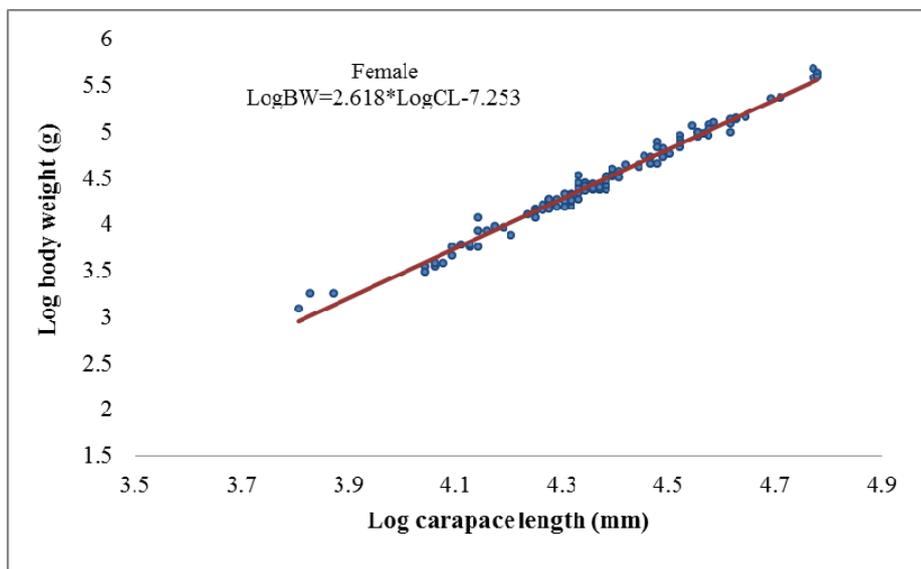

Fig 2: A scatter plot of log transformed carapace length and body weight for the female mud crab, *S. olivacea*
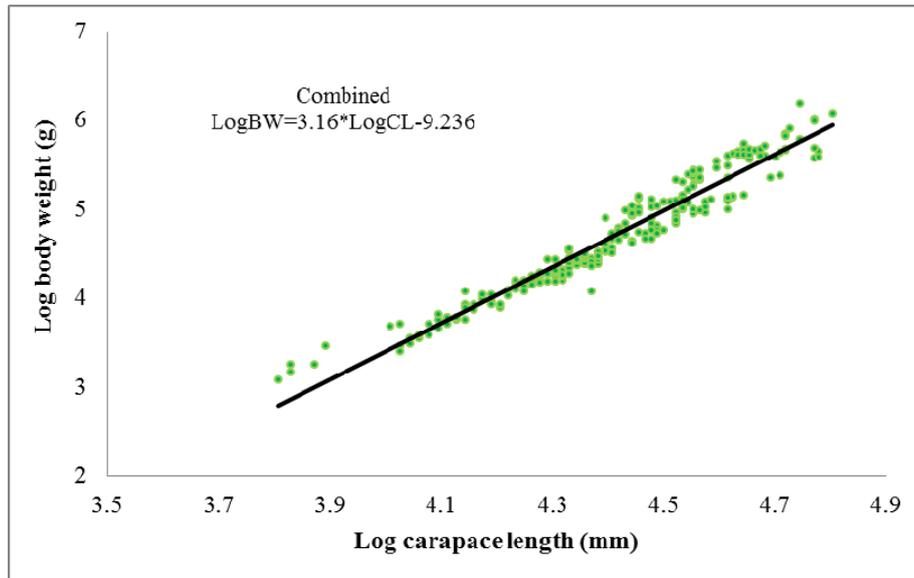
Fig 3: A scatter plot of log transformed carapace length and body weight for the combined mud crab, *S. olivacea*

3.4 Condition factor (K) and relative condition factor (Kn)
The mean condition factor (K) of male, female and combined sexes was 0.025, 0.019 and 0.022 (Table 2). A notable variation in mean condition factor of male and female was identified in this experiment. In general, the mean K was much higher in male crabs than female [15]. In contrast, sometimes mean K of female can be higher if gonadal maturation is attained [19]. Besides that food availability, life cycle, length, overall environment etc. affects the condition factor of crustaceans. In this study, gonadal maturation in female were not found, might be due to the selection of sampling months. Finally, the mean relative condition factor (Kn) was high in female (0.00014) rather than the male (0.0000057) and average was observed in combined sexes (0.0000017).

One of the limitations of this experiment was its relatively smaller sample size. Furthermore, higher sample size may help to reduce the variation in exponential value. To sum up, it can be said that there is a strong positive linear relation was observed in carapace length and body weight of wild samples of *Scylla olivacea* collected from the Sunderban mangrove forest. Thus, the growth of this species is in a decent condition under this mangrove ecosystem. Finally, the author believes this study will add valuable information to enrich the biological database of *S. olivacea* reported from Sunderban mangrove forest of Bangladesh as well as it will be helpful to set further conservation and management measures of the stock in future.

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