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Original Research

Sci Vis Vol 13 Issue No 2
April-June 2013
ISSN (print) 0975-6175
ISSN (online) 2229-6026

Spawning density and morphometric characteristics of the horseshoe crab *Tachypleus gigas* (Müller) on the Balasore coast of Bay of Bengal, India

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Received 6 May 2013 | Accepted 15 June 2013

Abstract

The spawning density and morphometric characteristics of the Asian horseshoe crab *Tachypleus gigas* (Müller) found along the Balasore coast of Bay of Bengal was studied during 2008-2011. The spawning population was generally higher during March and July and were significantly higher (2-sample *t*-tests, all $p \geq 0.1$) between the new moon and full moon. The relationship between various body parts of *T. gigas* revealed an increase in total length proportion to the of the prosomal (carapace) length. Similar relation was also observed with the carapace width with the advancement of total length. Telson length to the total length relationship also indicated a proportional increase. The body weight to total length relationship was also linear. The relationship between carapace width (dorsal prosomal breadth) with the body weight and total length with the body weight of the gravid females though showed a linear relationship but the r values were very weak. But there was a strong relationship between the body weights of the gravid female with that of the amount of the eggs present in the body.

Key words: Alleometry; *Tachypleus gigas*; Balasore coast; spawning density.

Introduction

The Asian horseshoe crab, *Tachypleus gigas* (Müller), also known as Asian king crab, belongs to the family Limulidae and is the only marine primitive invertebrates found on earth. In Asia, *T. gigas* are distributed from Bay of Bengal to south-west Japan.[1,2] This species is classified as either near threatened or data deficient.[3] Evidences from studies and fishermen suggest that this species once commonly found in different habitats throughout Asia is now declining and human disturbances have been attributed to the degradation and destruction of spawning beaches in India. Horseshoe crabs continue to grow for nine to ten years until they reach maturity. The young horseshoe crabs moult, or

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shed, their outer skeleton (exoskeleton) often until they reach sexual maturity, then moulting slows, occurring only about once annually. The animals increase in size by 25-30% with each moult by pumping in water to expand their new shells, which will harden in approximately 24 hours. Males are sexually mature at their sixteenth moult or ninth year. Females need at least 17 moults and mature in their tenth year.

The allometry (study of relationship between differences in one body parameters to the other) provides important information regarding comparative growth of various body parameters. A proper understanding of allometry in shell and soft body parts of the crabs also define the growth of the species. The concept of allometry was first postulated by Huxley and Tessier[4] and since then it has been extensively applied by many biologists to estimate the population growth characteristics of multitude organisms. Different body parts of a number of horseshoe crabs have been examined by different authors,[5-6] the shapes, colours and body patterns are also studied. The present paper reports the spawning density of *T. gigas* and relates its various body parts in order to assess the growth behaviour along the Balasore coast of Bay of Bengal.

Materials and Methods

Balasore coast of Bay of Bengal (21° 3' to 21° 59' North latitude and 86° 20' to 87° 29' East longitude) is about 81 km wide and shaped like a strip where sand dunes are noticed along the coast with some ridges. The coast has intertidal zones of about 6 km into the sea that provides wide opportunity for intertidal organisms like king crabs. To estimate the density of spawning population of *T. gigas*, surveys were made in the above mentioned three estuaries during 2008-2011 using quadrat/transect sampling. To standardize the minimum area to be surveyed, we examined several protocols for the survey adopted by various workers. Initially the quadrat size was restricted to 1mx1m and the number of quadrat in each site was 25 (twenty five), randomly laid to assess the spawning population. However, the data collected from these quadrats showed a lot of variations and we missed many a times to record the availability of *T. gigas* from the small size of the quadrat. Since the spawning density was observed to be relatively lower compared to many other studies reported, instead of using quadrats, we laid out four transects each measuring 25 m^2 (1 m width x 25 m long) in each site to increase the area covered by the survey. Transects were laid adjacent to water edge and extended to 1 m into the water and through 100 m length along the beach. A gap of 10 m was maintained between two transects. Spawning survey was carried out regularly twice a month, coinciding with full and new moon phases from January 2008 to December 2011. The samples were collected one hour prior to and one hour following the predicted high tides except under extreme weather conditions. Since the breeding activity was more pronounced in the daylight high tide than the night tides for *T. gigas*,[7] in our present study, we restricted all our observations to during day light hours at the highest high tides of full or new moon. All animals within transects were counted and recorded the number of single males, single females, pairs.

The specimen present in each of the transect during different visits were collected and examined for their sex. A total of 133 animals (85 females and 48 males) collected at different time of the year were measured for the body size and weight parameters. The specimens were measured using a Vernier callipers to 0.1 m accuracy. Data collected for all measurements were pooled together from different sites and also irrespective of the sexes. Similarly, data for measurement of body length, width and body weight of only gravid females pooled from three sites were analyzed separately. Similarly, analysis of various body parts of the males was carried out to have a comparison with the pooled data of all population (male and female) and with the gravid females. The total length of each specimen was considered as a basis for references for all other measurements.[8] The various body parameters included are: (i) prosomal length

(=carapace length), (ii) opisthosomal length, (iii) telson length, (iv) total length (= prosomal + opisthosomal + telson length), (v) dorsal prosomal breadth (=carapace width) and (vi) body weight. Out of the total crabs caught during the survey, a representative of 130 crabs were classified into different frequency classes based on the carapace width (dorsal prosomal breadth) of 1 cm intervals and the percent of the such animals were represented in graphical form for different sites so as to have an idea about the size of the animals that were mostly frequently visited the area during the survey period. A linear regression of various body measurements against the total length was carried out. Relationships of total length with different parameters were expressed using regression equation (Y=a+bX) where 'a' and 'b' were considered as additive and multiplying constants. A straight line was fitted to the scattered diagram using SPSS 15.0 version.

Statistical methods

The population data of *T. gigas* between the sites were subjected to analysis of variance (ANOVA, fixed effects method) to know the variations between the sites and seasons. Correlations between various body parameters of the crab was worked out and based on the results, regression equations were developed. Similarly, the number of eggs and the weight of the organisms were related to know if any relation existed using Microsoft excel softwares. An attempt was also made to draw frequency distribution curve of the spawning individuals arriving at different sites so as to depict the size of animals that occurs along the Balasore coast of Bay of Bengal.

Results and Discussion

Spawning density

The population of *T. gigas* has been found throughout the year, though the breeding season of this species is found to be restricted from March to September. The spawning density of *T. gigas* varied between high tide of full moon and low tide of new moon and between different months and years (Fig. 1). At Avana beach, during 2008, a total of 28 males/transect (=25 m^2) and 34 females were observed in new moon while a total of 22 males and 32 females area were observed during full moon. In 2009, 14 males and 21 females during new moon and 14 males and 27 females were reported and in 2010, the corresponding figures were 14 males and 23 females during new moon and 15 males and 23 females during full moon. In 2011, a total of 15 males and 18 females were observed during new moon and 12 males and 15 females during full moon. June was found to the peak spawning month at Avana beach showing the arrival of 9 crabs (4 males and 5 females) per 25 m^2 during new moon and 10 crabs (4 males and 6 females) per 25 m^4 during full moon in the year 2008. The year-wise variation of the males and females arriving different shores of the Balasore coast of Bay of Bengal (Table 1) reveal somewhat of a decreasing trend when compared to the base year 2008 which is applicable to both new moon and full moon period. Nevertheless high spawning activities in all the three beaches were found to be in April spreading over to September with peak during June.

The mean spawning densities of crabs (± SE) in January and February were quite consistent at 0.16 ± 0.01 and 0.32 ± 0.01 crabs m^{-2}, respectively in all transects. The densities in March and July were somewhat higher (0.25 ± 0.01 to 0.36 ± 0.01 crabs m^{-2} respectively) than in January and February. This trend was almost similar in all transects; however, there was a decreasing trend in spawning population m^{-2} when compared over the base year 2008. The comparisons of crab density estimates from the surveys (2008 to 2011) was significant (2-sample *t*-tests, all $p \geq 0.1$) between the new moon and full moon (Table 1). The most important factor that could probably influence the mating behaviour of *T. gigas* is the spawning adult population density.[9] Lunar phase is reported to influence the marine organism significantly.[10-13] The abundance of

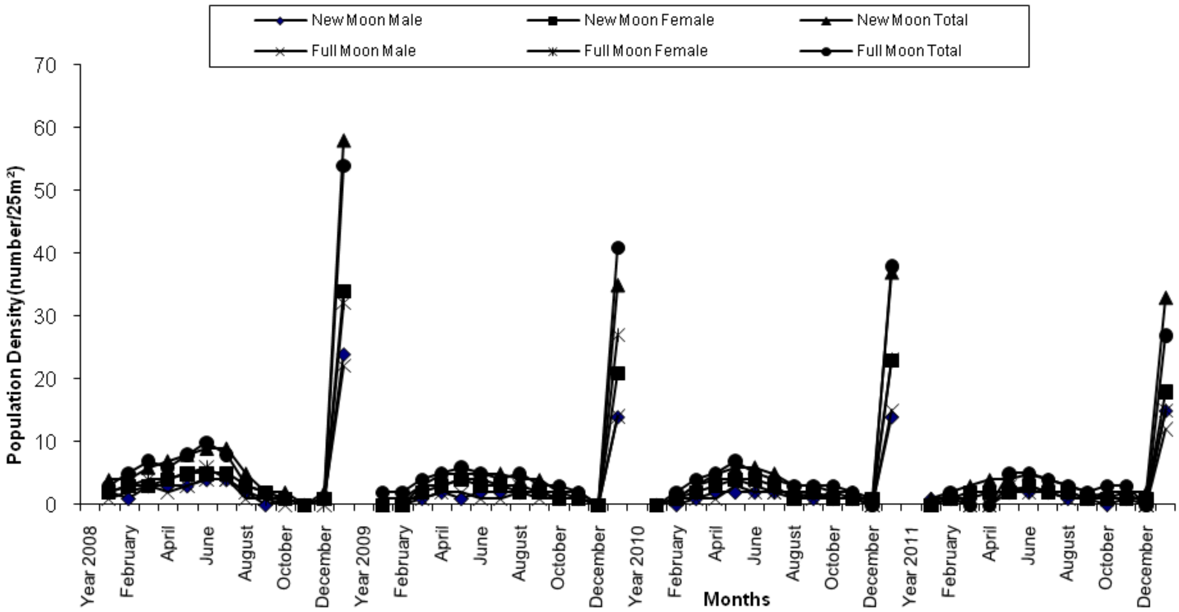

Figure 1. Occurrence of *T. gigas* during different times on the Balasore coast of Bay of Bengal.

Table 1. Analysis of variance on the spawning population of *T. gigas* due to years on the Balasore coast of Bay of Bengal.

Lunar cycle	2008		2009		2010		2011	
	F-Value	P-Level	F-Value	P-Level	F-Value	P-Level	F-Value	P-Level
New Moon	1.55010	0.22728	0.400446	0.673233	0.312000	0.734117	0.492140	0.615732
Full Moon	1.03454	0.36662	1.395168	0.262026	0.489726	0.617177	0.181890	0.834523

horseshoe crab population in relation to full moon tides has also been reported in Apalche Bay, Florida[12] and at Sea-horse key.[14]

Morphometric characteristics

The relationship between various body parts of *T. gigas* captured during the spawning and fishermen nets reveal linear relationship in most cases (Table 2, Figs. 2-6). The total length increases proportionally with the gradual increase of the prosomal (carapace) length. Similar relation was also observed with the carapace width with the advancement of total length. Telson length to the total length relationship also indicated a proportional increase. The body weight to total length relationship was also linear. However, the rate of body weight increase was of higher magnitude than that of the total length. The relationship between carapace width (dorsal prosomal breadth) with the body weight and total length with the body weight of the gravid females though showed a linear relationship but the r values were very weak. But, there was a strong relationship between the body weights of the gravid female with that of the amount of the eggs present in the body.

In the present study, the prosomal length of *T. gigas* ranged between 12.0 to 24.5 cm and the carapace width from 15.0 to 17.27 cm. We pooled the body parameters of both males and females together while relating between different

Table 2. Relationship between various body parts of *T. gigas* found on the Balasore coast of Bay of Bengal.

	Body parameters	**Regression relationship**
Irrespective of male & females (n=133):		
A	Total length (cm) vs Prosomal length (cm)	Y=2.0957X+12.837, R^2=0.6382
B	Opisthosomal length (cm) vs Prosomal length (cm)	Y=2.306X+18.24, R^2=0.429
C	Total length (cm) vs body weight (g)	Y=0.024X+26.61, R^2=0.508
D	Opisthosomal lentgth (cm) vs Prosomal length (cm)	Y=0.541X+1.754, R^2=0.528
E	Opisthosomal length (cm) vs body weight (g)	Y=0.006X+5.386, R^2=0.397
F	Prosomal length (cm) vs body weight(g)	Y=2.010X+6.95, R^2=0.690
G	Total length (cm) vs telson length (cm)	Y=1.756X+5.533, R^2=0.682
Only for gravid females (n=85):		
H	Total length (cm) vs telson length (cm)	Y=1.756X+5.533, R^2=0.682
I	Total length (cm) vs body weight (g)=	Y=0.021X+27.99, R^2=0.175
J	Dorsal Prosomal Breadth (cm) vs body weight (g)	Y=0.009X+17.85, R^2=0.140
Only for males (n=48):		
K	Prosomal length (cm) vs total length (cm)	Y=0.3125X-0.7722, R^2=0.6167
L	Prosomal length (cm) vs Opisthosomal length (cm)	Y=1.195X+1.253, R^2=0.513
M	Prosomal length (cm) vs telson length (cm)	Y=0.219X+5.656, R^2=0.12
N	Prosomal length (cm) vs carapace width (cm)	Y=0.197X+5.630, R^2=0.208
O	Prosomal length (cm) body weight (g)	Y=0.006X+7.672, R^2=0.243

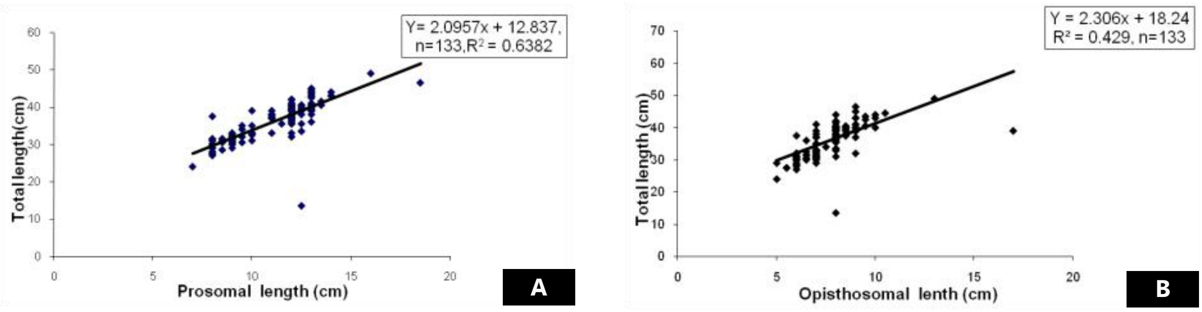

Figure 2. Regression relationship between (A) prosomal length with total length (B) opisthosomal length with total length.

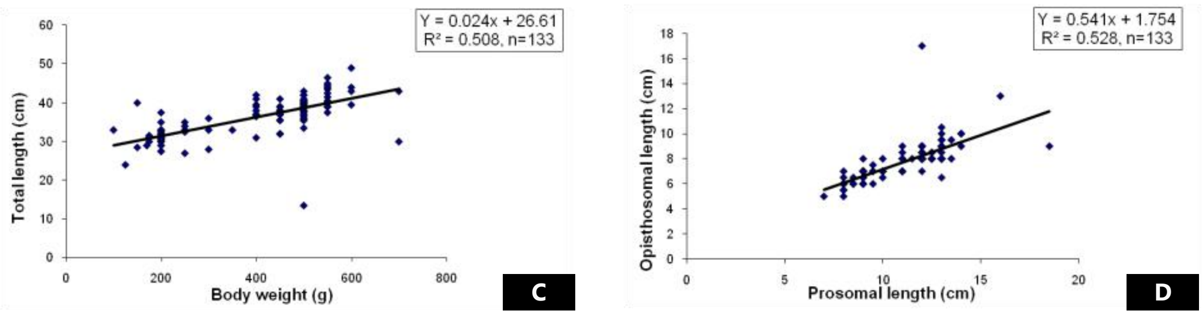

Figure 3. Regression relationship between (C) body weight with total length and (D) prosomal length with opisthosomal length of *T. gigas* found on the Balasore coast of Bay of Bengal.

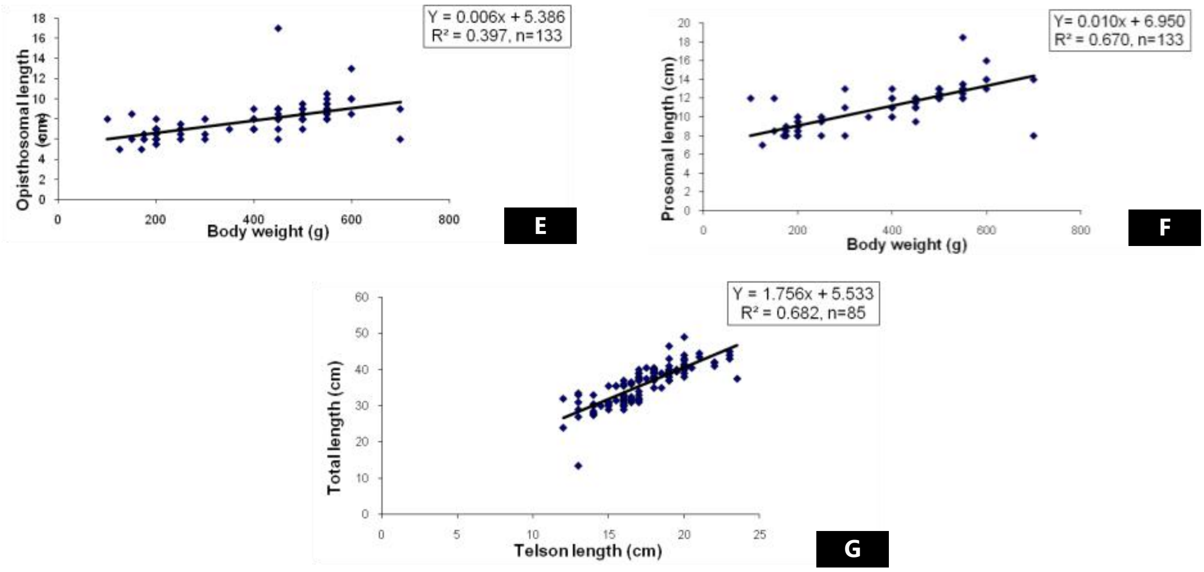

Figure 4. Regression relationship between (E) opisthosomal length vs body weight, (F) prosomal length with body weight (G) total length with telson length of *T. gigas* found on the Balasore coast of Bay of Bengal.

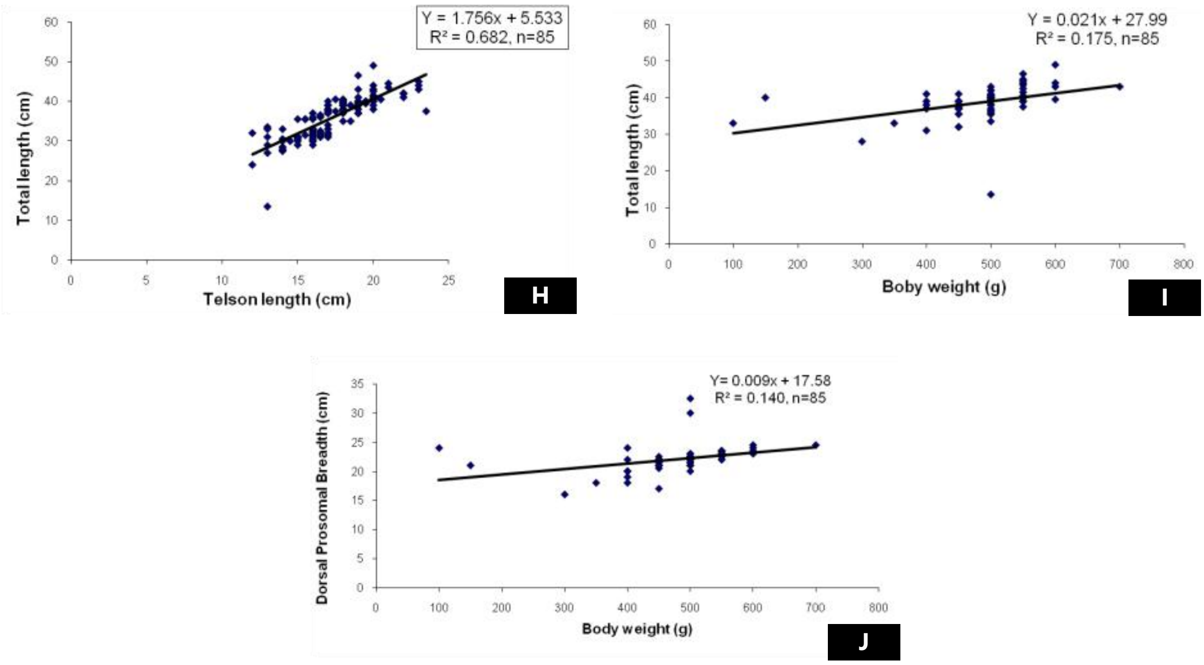

Figure 5. Regression relationship between (H) total length with telson length and (I) telson length (cm) body weight (g) and (J) dorsal prosomal breadth with body weight of the gravid females of *T. gigas* found on the Balasore coast of Bay of Bengal.

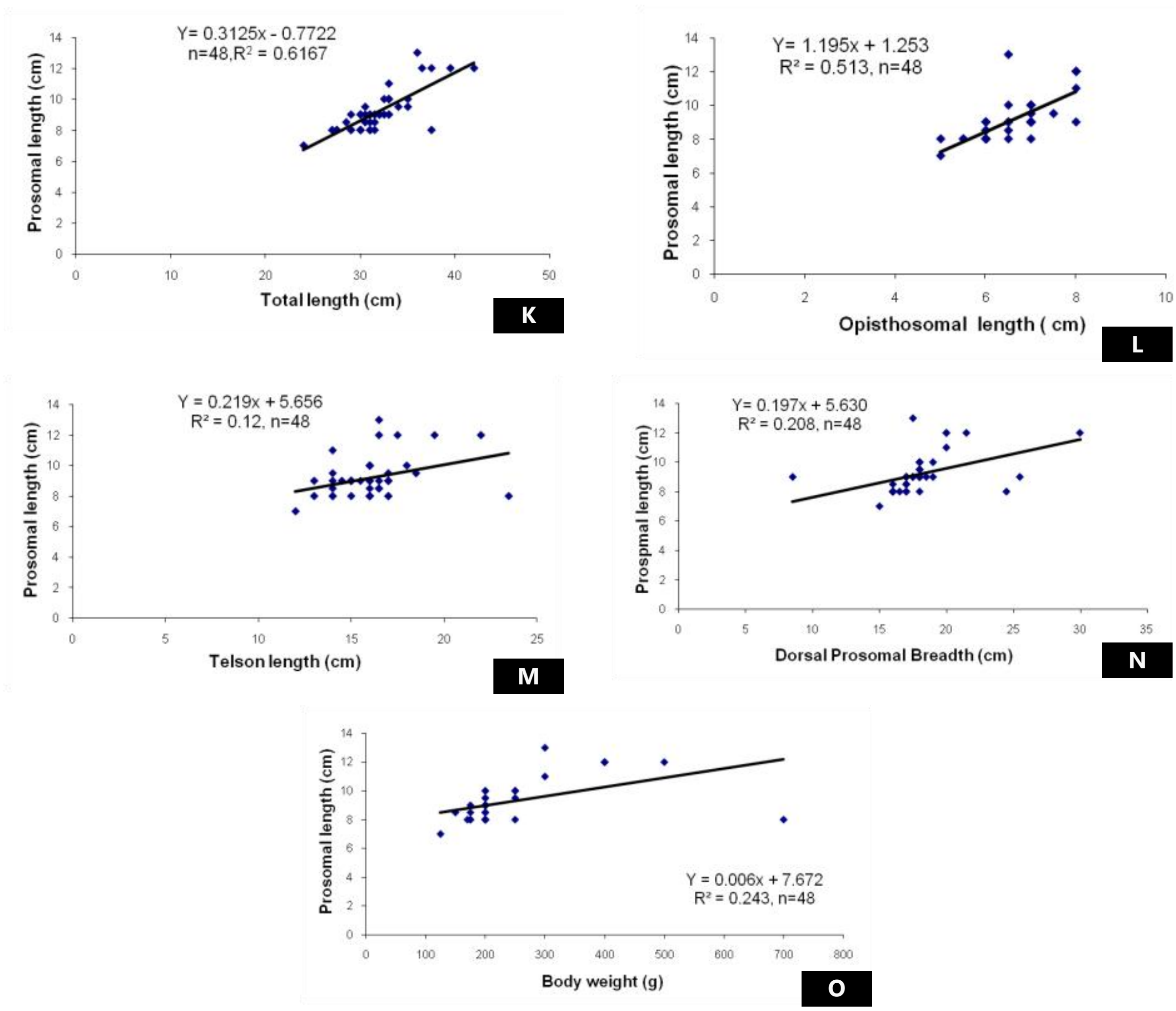

Figure 6. Regression relationship between (K) prosomal length with total length (L) prosomal length with opisthosomal length (M) prosomal length with telson length (N) prosomal length with dorsal prosomal breadth and (O) prosomal length with body weight of male population of *T. gigas* (n=48) found on the Balasore coast of Bay of Bengal.

parts. However, we also carried out a relationship between the prosomal length and prosomal width and the weight of the body of the gravid females. The intension in the later case was to know relate animal size with the egg number and in the case of former, the intention was to get an average picture of the animals morphometry visiting the Balasore coast of Bay of Bengal. The increase in body weight was associated with carapace length and width with almost equal degree of correlation. Vijaykumar *et al.* (2000) have found a high degree of correlation (r=0.87) between carapace length with the total length.[15] According to them, carapace length increases proportionally with the gradual increase of the total length. Similar relation was also observed with the carapace width with the advancement of total length. Telson length to the total length relationship also indicated proportional increase. The body weight to total length relationship was also linear. However, the rate of body weight increase was of higher magnitude than that of the total length. Some reports have been made in comparing the size variation between *T. gigas* that are present in East Bangladesh with that of West Bengal Bay, Orissa and other neighbouring places. The *T. gigas* of East Bangladesh, that is, East Bengal Bay has no different characteristics from the *T. gigas* of West Bengal Bay. Although the body sizes of *Tachypleus gigas* of West Bengal Bay are a little smaller than the East Bengal Bay, and the marginal spines of *T. gigas* of West Bengal Bay are relatively longer than those of the East Bengal Bay. It appears that the energy gained by *T. gigas* from ingested food gets evenly distributed in the body building process. Telson length to the total length relationship indicated a linear relationship and the observed proportional increase suggest an uniform body dimensions with the advancement of growth. The ratio of carapace width length increasing with the increase in age of horseshoe crab, suggest that as the animals grow older, they become wider and many a times carapace width exceeds carapace length. The changes in body dimensions of *T. gigas* indicate that the relationship could indirectly be influenced by population density, feeding efficiency, food availability and local environmental conditions. This study also suggests that the allometric relationship in *T. gigas* play an important role in understanding comparative morphometry.

The frequency distribution based on the carapace width (dorsal prosomal breadth, DPB) at three different sites during the survey period revealed that no crab below 12 cm carapace width came ashore for spawning during the survey period. A very small proportion of the crab (0.77 -1.45%) was noticed at 12 cm DPB in all the sites. A majority of the crabs (17.69-20.0%) of the crab population was found in 22-23 cm DPB class which revealed that all the crabs were of medium to large-sized ones.

ACKNOWLEDGEMENTS

The first author (ACS) wishes to thank the Principal, Belavoomi Mahavidyalaya, Avana, Balasore for providing necessary facilities to carry out this work. Fishermen of the site provided valuable information used in this paper.

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