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VARIABILITIES IN DIFFERENT BODY MEASUREMENTS OF THE HORSESHOE CRAB, *CARCINOSCORPIUS ROTUNDICAUDA* (LATREILLE) COLLECTED FROM SETIU AND GELANG PATAH HABITATS IN PENINSULAR MALAYSIA

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Comparisons of the body weight of two populations of *Carcinoscorpius rotundicauda* (Latreille) showed that the body weight of the crabs collected from Setiu was greater (males=145+18.06 gm; females=250+13.79 gm) than the crabs collected from Gelang Patah (males=126+18.25 gm; females=170+21.79 gm). Regression coefficients (b-value) differed significantly among groups and ranged from 0.41 (females of Setiu) to 2.93 (males of Gelang Patah). Length-weight relationship did not follow isometric growth except the total length and body weight relationship of males of Gelang Patah population. Maximum growth in weight was recorded for males from Setiu population where the increment in weight was found to be double as compared to the increment in total length (b=2.12). Maximum regression coefficient values were recorded in males of Gelang Patah population (b=2.93) which showed that the increment in body weight was greater than increment in carapace width confirming a significant relationship. Relationships between total lengths and carapace length and width with body weight for females from Setiu population showed isometric growth.

Key words: Variabilities, body measurements, horseshoe crab, *Carcinoscorpius rotundicauda*, Peninsular Malaysia

INTRODUCTION

Marine organisms in more stable environments show isometric growth which helps these organisms to adapt to a functional equilibrium of their body parts (Bas 1964). Geographically widespread marine organisms can experience variation in both environmental and anthropogenic impacts across their ranges that can differentially influence the expression of life history traits and population dynamics in different populations (Chatterji 1994). Several reports show that the size of an individual of the same species significantly changes with change in the environmental conditions where osmotic stress conditions play an important role on the normal physiology of the animals (Tarnowska *et al.* 2009). The study of morphological variations of marine organisms inhabiting different areas of their ranges is one of the directions of investigation for taxonomic diagnostic criteria.

Carcinoscorpius rotundicauda (Latreille), a eurytopic species, is adapted to extreme environmental conditions, like the low salinity or the extremely high summer temperatures of the sea. They belong to the benthic community and prefer calm sea or an estuary with muddy sand bottom (Grant 1984; Kelsey and Hassall 1989). Most of the biogenic activities of the horseshoe crab occur in the open ocean. The Asian species of horseshoe crab migrate towards the shore throughout the year to breed (Chatterji 1994). Although detailed information on the complete life cycle of the animal is not yet known, it is generally believed that the animal inhabits the littoral zone of the sea, for most part of its life. Among four extant species of horseshoe crab, *C. rotundicauda* has been reported to thrive well in low saline areas and as such considered to be a mangrove species (Mikkelsen 1988; Chatterji 1994).

Although ample data regarding the morphometric characteristics of *C. rotundicauda* have been published (Chatterji *et al.* 1988), there is no information available in literature regarding the hypothesis of environment-mediated morphometric changes in populations of this species collected from different habitats. The objective of this study was to analyze possible morphometric variations, including length and weight relationships, among populations of the horseshoe crab, *C. rotundicauda* (Latreille) collected from two different environments, namely Setiu (Terengganu) and Gelang Patah (Johor) in Peninsular Malaysia, to demonstrate the effects of different ecological habitats on the growth of the animal.

MATERIAL AND METHODS

Live horseshoe crabs, *C. rotundicauda* (Latreille) were collected along the eastern coast of Peninsular Malaysia at Setiu (Terengganu) (5° 42' 60" N; 102° 42' 0" E) and western coast at Gelang Patah (Johor) (1° 21' 4" N; 103° 32' 33" E) during November 2008 and June 2009 (Fig. 1). The salinity

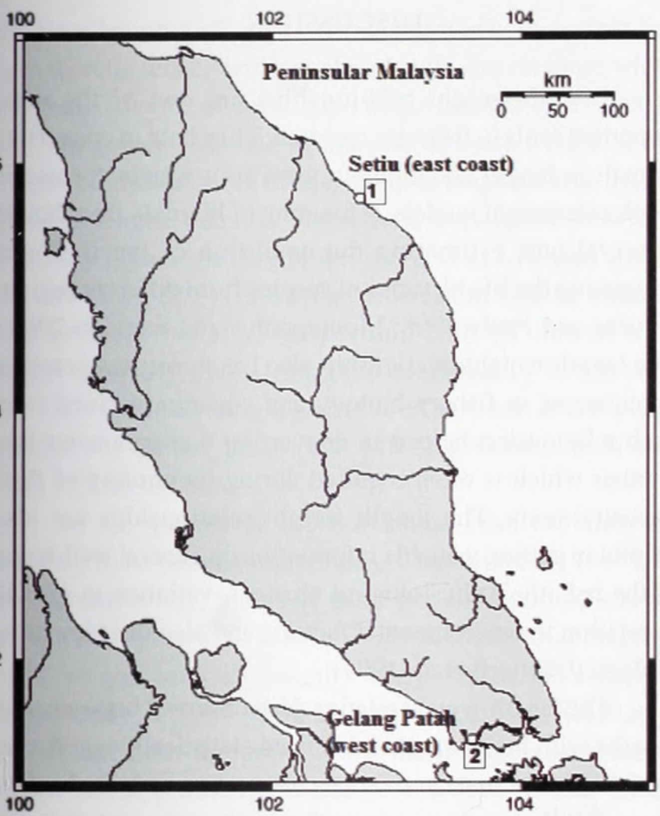

Fig. 1: Locations of the sampling sites: (1) Setiu and (2) Gelang Patah, Johor

of Setiu was within a range of 20-25 ppt, whereas that of Gelang Patah is 31-33 ppt during November to June (Zaleha *et al.* 2006). Samples were collected with the help of local fishermen using gill nets 25 m long and 6 m wide, with 10 mm mesh size. All collected crabs were brought to the laboratory and kept in two separate fibreglass tanks of 5,000 litre capacity provided with continuous circulation of seawater. Total length (tip of the carapace to tip of the telson), carapace length, carapace width and telson length of each specimen were recorded to the nearest millimetre using Vernier Callipers. Weights of the specimens were determined to 0.1 gm on a monopan balance (electronic). Horseshoe crabs were then grouped according to sex and sample location.

Length and weight data were analysed according to the method of LeCren (1951) and Chatterji (1976), log transformed and the regression of log length to weight calculated by least square method. The equation $ln\mathrm{W} = ln\mathrm{a} + \mathrm{b}\, ln\mathrm{L}$ was calculated separately for each group and a straight line was fitted to scatter diagram using SPSS 11.5 version software. Covariance Analysis (Chatterji 1976) was used to describe differences, if any, in the regression of *ln* weight on *ln* total length, *ln* carapace length, *ln* carapace width and *ln* telson length of the two populations of the horseshoe crab.

After logarithmic transformation of the data, slopes of the regression lines between body weight (BW) on total length, carapace length, carapace width and telson length

Table 1: Mean of different body measurements of the horseshoe crab collected from two different habitats

Parameters	Setiu		Gelang Patah	
	Males	Females	Males	Females
Total length	307 ±16.41	313 ±30.52	277 ±16.89	307 ±15.92
Carapace length	139 ±8.39	169 ±5.47	136 ±5.82	153 ±10.23
Carapace width	150 ±8.03	173 ±6.70	148 ±6.58	159 ±7.01
Telson length	178 ±9.64	188 ±4.55	149 ±10.96	163 ±13.01
Body weight	145 ±18.06	250 ±13.79	126 ±18.25	170 ±21.79

taken as an independent variable and expressed as $ln\mathrm{W} = ln\ \mathrm{a} + \mathrm{b}\ ln\mathrm{L}$. The comparison between slopes was carried out by means of ANOVA ($P < 0.05$). Two tests among the samples of each period were made: (1) slope comparisons between different morphometric relationships with weight to identify possible differences in time, and (2) test of allometry to observe the type of allometry and the changes that could have taken place in two populations. The significance of all regressions was tested by ANOVA, being significant for $P < 0.05$ (Sokal and Rohlf 1979).

RESULTS

Total sample size of the horseshoe crab was 308 from Setiu, ranging from 270 to 333 mm in total length and 112-178 gm in weight for males (N=133), and 241 to 389 mm in length and 225-356 gm in weight for females (N=175). Total sample size was 318 crabs from Gelang Patah ranging from 229 to 323 mm in length and 83-200 gm in weight for males (N=140), and 280 to 352 mm in length and 137-222 gm in weight for females (N=178).

In the Setiu crab population mean body weights were greater in males (145 ±18.06 gm) and females (250 ±13.79 gm) than crabs collected from Gelang Patah (males=126 ±18.25 gm; females=170 ±21.79 gm) (Fig. 2). Other measurements like total length, carapace length, carapace width and telson length in both sexes of Setiu population also showed relatively higher values as compared to crabs of Gelang Patah (Table 1).

A summary of the regression analysis between the body weights with different body measurements along with their test of significances of Setiu and Gelang Patah populations are presented in Table 2. Regression coefficients (b-values) differed significantly among groups and ranged from 0.41

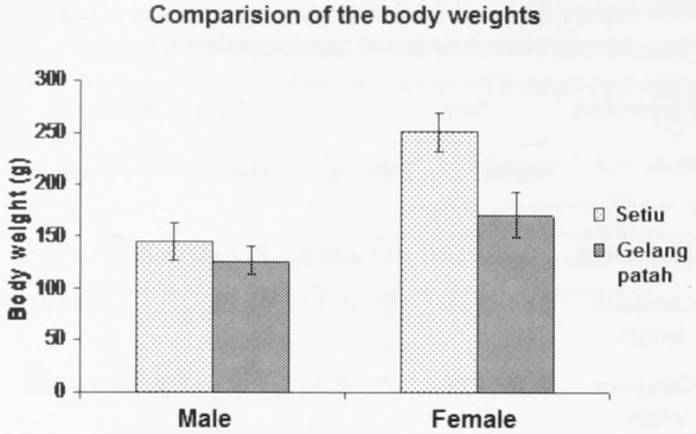

Fig. 2: A comparison of the body weights of the two populations collected from Setiu and Gelang Patah (Johor)

(females of Setiu) to 1.84 (females of Gelang Patah). b-values calculated for each group separately indicated deviance from isometric growth except for the total length and body weight relationships of males of Gelang Patah (r=0.90) (Table 2).

Logarithmic transformation of these data presented in Table 2 yielded a straight line and represented the calculated regression line. Maximum growth in weight was recorded in females of Setiu population where the increment in body weight was double as compared to the increment in total length (b=2.12) (Table 2). Maximum value of 'b' (2.93) recorded for the body weight-carapace width relationship in males of Gelang Patah population which showed that the increment in body weight was more than the increment in carapace width with high significance level. Regression analysis for other relationships showed that the growth in body weight with remaining parameters were isometric. In all crabs collected from Gelang Patah, the b-values were higher except for the body weight and telson length relationship of males of Setiu (Table 2) that showed that in Gelang Patah population the growth of all body measurements were relatively of lower magnitude.

DISCUSSION

Length-weight relationships are one of the most important tools in fisheries research. They help in converting growth-in-length equations to growth-in-weight for use in stock assessment models, estimating of biomass from length observations, estimating the condition of the fish, and comparing the life histories of species from different regions (Froese and Pauly 1998; Moutopoulos and Stergiou 2000). The length-weight relationship also has numerous practical applications in fishery biology and equation derived from such relationship helped in converting one parameter into another which is often required during monitoring of field measurements. The length-weight relationships are also helpful in getting valuable information on general well-being of the fish, their physiological changes, variation in growth in relation to environmental factors, and also their breeding biology (Chatterji *et al.* 1994).

The length-weight relationships observed between total lengths with body weight have been statistically significant ($p<0.05$) in the male and female Horseshoe crab *Tachypleus gigas* (Müller) collected from the north-east coast of India. In females, an increase in weight was isometric (Vijayakumar *et al.* 2000). The body weight – total length relationship in *T. gigas* was observed to be linear where the increase in the body weight was of higher magnitude than that of total length of the animals (Vijayakumar *et al.* 2000). In *T. gigas*, the body weight increased very sharply within the length range of 300-400 mm. The body weight – carapace length relationship shows a sharp increase in body weight, whereas the carapace length increases marginally in the specimens within the size from 100-200 mm with a linear relationship (Vijayakumar *et al.* 2000). Vijayakumar *et al.* (2000) further reported that the body weight – carapace width relationship in *T. gigas* was same as in the case of body weight and

Table 2: Regression analysis of different relationships along with their test of significance

Sex	Habitat	BW:TL	BW:CL	BW:CW	BW:Tel
Male	Setiu	*ln*Y= -3.12+2.12 *ln*X (r=0.81)	*ln*Y= -1.60+1.75 *ln*X (r=0.68)	*ln*Y= -2.44+2.11 *ln*X (r=0.80)	*ln*Y= -2.31+1.99 *ln*X (r=0.73)
	Gelang Patah	*ln*Y= -3.36+ 2.23 *ln*X (r=0.90)	*ln*Y= -4.04+2.88 *ln*X (r=0.71)	*ln*Y= -4.26+2.93 *ln*X (r=0.80)	*ln*Y= -1.82+1.81 *ln*X (r=0.86)
Female	Setiu	*ln*Y= 1.38+0.41 *ln*X (r=0.60)	*ln*Y= 0.38+0.91 *ln*X (r=0.30)	*ln*Y= 0.77+0.73 *ln*X (r=0.27)	*ln*Y= 0.97+0.63 *ln*X (r=0.08)
	Gelang Patah	*ln*Y= -2.36+1.84 *ln*X (r=0.57)	*ln*Y= -0.55+1.27 *ln*X (r=0.46)	*ln*Y= -2.31+2.06 *ln*X (r=0.53)	*ln*Y= -0.23+1.11 *ln*X (r=0.47)

TL=Total Length; CL=Carapace Length; CW=Carapace Width; Tel=Telson Length; BW=Body Weight carapace length. In *T. gigas*, the increase in body weight has been directly related with carapace length and carapace width with equal degree of correlation (Vijayakumar *et al.* 2000).

In general, the rate of increase of body weight in the present study was more or less of equal magnitude as that of the total length. Females in the Setiu population showed a relatively higher increase in weight (250 ±13.79 gm) within the size range of 241-3 89 mm, whereas in Gelang Patah it was lower (170 ±21.79 gm) within 280-352 mm of total length. Similarly, males from Setiu (size range: 270-333 mm) also showed higher weight gain (145 ±18.06 gm) as compared to males of Gelang Patah (126 ±18.25 gm) ranging in size from 229 to 323 mm.

In all species of the horseshoe crab females are reported to be heavier than males (Chatterji *et al.* 1994). In the present study, males of both populations had shown exponential growth as relationships between total length – body weight, carapace length – body weight and carapace width-body weight yielded smooth curves. Similarly, females of both the populations exhibited linear growth which could probably be due to increase in soft tissue specially ovaries where most of the energy was diverted for building up these organs resulting in slow growth of other body parts (Chatterji 1976).

Chatterji *et al.* (1988) reported that the weight of females *C. rotundicauda* collected from the Sunderbans area of West Bengal (India) showed relatively a lower weight gain as compared to males up to the size of 130 mm. It was higher in females after the size range of 130 mm as compared to males. The length-weight relationship data of females of *T. gigas* show that the weight of females increases gradually more than the cube of the carapace length whereas in males, the relationship did not follow the cube law (Chatterji *et al.* 1988). In juveniles of *Tachypleus tridentatus* and *C. rotundicauda*, prosomal width and wet weight were measured at weekly intervals to obtain growth data (Lee and Morton 2005). A positive allometric growth (b = 2.97) was estimated, which indicated that body weights gained by *T. tridentatus* and *C. rotundicauda*, were faster than the growth of prosomal width after each ecdysis.

The use of non-linear least-squares regression techniques for allometric modelling has been strongly supported by Zar (1968), and Hayes and Shonkwiler (1996). However, Xiao and Ramm (1994) concluded that the use of log-transformed data is appropriate for describing length-weight relationships in aquatic animals. In this study, the small sample sizes associated with several species are potentially problematic with respect to asymptotic variance properties of non-linear regression. Our choice of an allometric model was practiced as linear regression using log transformed data facilitated statistical comparisons of gender and habitat relationships, and allowed a single method to be applied to all specimens collected for the present study regardless of the sample size.

Fishing activities in Setiu has been increased dramatically in the last few years as compared to Gelang Patah. As a consequence of increase in the number of trawlers as well as gear size, and improvements in accompanying technology, the spawning grounds are continuously disturbed. This could be one of the reasons for shifting to an alternate breeding ground that might not be conducive to the species as such affecting the slower growth rate among new recruiting population of Gelang Patah.

There could be substantial physiological differences among the two populations of *C. rotundicauda* owing to individual acclimatization of the species or genetically fixed adaptations. As far as morphometric and physiological analyses are concerned, seasonal sampling appears to be insufficient for understanding the physiological performance of *C. rotundicauda* under different environmental conditions since there are probably also some short-term variations in these parameters. Therefore, monthly sampling to collect more information would be recommended in future studies.

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