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Research Article

MORPHOMETRIC ANALYSIS OF THE CRAB, *ATERGATIS INTEGERRIMUS* (LAMARCK, 1818) (DECAPODA, BRACHYURA, XANTHIDEA)

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ABSTRACT

The present paper envisages the relative growth of the xanthid crab, *Atergatis integerrimus,* collected (a sum of 256 crabs) from the benthic regions of Muttom. Allometry of the crabs were obtained for carapace length (CL) and width (CW), chelipede, propodus length (CPL), abdomen width in females (AW) and gonopod length (GL) in males. The size of the crabs (CW) ranged from 7-10.5 cm and 8.3-12.2 cm for males and females respectively. The AW grew in positive allometry: higher in juveniles (b=2.88) than adults (b=1.07). In males, the gonopod as well as the propodus length of the chelae showed positive allometry for juveniles while negative for adults. CPL vs CW demonstrated positive allometry to males and negative to females. The relationship between GL and CW based on the equation $Y = aX^b$, revealed that the males reached their sexual maturity ~7 cm for CW. The females arrived their sexual maturity at 8.3 cm based on the relationship of AW and CW.

Keywords: Morphometry, *Atergatis integerrimus*, Allometry, Brachyurans, Crustaceans, Relative Growth.

INTRODUCTION

Growth is a morphometric relationship which relates the dimensions of parts of the body or an organ to the entire animal (Rodriguez, 1985). In crustaceans, the dimensions of the animal's body grow as development progresses, resulting in the phenomenon known as the relative growth (Kardavani, 1995).Disparity in the growth pattern between sexes of the same species or among different species has biological significance (Fransozo *et al*., 2009). The unique relationship yields information on the healthiness or "well being" of the species within its surroundings, through the condition factor (Vazzoler, 1996; Jasmine, 2013).

The external morphological characters and changes in the body parts are generally applied to determine the sexual maturity in many decapods (Paul and Paul, 1990; Sainte-Marie *et al.*, 1995; Jasmine, 2013). The size at sexual maturity in crustacean is understood when there is morphological and physiological transformation, which leads to habit and/or behavioural changes (Mantelatto and Fransozo, 1996; Masunari and Dissenha, 2005). The size, maturity is a particular interest of the reproductive system in brachyurans, because they are morphologically diverse yet taxonomically very conservative, and thus provides valuable taxonomic and phylogenetic information (Lai *et al*., 2010; Padate *et al*., 2010; Guinot *et al*., 2013). Subject areas of relative growth and morphological sexual maturity of crab population is an important parameter for determining the reproductive potential and management of a population (Guerrero-Ocampo *et al*., 1998). Nevertheless, the morphometric analysis serves as a handy tool for both taxonomists and ecologists to investigate intra and interspecific morphological variations (Costa and Soares-Gomes, 2008) and also complements well with genetic and environmental stock identification methods (Cadrin, 2000).Among brachyurans, the carapace, chelipede, pleopods/gonopods and abdomen exhibit allometric changes in both the sexes, during their transition from juvenile to adult phases (Hartnoll, 1974).

The biology of *Atergatis integerrimus*, a xanthid crab is poorly studied on relative growth and sexual maturity of species of Xanthoidea. *A. integerrimus,* commonly called as red egg crab owing to red-coloured carapace. The chelipeds are smooth with spoon-shaped black tips.The present study aims to characterize the relative growth based on the degree of allometryand to determine the

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morphological sexual maturity of males and females of *A. integerrimus* based on the relationship of carapace length and width, cheliped propodus length, abdominal width (in females) and gonopod length (in males).

MATERIALS AND METHODS

The red egg crabs of*A. integerrimus*were collected from the benthic regions of Muttom (983'N; 7671'E), Tamil Nadu, India, using a fish net or clam baiting. Morphometric characters (Table1) such as carapace length (CL) and width (CW), cheliped propodus length (CPL), Gonopod length (GL) and abdomen width (AW) were assessed to the nearest 0.1mm, and 0.1cm using calipers and scales. Maturation stages (juvenile and adult) were identified by the vividness of the carapace and the size at which differential growth of the secondary sexual characters (gonopodium in males and abdomen in females). The dimensions used in the analysis are illustrated in Figure 3.1 to 3.5. Carapace width (CW)was taken as the distance between the lateral carapace margin. Carapace length (CL) was measured dorsally along the midline, between the frontal notch and the posterior margin of the carapace (Figure 3.1). The measurement of propodus length (CPL) was taken from the base of the propodus to the fixed dactylus of the Chela (Figure3.2) and gonopod length (GL) between the end of the distal part to the basal part (Figure 3.3). The maximum width across the second somite in male (Figure 3.4) and third somite in female (Figure 3.5) was considered as the abdominal width (AW).

Statistical Analysis

The student *t*-test was used to compare the biometric values between sexes ($\alpha = 0.05$) (Zar, 1996).The allometric growth in crustacean was determined by logarithmic transformation expressed as Y= log a + b log X. 'A' and 'b' was estimated by the linear regression where 'a' = Intercept of the regression curve and 'b' = Regression coefficient (Slope). The 'b' value represents as the relative growth constant (b = 1 means isometric growth; b > 1 means positive allometric growth; and b < 1 means negative allometric growth (Hartnoll, 1982; Tessier, 1960). The Fulton's condition factor was calculated according to Bagenal and Tesch (1978) and Gayanilo and Pauly (1997) with the formula.

$$K = 100W/L^3$$

Where, K = condition factor

W = Mean of body weight of the crab (GM)

L = Mean carapace length of the crab (mm)

3 = constant

RESULTS AND DISCUSSION

A sum of 296 crabs (140 males and 156 females) with CW ranging from 5.2–12.2 cm were collected (Table1). The sex ratio obtained for the total sampled *A. integerrimus* of juveniles was 1.1:1 and adult 0.6:1 (male:female).The candidate crab exhibits sexual dimorphism in size, with females: larger than males and this may be an adaptation to increase the production of eggs (Costa and Fransozo, 2004; Castilho *et al*., 2007). Sexual dimorphism, with males larger than females (Costa and Negreiros-Fransozo, 2003; Bede *et al*., 2008; Johnson, 2003; Benedetto and Masunari, 2009) and females larger than males (Johnson, 2003; Litulo, 2005; Castilho *et al.*, 2007; Semensato and Beneditto, 2008; Costa *et al*., 2010) was observed in several brachyuran crabs. Several researchers have suggested that the female bias generally the result of the common behaviour of reproductively active females as reported in *U. pugilator* (Colby and Fonseca, 1984), *Aratus pisonii* (Conde and Diaz, 1989) and *Macrophthalmus boscii* (Litulo, 2005).

Irrespective of sex, the juveniles of *A. integerrimus* have a distinct color pattern: the carapace is pale red in gloss with white bands on the brim and white markings along the front and central shield. As the animals reach maturity, the carapace turns out to be red colored with consistent distribution of white spots, however, the white band was missing in the margin. Such a variance in the color pattern has not been covered in any other marine crabs notwithstanding in the coastal crab, Cardisoma guanhumi (Gifford, 1962) and freshwater crab, *Travancoriana schirnerae* (Sudha Devi and Smija, 2015).We presume that the color may reduce the vulnerability from a diversity of predators in juveniles that may be borne out by the report of Hemmi *et al.* (2006), who detailed the colour variations in Uca vomeris in relation to their background and predation. Semi-terrestrial crabs display change in colour, pattern during growth (Detto *et al*., 2004), seasonality (Nakasone*et al.*,1983), stress (Crane, 1975) and endogenous rhythms (Palmer, 1995).

The CW of adult females (Mean ± SD; 9.86 ± 1.03) was statistically higher (CW: $t = 7.40$; $p< 0.05$) than the males (Mean ± SD; 8.55 ± 0.96) (Table 2). The relationship between CL and CW showed a positive increase in juveniles and negative in adults, regardless of their gender (Table 3).The CW has been broadly viewed as an independent variable in morphometric studies of Brachyura because it exhibits few morphological changes throughout the crab's life (Castiglioni and Negreiros-Fransozo, 2004; Araujo *et al*., 2012) due to latitude effect, food availability and habitat characteristics. The kinship between the CPL vs CW was positive in males (juveniles - b = 1.131, r^2 =

0.980; adults - b = 1.845, r^2 = 0.994) (Table 2,3) and juvenile females (b = 1.263, r^2 = 0.987) while the adult females were isometry (Figure 4.1, 4.2). Such a sexual difference in cheliped size is common with crabs, although the degree of sexual dimorphism varies (Abello *et al*., 1990; Lee, 1995; Razek *et al*., 2006), that favours a selective advantage in competition for mate, food or space (Hartnoll, 1982) and escape from predators (Koch *et al*., 2005).

The most distinct sexual dimorphic character of crabs is the shape and size of the abdomen of females, which serve as the brood chamber (Hartnoll, 1982). The abdomen was narrow and triangular and revealed an isometric relationship with adult males (b = 1.072) while positive in adult females (b = 1.655; t = 14.79) (Figure 4.3, 4.4). This fact corroborates with the previous studies on other brachyuran crabs(Negreiros-Fransozo *et al.* 2003; Benetti and Negreiros-Fransozo, 2004; Masunari and Dissenha, 2005; Jasmine, 2013). Probably, the juvenile females invest in their abdominal growth and will be ready to incubate the eggs once they reach the sexual maturity(Benetti and Negreiros-Fransozo, 2004; Masunari and Dissenha, 2005).

In *A. integerrimus*, when the abdomen reaches the basis of pereiopods coxae (maximum AW), the female is considered to be morphological mature (8.3 cm in CW). It has also been reported in other crabs namely *Chasmargnathus granulates* (Luppi *et al*., 2004), *Trapezia ferruginea* (Finney and Abele, 1981), *Eriphia gonagra* (Goes and Fransozo, 1997), *Eurytium limosun* (Guimaraes and Negreiros-Fransozo, 2002) and *Panopeus austrobesus* (Negreiros-Fransozo and Fransozo, 2003).

The abdomen of male brachyuran crabs stores, two pairs of gonopods, responsible for the transference of spermatophores during coitus (Hartnoll, 1982). Due to this simple function, particulary when compared to the functionality of the female's abdomen, the growth of the male's abdomen is allometrically negative or isometric in all ontogenetic phases (Fransozo *et al*., 2002; Benetti and Negreiros-Fransozo, 2004; Pralon and Negreiros-Fransozo, 2008).The regression coefficient between the relationship of GL and CW of juveniles (b = 1.24; t = 55.76)demonstrated a significant increase than the adult males(b= 0.162; t = 39.60) (Figure 4, 5) as observed by Negreiros-Fransozo *et al.* (2003), Castiglioni and Negreiros-Fransozo (2004) and Pralon and Negreiros-Fransozo (2008). Flores *et al*. (2002) assumed that the high positive allometric growth of the gonopods was due to the development of pleopods into functional gonopods.

The present work revealed the acquisition of morphological sexual maturity was the absence of white band along the brim of the red colored carapace (Figure 1, 2). The size at which the sexual maturity of male was commenced from 7 to 10.5 cm and 8.3 to 12.2 cm CW respectively.The size of the onset of sexual maturity and the number of instars following the puberty molt provide important information on the reproductive biology of brachyuran crabs (Pinheiro and Fransozo, 1998). This cognition is indispensable for managing commercially exploited populations (Campbell and Eagles, 1983).

The condition factor (cf) is named to as the K factor which indicates the state or overall wellbeing of the crab, *A. integerrimus*. The K values of male crabs was ranged from 21.69 to 233 and 22.2 to 275 for females (Table 4). The condition factor of the females was higher than the males and the carapace length was positively correlated with the weight of the species. The condition factor is strongly determined by the environmental factors, gonad development, feeding and growth rate, degree of parasitism of the (Atar and Secer, 2003; Pinheiro and Taddei, 2005; Araujo and Lira, 2012), nutritional aspects, stage of maturity and time of recruitment might also affect sexual differences of the condition factor (Froese, 2006; Pinheiro and Fiscarelli, 2001).

Table1. Minimum, mean, SD and maximum values in cm of the selected morphometrics of *Atergatis integerrimus.*

Phases	Juvenile male (N=80)		Juvenile female (N=86)		Adult male (N=60)		Adult female (N=70)	
	Min	Max	Min	Max	Min	Max	Min	Max
Cl	3.9	5.5	4.3	6.0	6.1	8.6	6.3	10.1
Cw	5.2	6.8	6.1	8.2	7.0	10.5	8.3	12.2
Cpl	2.4	4.1	2.0	4.2	3.7	5.5	2.1	5.8
Aw	1.3	3	2.3	4.3	2.1	5	3.9	6.0
Gl	0.3	1.5	-	-	1.6	2.6	-	-

N- Number of crabs.

Table 2. t- test analysis on the morphological variables of *Atergatis integerrimus*.

Phases	N	Sex	Mean±SD	DF	't' value
CW	80	JM	5.08 ± 0.43	164	5.65*
	86	JF	5.98 ± 0.49		
	60	AM	8.55 ± 0.96	128	4.40*
	70	AF	9.86 ± 1.03		
CL	80	JM	5.08 ± 0.43	164	3.93*
	86	JF	5.42 ± 0.66		
	60	AM	7.35 ± 0.77	128	2.68*
	70	AF	7.79 ± 1.04		
CPL	80	JM	3.20 ± 0.42	164	3.31*
	86	JF	2.91 ± 0.66		
	60	AM	4.57 ± 0.52	128	3.17*
	70	AF	3.67 ± 0.84		
AW	80	JM	2.08 ± 0.43	164	4.79*
	86	JF	3.23 ± 0.55		
	60	AM	3.40 ± 0.80	128	5.55*
	70	AF	4.84 ± 0.61		

JM: Juvenile Male; JF: Juvenile Female; AM: Adult male; AF: Adult Female; N: number of crabs.

*Significance at 0.05%.

Table 3. Results of Linear equation, Correlation coefficient (r^2), *t* - test and allometric level (Al) of *Atergatis integerrimus*.

Relation	Phase	N	Linear equation Log y = log a + b log x	r²	*t* test	SE	Al
CL vs CW	JM	78	LogCL = Log 0.343 + 1.111 LogCW	0.985	4.92*	0.02	+
	AM	70	LogCL = Log 0.012+ 0.980 LogCW	0.947	4.42*	0.02	_
	JF	56	LogCL = Log 1.150 + 1.127 LogCW	0.993	4.19*	0.01	+
	AF	92	LogCL = Log -2.314+ 0.970 LogCW	0.979	5.31*	0.02	_
CPL vs CW	JM	78	LogCPL = Log 2.942 + 1.131 LogCW	0.980	4.90*	0.01	+
	AM	70	LogCPL= Log 0.123 + 1.845 LogCW	0.994	4.72*	0.02	+
	JF	56	LogCPL = Log 2.762 + 1.263 LogCW	0.987	4.16*	0.02	+
	AF	92	LogCPL= Log 5.186 + 1.001 LogCW	0.999	5.46*	0.04	0
AW vs CW	JM	78	LogAW = Log 3.658 + 1.124 LogCW	0.990	4.96*	0.02	+
	AM	70	LogAW = Log 3.868 + 1.072 LogCW	0.956	4.48*	0.03	0
	JF	56	LogAW = Log 0.016 + 1.655 LogCW	0.983	4.14*	0.07	+
	AF	92	LogAW = Log 4.290 + 1.176 LogCW	0.979	5.31*	0.02	+
GL vs CW	JM	78	LogCW = Log 4.884 + 1.240 LogCW	0.988	4.95*	0.002	+
	AM	70	LogCW =Log 2.437 + 0.162 LogCW	0.979	4.62*	0.10	-

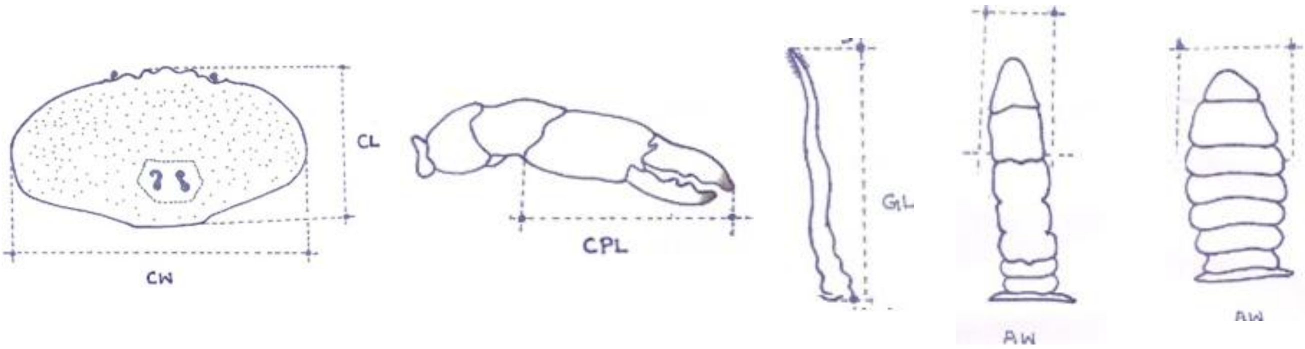
JM: Juvenile Male; JF: Juvenile Female; AM: Adult male; AF: Adult Female; n: Number of crabs; +: Positive allometry; -: Negative allometry; = ; Isometry,* - Significance at 0.05%.

Table4. Fulton's condition factor (K)of *Atergatis integerrimus.*

	Carapace length (cm)				Weight (g)		
Sex	No.	Mean	Min	Max	Mean	Min	Max
Male	131	5.5	3.5	8.6	118.6	28.2	209
Female	165	6.3	4.3	10.1	170	62.5	223.4
Total	296	7.28	3.9	9.3	144.3	45.3	216.2

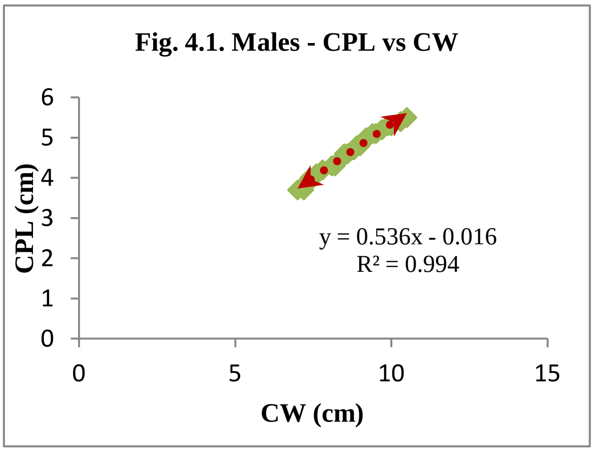
Figure 1. Juvenile - *Atergatis integerrimus*

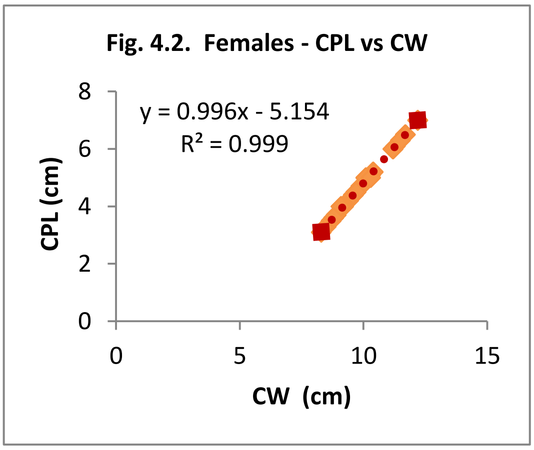
Figure 2. Adult - *Atergatis integerrimus*

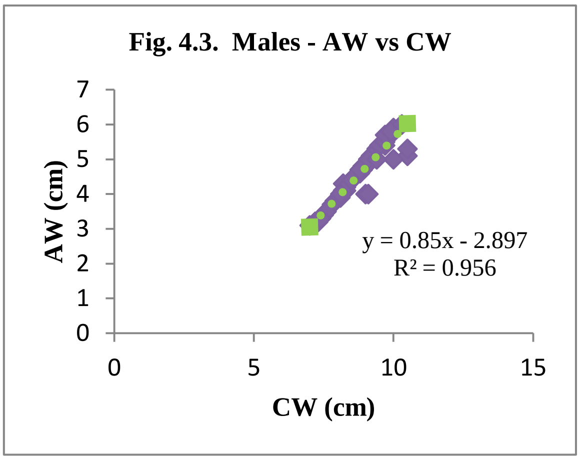


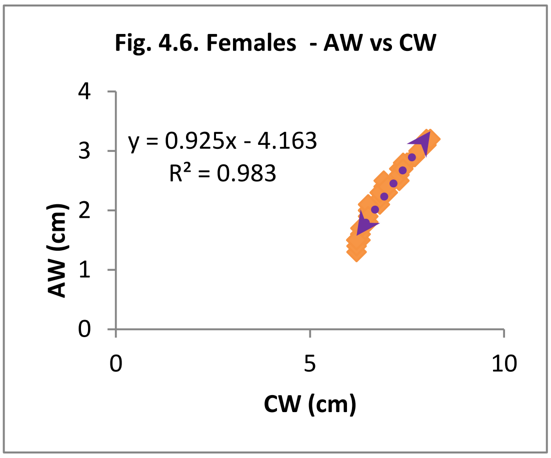
1	2	3	4	5
Carapace	Chela	Gonopod	Abdomen (M)	Abdomen (F)

Figure 3. Schematic drawings of a *Atergatis intigerrimus* illustrating morphological variables measured in the Carapace (1), Chela (2), Gonopod (3) and Abdomen (4) of Male (4) and Female(5) of the specimens (CL=Carapace Length,CW=Carapace Width, CPL=Chelar Prduct Length, CL= Chela Length, AW=Abdomen Width).









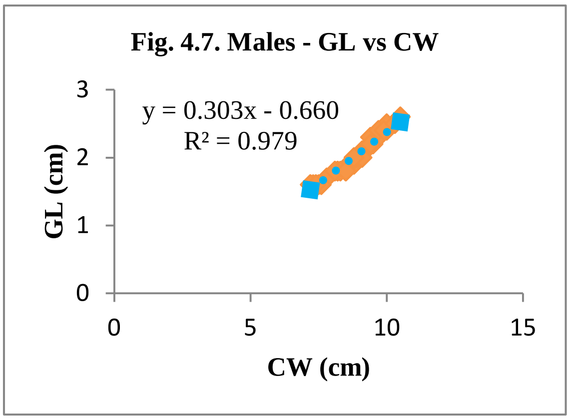


Figure 4. Scatter plot between representing the allometry of adult *A. integerrimus.*

CONCLUSIONS

To close, the morphological and sexual maturity of*A. integerrimus* would be evaluated by observing the colour patterns of the carapace, the propodus length in males and abdominal width in females.

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