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Relative Growth and Sexual Maturity of the Stone Crab *Menippe nodifrons* Stimpson, 1859 (Brachyura, Xanthoidea) in Southeastern Brazil

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ABSTRACT

The relative growth and size at onset of morphological sexual maturity of the stone crab Menippe nodifrons *were investigated. A total of 399 crabs was captured on Praia Grande and Tenório beaches at Ubatuba. Carapace width (CW) and length, cheliped propodus length and height, abdomen width in females, and gonopod length in males were recorded. In females, the abdominal width showed negative allometry for juveniles and positive allometry for adults; the puberty molt occurred at 31.6 mm CW. In males, the size at onset of morphological sexual maturity was estimated as 29.7 mm CW; the gonopod growth showed positive allometry for juveniles, and an isometric relationship for adults. The gonopod length and the abdominal width were the most appropriate morphometric variables to estimate size at onset of sexual maturity in this stone crab.*

Key words: Growth, Sexual Maturity, *Menippe*, Xanthoidea

INTRODUCTION

Stone crabs of the genus *Menippe* occur in tropical and subtropical regions. They support important fisheries in the United States, Mexico and Cuba (Ehrhardt, 1990). In many localities, only their claws are widely sold; the animals are returned to their environment, where they are later recaptured. The biology, life history, and fisheries of stone crabs have been investigated mainly for *Menippe mercenaria* (Say, 1818) and *M. adina* Williams and Felder, 1986, which grow large and are widely exploited commercially (Simonson and Steele, 1981, Wilber, 1989, Ehrhardt, 1990, Landry, 1992, Caldwell, 1992, Stuck and Perry, 1992). Only one species of this genus, *M. nodifrons* Stimpson, 1859, occurs along the coast of Brazil. According to Oshiro (1999), *M. nodifrons* is little exploited commercially, probably because it is smaller than the North American species. Therefore, it is caught only by a few tourists and amateur fishermen.

Studies of relative growth and morphological sexual maturity are important parameters for determining the reproductive potential of a species, and for the management of populations of commercial interest (Campbell and Eagles, 1983; Guerrero-Ocampo et al., 1998). Certain species of xanthoid crabs have been investigated in relation to these subjects, notably by Caldwell (1992) with *M. mercenaria*; Finney and Abele (1981) with

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Trapezia ferruginea Latreille, 1828; Huber (1985) with *Trapezia ferruginea, T. corallina* Gerstaecker, 1857 and *T. formosa* Smith, 1869; Vannini and Gherardi (1988) with *Eriphia smithi* MacLeay, 1838; Góes and Fransozo (1997) with *Eriphia gonagra* (Fabricius, 1781) and Guimarães and Negreiros-Fransozo (2002) with *Eurytium limosum* (Say, 1818).

Knowledge of the biology of *M. nodifrons* is limited to studies of its larval development by Scotto (1979), juvenile development and population biology and habitat utilization by Fransozo et al. (1988 and 1999) and aspects of its reproduction by Oshiro (1999). Further investigations may elucidate fundamental questions regarding the life history of this stone crab and may make possible its commercial exploitation. The goal of this study was to analyze the relative growth of *M. nodifrons*, focusing on the morphometric relationships between the carapace width and the dimensions of certain appendages. Also, the transition intervals between the immature and mature growth phases in allometric relationships were assessed, in order to estimate the size at onset of morphological maturity.

MATERIAL AND METHODS

Crabs were collected manually from 1997 to 1999, during low tide, on the rocky shores of Praia Grande and Tenório beaches in Ubatuba, state of São Paulo, southeastern Brazil. Body dimensions were measured with a caliper to the nearest 0.01 mm. The following dimensions were selected for morphometric analyses: carapace width (CW), carapace length (CL), left cheliped propodus length (LPL) and height (LPH), right cheliped propodus length (RPL) and height (RPH), abdomen width (AW) of the fifth somite in females, and gonopod length (GL) (the exopodite of the first pair of pleopods) in males. The relative frequency of adults (%) in each size class was plotted on a graph, which was fitted as a sigmoid curve following the result of the logarithmic equation $y = \frac{1}{1+e^{r(CW-CW50)}}$, where CW_{50} = carapace width at which 50% of the individuals reach sexual maturity, and r = slope of the curve. The adjusted equation was fitted by the least-squares regression method (Vazzoler, 1996).

Carapace width was considered the independent variable, and the allometric equation $Y = a.x^b$ for each sex and maturation phase was calculated using the least-squares regression method (Hartnoll, 1982). The values of b define the type of allometry (b = 1: isometry; b < 1: negative allometry; b > 1: positive allometry). Departures from isometry (H_o: b = 1) were tested using Student's t-test on the slope values obtained (α = 0.05). An analysis of covariance (ANCOVA) was performed to compare slopes and intercepts of the regressions obtained within each allometric relationship (Zar, 1996).

RESULTS

A total of 399 specimens of *M. nodifrons* was captured during the study period. Their sizes ranged from 5.0 to 69.6 mm CW for males (N = 195), and from 3.6 to 82.5 mm CW for females (N = 204). The size at which 50% of the population was morphologically mature is shown in Fig. 1. The estimated sizes at onset of sexual maturity were 29.7 and 31.6 mm CW for males and females, respectively.

All of the relationships, numbers of specimens analyzed, and linearized allometric expressions followed by the power functions, the r^2 values, and the allometric level of each relationship are given in Table I. The overall CL to CW ratio was 0.70. The CL *vs.* CW regression plotted for all individuals indicated isometric growth between these variables. Because the intercepts and slopes of a given allometric relationship did not differ between males and females, a single regression line could be fitted for both sexes combined (Table I). For the regression calculated for the male chelipeds, the only difference in relative growth was observed in the LPH *vs.* CW relationship, in which the juveniles showed isometric growth (b = 1.02), and the adults showed positive allometric growth (b = 1.23) (Fig. 2).

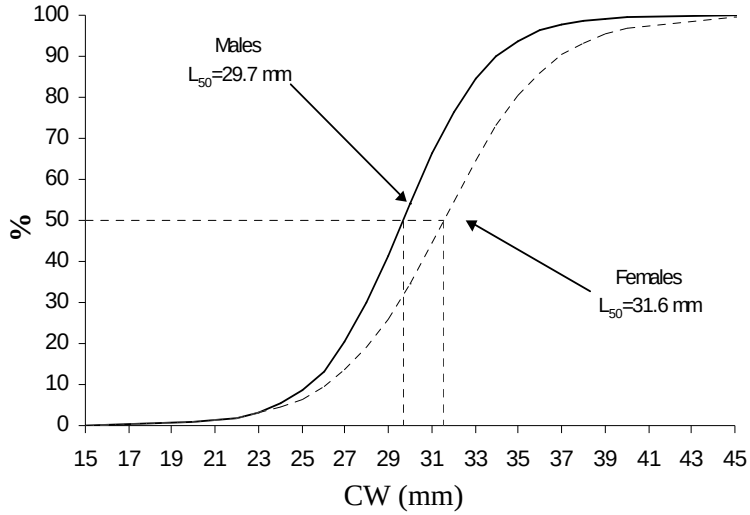

Figure 1 - *Menippe nodifrons*. Logarithmic curve between the carapace width (CW) and percentage of adults, for males and females.

Table 1 - Relationships between morphometric parameters and carapace width in *Menippe nodifrons* by means the allometric technique.

Variables	Group	N	Equation $Y = a.x^b$	Linear transformation lny = lna + b.lnx	r^2	Allometry level*
CL	Total	399	$CL = 0.757.CW^{0.98}$	lnCL = -0.278 + 0.98lnCW	0.99	=
	TM	195	$CL = 0.754.CW^{0.98}$	lnCL = -0.282 + 0.98lnCW	0.99	=
	TF	204	$CL = 0.757.CW^{0.98}$	lnCL = -0.278 + 0.98 lnCW	0.99	=
RPL	TM	170	$RPL = 0.699.CW^{1.02}$	lnRPL = -0.358 + 1.02 lnCW	0.98	+
	JF	95	$RPL = 0.829.CW^{0.95}$	lnRPL = -0.188 + 0.95 lnCW	0.96	-
	AF	74	$RPL = 0.475.CW^{1.12}$	lnRPL = -0.744 + 1.12 lnCW	0.89	+
RPH	TM	173	$RPH = 0.377.CW^{0.99}$	lnRPH = -0.975 + 0.99 lnCW	0.97	=
	JF	97	$RPH = 0.424.CW^{0.95}$	lnRPH = -0.857 + 0.95 lnCW	0.95	-
	AF	69	$RPH = 0.183.CW^{1.18}$	lnRPH = -1.7 + 1.18 lnCW	0.87	+
LPL	TM	154	$LPL = 0.569.CW^{1.07}$	lnLPL = -0.564 + 1.07 lnCW	0.98	+
	TF	162	$LPL = 0.639.CW^{1.03}$	lnLPL = -0.448 + 1.03 lnCW	0.99	+
LPH	JM	120	$LPH = 0.313.CW^{1.02}$	lnLPH = -1.162 + 1.02 lnCW	0.96	=
	AM	27	$LPH = 0.152.CW^{1.23}$	lnLPH = -1.880 + 1.23 lnCW	0.88	+
	TF	166	$LPH = 0.319.CW^{1.02}$	lnLPH = -1.142 + 1.02 lnCW	0.98	+
GL	JM	86	$GL = 0.039.CW^{1.63}$	lnGL = -3.244 + 1.63 lnCW	0.92	+
	AM	42	$GL = 0.397.CW^{0.94}$	lnGL = -0.924 + 0,94 lnCW	0.93	=
AW	JF	117	$AW = 0.231.CW^{0.95}$	lnAW = -1.465 + 0.95 lnCW	0.93	-
	AF	84	$AW = 0.047.CW^{1.47}$	lnAW = -3.048 + 1.47 lnCW	0.92	+

* *t* test; $p<0.05$

(N = number of individuals; TM = total males; JM = juvenile males; AM = adult males; TF = total females; JF = juvenile females; AF = adult females; r^2 = determination coefficient; CL = carapace length; RPL = right cheliped propodus length; RPH = right chelar propodus height; LPL = left cheliped propodus length; LPH = left cheliped propodus height; GL = gonopod length; AW = abdomen width).

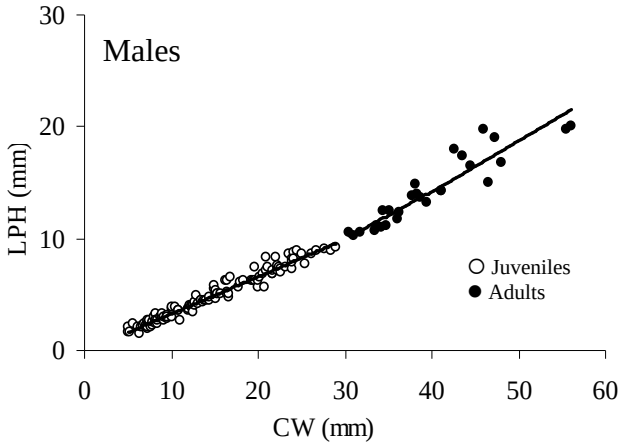

Figure 2 - *Menippe nodifrons.* Scatter plot between the carapace width (CW) and left cheliped propodus height (LPH) in males.

For females, the regression calculated for the right propodus (RPL *vs.* CW and RPH *vs.* CW) indicated two statistically different regression lines between the maturation phases ($p < 0.05$). There was negative allometric growth in the early phase, and positive allometric growth in the adult phase (Figs. 3, 4).

The relationships which best indicated the change in the allometric coefficient between juveniles and adults were AW *vs.* CW for females (Fig. 5) and GL *vs.* CW for males (Fig. 6). These regressions were statistically different between the maturation phases. Males showed positive allometric growth during the juvenile phase, and isometry during the adult phase. Females showed negative allometric growth during the juvenile phase, and positive allometric growth after the puberty molt.

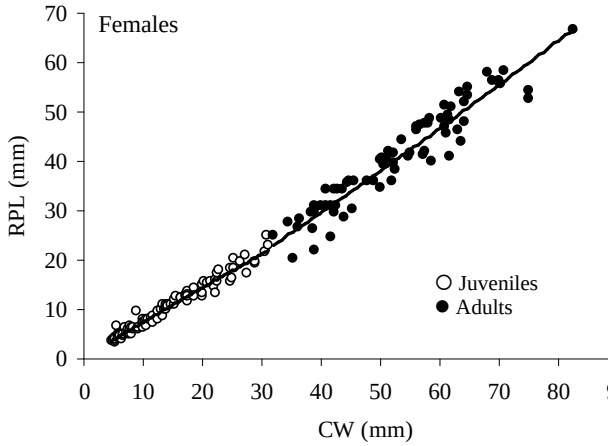

Figure 3 - *Menippe nodifrons.* Scatter plot between the carapace width (CW) and right cheliped propodus length (RPL) in females.

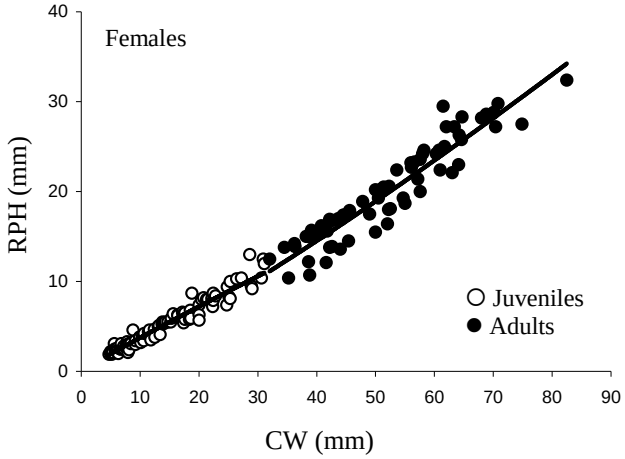

Figure 4 - *Menippe nodifrons.* Scatter plot between the carapace width (CW) and right cheliped propodus height (RPH) in females.

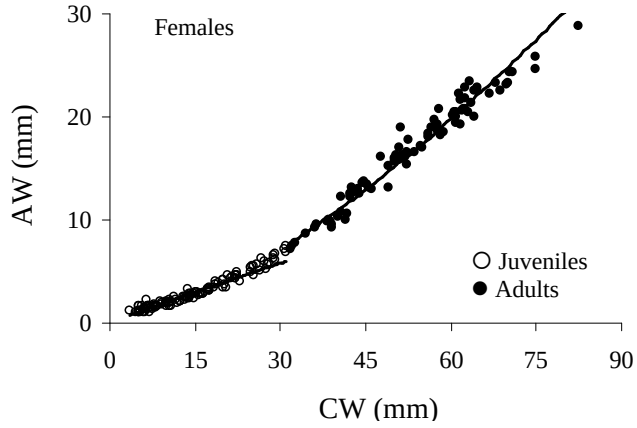

Figure 5 - *Menippe nodifrons*. Scatter plot between the carapace width (CW) and abdomen width (AW) in females.

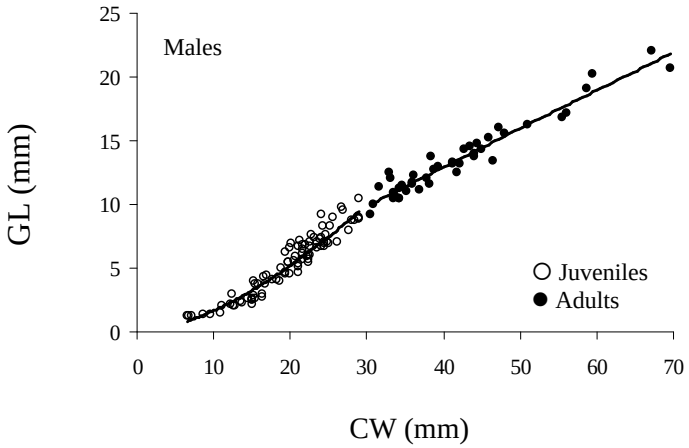

Figure 6 - *Menippe nodifrons.* Scatter plot between the carapace width (CW) and gonopod length (GL) in males.

DISCUSSION

The size at 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 knowledge is essential for managing commercially exploited populations (Campbell and Eagles, 1983). In general, when two dimensions of the carapace of brachyurans are correlated, growth tends to be isometric during ontogeny, and does not change much with the molt to puberty. However, Fransozo et al. (1988) found that in *M. nodifrons* there were variations in the length-width proportions of the carapace up to juvenile stage V, which coincides with the appearance of secondary sex characters, and only after this instar these proportions stabilize with the length about 70% of the width. This variation in the CL/CW proportion also occurred in the juvenile stages of other xanthoids, as observed by Fransozo and Negreiros-Fransozo (1987) in *Eriphia gonagra* and *Eurypanopeus abbreviatus* (Stimpson, 1860). Savage and Sullivan (1978) in Florida and Caldwell (1992) in South Carolina also observed that the carapace length was proportionally longer than the carapace width in *M. mercenaria*.

In the males of *M. nodifrons*, the relationships of the chelipeds were not good indicators of the molt to puberty. This was also found for other xanthoids by Góes and Fransozo (1997) with *Eriphia gonagra*, and by Guimarães and Negreiros-Fransozo (2002) with *Eurytium limosum*. However, most of the relationships showed positive allometric growth, indicating that these structures had an important role in agonistic behaviors. As described by Porter (1960), the males of *M. mercenaria* used their chelipeds to protect the entrances of holes occupied by pre-molt females, prior to copulation. Savage and Sullivan (1978) also found that the propodus length of *M. mercenaria* showed positive allometric growth, so that the propodi of adult males were proportionately larger than those of females. Caldwell (1992) found similar results for this species, and noted that because of this difference, the males could be harvested commercially at a smaller carapace width than the females.

Among xanthoids, this sexual dimorphism may be greatly accentuated, as occurs in *Eriphia smithi*, in which the presence of a powerful chela is related to the conquest and defense of suitable burrows. The number of these burrows, especially copulatory burrows, may be a limiting factor on the rocky shores where this species lives (Vaninni, 1987; Vaninni and Gherardi, 1988).

The regression analysis CW *vs.* GL for *M. nodifrons* indicated positive allometric growth during the juvenile phase. With the passage to the adult phase, growth was isometric. This result is similar to observations by Hartnoll (1965) for *Aratus pisonii* (H. Milne Edwards, 1837) and by Góes and Fransozo (1997) for *Eriphia gonagra*. In other species, the positive allometric relationship only decreased slightly, as observed by Vannini and Gherardi (1988) for *Eriphia smithi*, by Cobo and Fransozo (1998) for *Goniopsis cruentata* (Latreille, 1803), and by Fransozo et al. (2002) for *Ocypode quadrata* (Fabricius, 1787). Guimarães and Negreiros-Fransozo (2002) established that gonopod growth in *Eurytium limosum* passed from positively allometric in the juvenile phase, to negative in the adults.

This differential growth of the male gonopod is related to the ability of these individuals to copulate successfully (Hartnoll, 1974). The decrease in growth at the puberty molt may be adaptive, allowing males to copulate with females of a wide range of sizes. However, in this species, no standardization (*sensu* Hartnoll, 1965, 1972) was observed. This suggested that the remarkable positive allometry in the juvenile phase of *M. nodifrons* could confer an advantage, in that males could reach sexual maturity at a smaller size than could females, allowing them to compete successfully with other males to copulate with the mature females.

The ontogenic changes in the abdomen width of females of *M. nodifrons* are related to the capacity of the female to incubate the egg mass, following the common pattern of most brachyuran species. This allometric relationship is often used to detect the molt to puberty in the females (Hartnoll, 1965; Finney and Abele, 1981; Pinheiro and Fransozo, 1998; Fransozo et al., 2002).

The estimated value (31.6 mm CW) for the beginning of morphological sexual maturity of the females of *M. nodifrons* was lower than that obtained by Oshiro (1999). Oshiro estimated that the mean size at the first gonadal maturation of this species was 37.8 mm CW, and the smallest ovigerous female caught in the area of her study

(Sepetiba Bay, Rio de Janeiro) was 38 mm CW. This suggested that these two events did not occur in synchrony in this species.

In another xanthoid, *Eriphia gonagra*, studied by Góes (2000), morphological maturity occurred practically in synchrony with physiological maturity in both sexes. Nevertheless, these events commonly occurred asynchronously in brachyurans, as for instance in the portunids *Liocarcinus puber* (Linnaeus, 1767), studied by Choy (1988); *Callinectes ornatus* Ordway, 1863, by Haefner (1990); and *Ovalipes stephensoni* Williams, 1976, by Haefner (1985). In all these cases, the females reached morphological maturity before they reached physiological maturity.

Menippe nodifrons appears to mature precociously in relation to other species of the genus *Menippe*. *M. mercenaria* reached sexual maturity at 60 mm CW, according to the work of Sullivan (1979) who reported the smallest ovigerous female caught in southwest Florida, and to the analysis of Wilber (1992) of the presence of spermatozoids in the seminal receptacle in individuals in the northeastern Gulf of Mexico. In South Carolina, Caldwell (1992) reported that the females of this species initiated maturation at 55 mm and the males at 60 mm CW; the largest individuals caught were 135 mm CW. This later maturation in *M. mercenaria* than in *M. nodifrons* was probably related to the larger size reached by the former species.

Although *M. nodifrons* is smaller than *M. mercenaria* and *M. adina*, raising this commercially species could be interesting. Oshiro et al. (1998) estimated that the average meat yield from *M. nodifrons* was higher than from other species of crabs which were commercially important in Brazil, such as *Ucides cordatus* (Linnaeus, 1763) and *Cardisoma guanhumi* Latreille, 1825.

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RESUMO

O objetivo do presente estudo foi determinar o crescimento relativo e a maturidade sexual morfológica de *Menippe nodifrons*. As coletas foram realizadas na Praia Grande e Tenório, Ubatuba, São Paulo. Os caranguejos foram separados quanto ao sexo e mensurados na região da largura (LC) e comprimento da carapaça, comprimento e altura dos própodos quelares direito e esquerdo, largura do abdome (LA) nas fêmeas e comprimento do gonopódio (CG) nos machos. Obteve-se 399 indivíduos, sendo 195 machos e 204 fêmeas. Os machos atingiram a maturidade sexual com 29,7mm LC e as fêmeas com 31,6mm LC. Para as fêmeas a melhor relação que indicou a muda da puberdade foi LA *vs.* LC, sendo que o crescimento foi alométrico negativo na fase jovem e alométrico positivo após a muda da puberdade. Para os machos foi CG *vs.* LC evidenciando crescimento alométrico positivo na fase jovem e isométrico na fase adulta.

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