Latin American Journal of Aquatic Research
E-ISSN: 0718-560X
lajar@ucv.cl
Pontificia Universidad Católica de Valparaíso
Chile

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Latin American Journal of Aquatic Research, vol. 39, núm. 2, julio, 2011, pp. 261-270
Pontificia Universidad Católica de Valparaíso
Valparaiso, Chile

Research Article

Relative growth and sexual dimorphism of *Austinixa aidae* (Brachyura: Pinnotheridae): a symbiont of the ghost shrimp *Callichirus major* from the southwestern Atlantic

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ABSTRACT. Species of the family Pinnotheridae constitute an ideal group for morphometric studies due to their complex morphological adaptations. These adaptations respond to the selective pressure of a symbiotic life style. This study describes the relative growth and morphometric features of the symbiotic pea crab *Austinixa aidae* (associated with the ghost shrimp *Callichirus major*), from the sandy beaches in the southwest Atlantic, Brazil. Significant differences were detected in the biometric proportions, particularly the chelar propodus length and carapace width, of each sex. These dimensions were also related to the size at which the individuals reached morphological sexual maturity (5.1 mm of carapace width for both sexes). Males and females were 2.4 times wider than long, which corresponds to the principal adaptation developed by *Austinixa* species to live in cryptic environments. Moreover, juveniles were proportionally more rounded. The changes in the biometric proportions of carapace length and width of *A. aidae* were more pronounced in males and females, adaptations that facilitate roaming within the galleries of their hosts.

Keywords: pinnotherid crabs, traditional morphometry, size-at-maturity, sexual dimorphism, southwestern Atlantic.

Crecimiento relativo y dimorfismo sexual en *Austinixa aidae* (Barchyura: Pinnotheridae): un simbionte del camarón fantasma *Callichirus major* del Atlántico sudoccidental

RESUMEN. Las especies de la familia Pinnotheridae constituyen un grupo ideal para la realización de estudios morfométricos, debido a sus complejas adaptaciones morfológicas. Estas adaptaciones son respuesta a la presión de selección debida a su vida simbionte. En este estudio se describió el crecimiento relativo y las características morfométricas del cangrejo simbionte *Austinixa aidae* (asociado con el camarón fantasma *Callichirus major*), de una playa de arena del Atlántico suroeste de Brasil. Se determinaron diferencias significativas en las proporciones biométricas de cada sexo, entre la longitud del propodio y ancho del caparazón. Estas dimensiones estuvieron relacionadas también con la talla en que los individuos muestran cambios morfológicos en su madurez sexual (5.1 mm de ancho del caparazón en ambos sexos). Los machos y hembras fueron 2,4 veces más anchos que largos, lo que corresponde a la adaptación principal que las especies del género *Austinixa*, han desarrollado para vivir en ambientes crípticos. Además, los juveniles fueron proporcionalmente más redondeados. Los cambios en las proporciones biométricas de longitud y ancho del caparazón de *A. aidae*, fueron más pronunciados en machos y hembras, adaptaciones que facilitan el desplazamiento al interior de las galerías construidas por sus hospederos.

Palabras clave: cangrejos pinnothéridos, morfometría tradicional, talla de madurez, dimorfismo sexual, Atlántico sudoccidental.

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INTRODUCTION

Pea crabs of the family Pinnotheridae De Haan, 1833 constitute a promising group for morphometric studies because of their complex morphological adaptations to symbiotic life style. Over 300 species of this family display symbiotic relationships (both facultative and obligated) with a wide variety of bivalves, gastropods, polychaetes, crustaceans, echinoderms, echiurids, brachiopods, balanoglossids and ascidians (Schmitt *et al*., 1973; Harrison & Hanley, 2005; Ng *et al*., 2008). These symbioses are an intriguing system and, consequently, almost all the morphological features of these crabs are strongly adapted in order to achieve a successful relationship. Their adaptation to this variety of hosts likely accounts for their diversity, and this can consequently drive towards a confused state of systematics in some members of the group (Palacios-Theil *et al*., 2009).

Among representatives of this family, the polyphyletic pinnotherid crab genus *Austinixa* Heard & Manning, 1997 (*sensu* Palacios-Theil *et al*., 2009) is less diverse than other members of the Pinnotheridae, and comprise currently eight described species (Ng *et al*., 2008). The enlargement of carapace, the third pair of pereopods, and a conspicuous lobe on the outer margin of the basal segment on the exopod of the third maxilliped are the main synapomorphies with the *Pinnixa* complex (in which *Austinixa* was included) (Heard & Manning, 1997; Campos, 2006). These morphological modifications presumably facilitate lateral movement within the microhabitats (narrow tubes and burrows) occupied by these crabs (Zmarzly, 1992; McDermott, 2006).

As far as we know, only three studies have been devoted exclusively to understand the relative growth (allometry) in *Austinixa*: Alves & Pezzuto (1999), Alves *et al.* (2005) and Valença-Silva *et al.* (2008), all on *Austinixa patagoniensis* (Rathbum, 1918). For *Austinixa aidae* (Righi, 1967), no studies have been published.

Likewise the lifestyle, the allometry of pea crabs varies considerably, and some body characteristics/features are poorly understood for species of *Austinixa*. Taking into account the lack of descriptions on the allometry, the aim of this study was to describe the relative growth and body features of the symbiotic crab *A. aidae* [associated with the thalassinid ghost shrimp *Callichirus major* (Say, 1818)], from a sandy beach in the southwest Atlantic. We also estimated the size at maturity and the existence of sexual dimorphism in this population.

MATERIALS AND METHODS

Sampling was carried out bimonthly during daytime at low tide (in an area of approximately 400 m length and 30 m width), from May 2005 to September 2006 in the intertidal zone of Perequê-açu Beach, Ubatuba, northern coast of State of São Paulo, Brazil (23°24'59.99"S, 45°03'17.13"W), a semi-protected and dissipative beach composed by fine sand. Crabs were collected with commercial yabby pumps, developed by Rodrigues (1966) and similar to the one described by Manning (1975), from *Callichirus major* galleries, separated from the sand by a 1 mm mesh sieve, frozen, and analyzed in laboratory.

Crabs were sexed by revising the shape of the pleopods. Males have a pair of long, thin pleopods on the ventral surface of the first abdominal somite and a pair of short pleopods on the second abdominal somite (together they compose the gonopods); females have four pairs of short pleopods from the second to the fifth abdominal somites (Narchi, 1973). Specimens with undifferentiated or not developed pleopods and gonopore were considered/named juveniles (no identified as males or females). The following measurements were taken under a stereomicroscope with the aid of a drawing tube (0.1 mm precision): carapace width (CW), carapace length (CL), abdomen width (AW) (between fourth and fifth abdominal tagma), height (HQ) and length (LQ) of cheliped propods (left and right), and the gonopod length (GN) (from the shaft to tip). The wet weight (WW) was measured, after the samples were drained by paper towel, with an electronic analytical balance (0.0001 g precision), to assess changes in weight related to sexual maturity.

The carapace width was used as independent variable, because it represents the crab's body size. To assess the chelae dimorphism (heterochely), the Mann-Whitney Rank Sum Test (due the non-normality of the data) was applied to compare differences in mean values of HQ and LQ, in both chelipeds. The same test was applied to compare differences on sizes of males and females.

Relative growth was quantitatively described by fitting the allometric equation ($Y = aX^b$) for each body dimension against the independent variable (CW) by least-squares regression analysis (Hartnoll, 1974, 1978). Inflection (transition) points corresponding to changes in the allometry pattern during the growth were first identified by eye on dispersion graphs. They were then iteratively searched by a specific routine of the software *Regrans* (Pezzuto, 1993); the routine seeks the CW value where the data could be split into two subsets resulting in the lowest combined residual sum of squares. An Overall Test for Coincidental Regressions (Zar, 1996, p. 368) was conducted to check the validity of the transition point. It compares the difference between the global sum of squares (calculated from a single model fitted to the data), and the pooled residual sum of squares (*i.e.* of the subsets located to the left and right sides of the transition point) (Zar, 1996). If a significant difference was found, the ANCOVA (α = 0.05) was used to test the difference between intercepts and slopes of the two regressions, corresponding then to the pre and post-pubertal phases of growth (Zar, 1996). On the analysis of the allometric growth, constant (*b*) gives information about the increase of one biometric dimension in relation to another; isometric growth was considered when *b* was = 1, negative allometric growth with $b < 1$, and positive allometry with $b > 1$ (Hartnoll, 1982). When involved different units, like the CW and the WW, the value of isometry assume $b = 3$ (Valenti, 1984; Biagi & Mantelatto, 2006).

The sexual dimorphism in Decapoda occurs by differences in relative growth between males and females, which in initial stages are not clear. There are body structures that present strong and consistent patterns of variations in allometry associated to maturation, for example the cheliped of males and the abdomen of females in Brachyura (Hartnoll, 1978, 1982). These structures are related to reproductive activities of both sexes, and are associated to dimorphism in mature stages. The body dimension related to maturation and reproductive activity increase in major rates than the carapace (positive allometric growth) (Hartnoll, 1982).

Maximum and minimum sizes of males and females were verified, as well as the minimum size of ovigerous females and the length of their reproductive period, which was identified by the percentage of ovigerous females in relation to the total number of females caught bimonthly (Alves *et al*., 2005).

The normality of data-set was evaluated before to the use of parametric tests. The statistical analysis were conducted by using Sigma-Stat® 2.03 and *Regrans* (Pezzuto, 1993), according to Zar (1996) ($P < 0.05$ significance). All material was preserved in ethanol 80% and deposited in the Crustacean Collection of the Departamento de Biologia, Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto, Universidade de São Paulo, (CCDB/FF CLRP/USP) under the catalogue # 2102.

RESULTS

Relative growth

In total, 246 males (42.2%), 263 females (45.1%) and 74 juveniles (12.7%) of *A. aidae* were analyzed for relative growth. This analysis revealed differences in growth rates of a few body structures in both males and females (Table 1).

The carapace length of males, females, and juveniles showed negative allometric growth ($b < 1$), with no transition points (Fig. 1a, Table 1). The same pattern was also found for the abdomen width of males (Fig. 1b). On the other hand, the female abdomen width exhibited two transition points at 5.1 and 7.2 mm CW. Below 5.1 mm and between 5.1 and 7.2 mm, growth was positive allometric, and from 7.2 mm growth was isometric. For juveniles, growth was positive allometric, without transition points.

Because no statistical differences were found between the HQ and HL of both left and right chelar propodus ($P = 0.931$ and $P = 0.942$ for total of individuals; males $P = 0.897$ and $P = 0.772$; females $P = 0.982$ and $P = 0.822$; and juveniles $P = 0.513$ and $P = 0.577$, respectively), only the measurements of the left chelar propodus were used in the relative growth analysis.

The maximum height of the chelar propodus of males and females (Fig. 1c) showed positive allometric growth, with no transition points. For juveniles, growth showed negative allometry, with no transition points.

The maximum length of the male chelar propodus showed positive allometric growth, with a break in the dispersion data and an inflection at 5.1 mm CW (Fig. 1d). For females, growth was positive allometric, while for juveniles, growth was isometric, both with no significant transition points.

The wet weight of males showed positive allometric growth up to 5.7 mm CW, and after this size, growth changed to negative allometric. In females, growth was positive allometric up to the transition point at 5.4 mm CW, changing to isometric in larger sizes. For juveniles, growth was described by a single, positive allometric equation (Fig. 1e).

The gonopods showed isometric growth up to 3.0 mm (CW), and after that the growth was negative allometric (Fig. 1f).

Body features, maturity and sexual dimorphism

The CW of male crabs varied between 2.0 and 10.1 mm (mean 5.8 ± 2.2 mm CW), and females between 2.5 and 10.5 mm (mean 6.1 ± 2.0 mm CW). No significant differences in CW between the sexes were detected ($P = 0.154$).

The CW of males was, on average, 2.4 ± 0.4 (standard deviation) times the CL; for females and juveniles, the means were 2.4 ± 0.3 and 1.9 ± 0.3, respectively. Smaller individuals had, therefore, a

Table 1. *Austinixa aidae*. Regressions for body dimensions: carapace length (CL), abdomen width (AW), height of left cheliped propodus (HQ), length of left cheliped propodus (LQ), wet weight (WW), and gonopod length (GL) *versus* the carapace width (CW), separately for males, females and juveniles. Sample number (n), equation for total data (Total) when no transition points are present, correlation coefficient (r), allometric level (a), positive (+), negative (-), isometric (=), allometric growth constant (b). All measurements are in mm. All correlations were significant ($P < 0.05$).

Tabla 1. *Austinixa aidae*. Análisis de regresión entre diferentes dimensiones corporales: Longitud del caparazón (CL), ancho del abdomen (AW), altura del propodio del quelípodo izquierdo (HQ), longitud del propodio del quelípodo izquierdo (LQ), peso húmedo (WW), longitud del gonoporo (GL) *versus* el ancho del caparazón (CW), análisis separado para machos, hembras y juveniles. Número de individuos (n), ecuación de regresión (Total) cuando no están presentes puntos de transición, coeficiente (r), alometria (a), positivo (+), negativo (-), isometría (=), constante de crecimiento alometrico (b). Todas las medidas son en mm. Todas la correlaciones fueron significativas ($P < 0,05$).

Dimension	Sex	n	Segment	$Y = aX^b$	r	a	b
CL	Males	246	Total	$CL = 0.671CW^{0.711}$	0.967	-	0.711
	Females	263	Total	$CL = 0.628CW^{0.764}$	0.956	-	0.764
	Juveniles	74	Total	$CL = 0.743CW^{0.627}$	0.861	-	0.627
AW	Males	244	Total	$AW = 0.303CW^{0.884}$	0.985	-	0.884
	Females	97	< 5.1	$AW = 0.139CW^{1.692}$	0.889	+	1.692
		164	5.1 < CW < 7.2	$AW = 0.143CW^{1.783}$	0.715	+	1.783
			> 7.2	$AW = 0.597CW^{1.097}$	0.731	=	1.097
	Juveniles	70	Total	$AW = 0.228CW^{1.197}$	0.916	+	1.197
HQ	Males	238	Total	$HQ = 0.096CW^{1.379}$	0.974	+	1.379
	Females	252	Total	$HQ = 0.114CW^{1.193}$	0.965	+	1.193
	Juveniles	69	Total	$HQ = 0.156CW^{0.854}$	0.847	-	0.854
LQ	Males	102	< 5.1	$LQ = 0.243CW^{1.197}$	0.949	+	1.197
		136	> 5.1	$LQ = 0.195CW^{1.312}$	0.949	+	1.312
	Females	255	Total	$LQ = 0.275CW^{1.084}$	0.989	+	1.084
	Juveniles	69	Total	$LQ = 0.308CW^{0.978}$	0.922	=	0.978
WW	Males	108	< 5.7	$WW = 0.00002CW^{4.557}$	0.808	+	4.557
		110	> 5.7	$WW = 0.0003CW^{2.834}$	0.957	-	2.834
	Females	135	< 5.4	$WW = 0.0001CW^{3.646}$	0.796	+	3.646
		90	> 5.4	$WW = 0.0002CW^{3.133}$	0.961	=	3.133
	Juveniles	70	Total	$WW = 0.000008CW^{5.000}$	0.601	+	5.000
GL	Males	31	< 3.0	$GL = 0.134CW^{1.629}$	0.637	=	1.629
		209	> 3.0	$GL = 0.362CW^{0.876}$	0.974	-	0.876

slightly more rounded body than males and females, whose carapaces become progressively narrower with size.

As identified by dispersion points and values obtained by the regression function between LQ and CW, males attain sexual maturity at 5.1 mm CW (Fig. 1d, Table 1). In females, sexual maturity also occurs from 5.1 mm CW, as indicated by the AW/CW relationship (Fig. 1b, Table 1). This value corresponds also to the smallest ovigerous females observed during the study period. The ovigerous females occurred on almost all sampled months and seasonal increases in the frequency of this sexual category were also identified. These features led us to characterize the reproductive period as seasonal continuous.

DISCUSSION

Relative growth

The carapace length of males and females did not show significant changes in the allometric pattern during the growth. Only a few differences, for both sexes, were detected in the CL *vs* CW relationship. This pattern can be observed in many species of

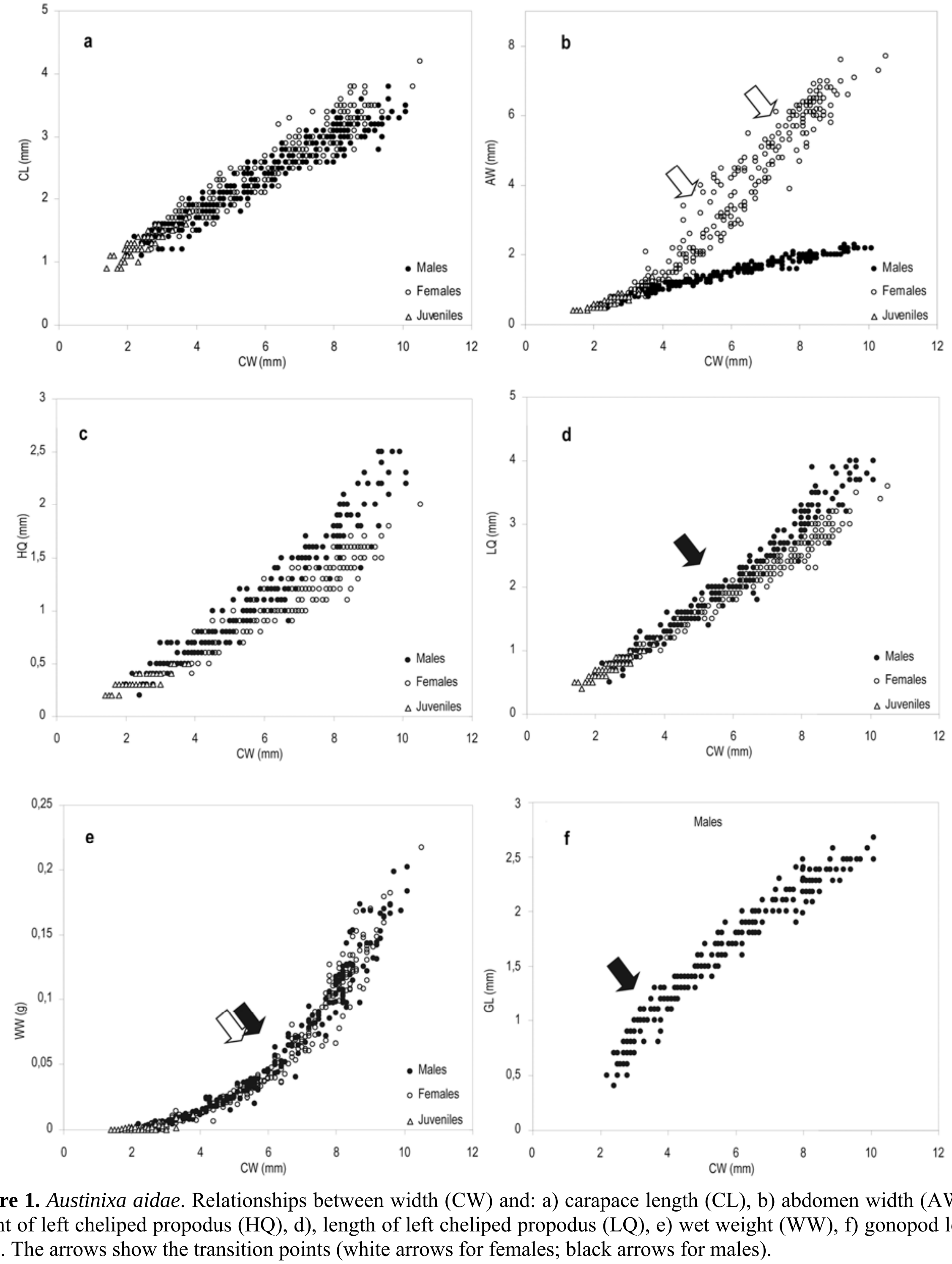

Figure 1. *Austinixa aidae*. Relationships between width (CW) and: a) carapace length (CL), b) abdomen width (AW), c) height of left cheliped propodus (HQ), d), length of left cheliped propodus (LQ), e) wet weight (WW), f) gonopod length (GL). The arrows show the transition points (white arrows for females; black arrows for males).

Figura 1. *Austinixa aidae*. Representación de diferentes relaciones biométricas entre las variables dependientes a) longitud del caparazón (CL), b) ancho del abdomen (AW), c) altura del propodio del quelípodo izquierdo (HQ), d) longitud del propodio del quelípodo izquierdo (LQ), e) peso húmedo (WW), f) longitud del gonopodo (GL) *versus* ancho del caparazón (CW) como variable independiente. Las flechas indican los puntos de transición (flechas blancas para hembras y negras para machos).

Brachyura (Hartnoll, 1982; Alves *et al*., 2005), including *A. patagoniensis* (Alves & Pezzuto, 1999; Alves *et al*., 2005; Valença-Silva *et al*., 2008). In contrast, the abdomen allometry is one of the best dimensions to evidence sexual dimorphism in brachyuran crabs (Hartnoll, 1974). The enlargement of the female abdomen is more evident in sexually mature individuals (Hartnoll, 1982). In Pinnotheridae, the discontinuity in the relative growth of abdomen is related to the sexual maturity of females (Pohle & Telford, 1982; Bell, 1988; Alves & Pezzuto, 1999; Alves *et al*., 2005), probably related to pleopodial incubation mechanism. In the present study, a transition stage in female abdomen growth was apparent at 5.1 mm CW, which is probably the size at the puberty molt. This estimate of maturity size coincided with the size of the smallest ovigerous females captured (5.1 mm CW). In addition, another transition point at 7.2 mm (CW) reflects the end of the increase in abdomen growth. As observed in the present study, the relative growth rate of the abdomen has a tendency to decrease as soon as it attains the functional size (Hartnoll, 1978). This occurs because any disproportionate increase in abdomen width could reduce the efficiency of egg incubation, and creates difficulties for the crab's locomotion (Hartnoll, 1982), especially for pinnotherids which live associated with hosts and are sometimes limited in terms of locomotion because of the small internal space available. In addition, the pattern of sexual dimorphism in body size herein observed for *A. aidae* represents one of some other lines of reasoning that argues in against the idea of social monogamy in this species, which is polygynandrous (Peiró *et al*., submitted). In this sense, this topic need more work and to be experimentally explored in the future.

In males it is possible to identify an interval in the dispersion points at 5.1 mm CW in the relationship involving the maximum length of the cheliped propodus, which is related to the acquisition of sexual maturity. The meaning of full chelar development occurring only with maturity is related to economy of resources, reducing the waste of energy on increase of these structures causes during the initial instars (Hartnoll, 1982).

Females did not show noticeable changes of allometry in the chelae, although the relationships showed positive allometry. Some species of Pinnotheridae have sexually dimorphic chelae, *e.g.*: *Austinixa behreae* (Manning & Felder, 1989), *Austinixa chacei* (Wass, 1955), *A. patagoniensis* (Rathbun, 1918), (see Manning & Felder, 1989), *Pinnixa faba* (Dana, 1851), *Pinnixa littoralis* Holmes, 1894, *Pinnixa minuscula* Zmarzly, 1992, *Pinnixa occidentalis* Rathbun, 1893, among others (see Zmarzly, 1992). The relationships involving the chelae indicate a smaller investment in the growth of this structure in females, probably due to absence of fights for territory, burrow construction or courting behaviour, allowing females to allocate energy to the somatic growth.

The dimensions of the left and right chelar propodus (HQ and LQ) of *A. aidae* represent reliably the size of these structures when compared with each other, considering that both sides do not differ in size, shape, and probably function. The same was observed in *A. patagoniensis* in two different localities (Alves & Pezzuto, 1999; Alves *et al*., 2005). This similarity between both sides differs from the frequently pattern observed in Brachyura with many levels of heterochely (Hartnoll, 1982). The shape and size of chelipeds are important parameters for brachyuran lifestyles, since these structures are used in reproductive and agonistic interactions, as well as in feeding (Negreiros-Fransozo & Fransozo, 2003). In mature individuals of *A. aidae*, the chelipeds are strong with the palm quadrangular in males, and rectangular with convex edges in females (Melo, 1996).

The wet weight of males showed a break in the continuity of dispersion points at 5.7 mm CW, which may reflect the weight at sexual maturity, occurring 0.6 mm after the relationships involving the chelae. In females, a discontinuity of this relationship occurred at 5.4 mm CW, which is also related to the estimated size at sexual maturity. Although these results corroborate the estimated sizes at maturity, they should be treated with caution because weight can be strongly influenced not only by body size but also by the nutritional state of individuals and the time of year, which add variability to the data. The juveniles did not show transition points in weight, probably because of limitations in the accuracy of the measurements and/or low variation in this dimension during this life stage.

Carapace size of male and female *A. aidae* was very similar. This pattern between both sexes appears to be common among the members of this genus (*A. patagoniensis* - Alves & Pezzuto, 1998; Alves *et al*., 2005; Valença-Silva *et al*., 2008; *A. gorei* - McDermott, 2006), which may be related to the small size attained by the specimens. However, some differences in this size pattern were detected; for instance, females of *A. aidae* attained a slightly larger size (10.5 mm CW) than males (10.1 mm CW), which may indicate sexual differences in growth. Females being larger than males is not a common pattern in brachyurans, and differs from that found for

Table 2. *Austinixa aidae*. Maximum size of males and females, minimum size of ovigerous females and the known reproductive periods of species of the genus *Austinixa*. All measures refer to carapace width (mm).

Tabla 2. *Austinixa aidae*. Tamaño máximo de machos y hembras y tamaño mínimo de hembras ovígeras y los periodos reproductivos de especies del género *Austinixa*. Todas las medidas están referidas al ancho del caparazón (mm).

Species	Locality (Latitude)	Maximum size		Minimum size of ovigerous females	Reproductive period	References
		Males	Females			
Austinixa patagoniensis	Balneário Cassino (32°13'S)	11.5	11.5	8.0	Seasonal (October to March)	Alves & Pezzuto (1998)
Austinixa patagoniensis	Balneário Camboriú (26°59'S)	13.6	13.1	7.9	Continuous	Alves *et al.* (2005)
Austinixa patagoniensis	Ubatumirim Beach (23°20'S)	9.5	9.4	6.7	No data available	Valença-Silva *et al.* (2008)
Austinixa aidae	Perequê-açu Beach (23°24'S)	10.1	10.5	5.1	Seasonal continuous	Present study; Peiró & Mantelatto (2011)

A. patagoniensis in Brazil (Valença-Silva *et al*., 2008) (Table 2). The larger size attained by the females allows us to hypothesize that 1) they have a faster growth rate than males, and 2) this may be advantageous because the larger size may be related to high reproductive potential and incubation of more eggs. The physical space available for egg attachment is a limiting factor in decapods (Reid & Corey, 1991; Hines, 1982), and for associated pinnotherid crabs there are still many questions to be answered, *e.g.*, the reproductive features (fecundity, reproductive output), and which aspects of the reproductive biology are adaptable to locally occurring environmental factors.

Comparing the maximum size of *A. aidae* with other *Austinixa* species, *A. aidae* is slightly smaller than *A. patagoniensis* and larger than *A. gorei*, *A. cristata*, *A. behreae,* and *A. chacei* (see Manning & Felder, 1989; Alves & Pezzuto, 1998; McDermott, 2006), which probably is related to differences in local dynamics and hosts where the species live, and including availability of resources in the environment, effects of predation, and influence of latitude as well.

These small size differences among the species and sexes may be related to latitudinal variation. In terms of carapace size, the members of *A. patagoniensis* from the southernmost regions (32^o and 26^oS) are larger than at Ubatuba (23ºS) (Alves & Pezzuto, 1999; Alves *et al*., 2005). The pattern of mean size of the specimens, with southern crabs reaching larger sizes, agrees with that proposed by Abele (1982), who postulated that the size of crustaceans decreases with decreasing latitude. According to Mantelatto *et al*. (2010), the explanations for this size difference may be related to 1) less-stressful social and energy-demanding activities in the southern population, and 2) the possibility that this profile is acting in combination with differences in food limitations and temperature between the two areas. Obviously, the lack of information available on the size of specimens along the species' geographical distribution does not at present allow a comparative analysis. Reproduction is outside the scope of this paper, but it is important to highlight the possible influence of latitude on reproductive period. Ubatuba is subtropical and a biogeographical boundary, where the geographical distributions of many tropical species end and those of temperate and subantarctic species begin (Costa *et al*., 2000). This situation explains the continuous presence of egg-bearing females of *A. aidae* in Ubatuba, in contrast to the seasonal reproduction in the southernmost population of *A. patagoniensis* (Table 2). The differences in minimum size attained by ovigerous females for the different regions (Table 2) also corroborate our hypothesis. The underlying reasons for these differences need to be investigated in the future, in order to clarify these patterns.

Body features, maturity, and sexual dimorphism

The carapace width of differentiated males and females of *A. aidae* was, on average, 2.4 times the length, which corresponds to the principal adaptations of *Austinixa* species to live in cryptic environments. On the other hand the unsexed juveniles were proportionally more rounded. This feature, is shared among species of *Pinnixa* and *Austinixa*, and has been suggested by various authors (Zmarzly, 1992; Heard & Manning, 1997; McDermott, 2006) to represent an adaptation to the symbiotic lifestyle of these crabs, which inhabit callianassid galleries and polychaete tubes. The wider and slimmer (anterior-posterior) body facilitates the locomotion inside the burrows constructed by its hosts. The complexity of host use pattern can be influenced by several factors that have not been evaluated by us as fitness payoffs to hosts and their symbionts, spatial patterning or density of the host population, and the ability of symbionts to recognize suitable hosts and to initiate and maintain the symbiotic relationship (see Grove & Woodin, 1996, for review).

In agreement with the recognized role of the cheliped and abdomen in reproductive functions in Brachyura (Hartnoll, 1982; Alves *et al*., 2005), and the importance for determination of morphological maturation, the probable size of maturity for *A. aidae* is 5.1 mm CW for males and females. Like their congener, males and females of *A. aidae* reach sexual maturity at similar sizes. The size of maturity of *A. patagoniensis*, based on allometry studies, were established between 7.8 and 7.9 mm CW for males (obtained by transition points for the growth of chelae), and between 7.9 and 8.3 mm CW for females (obtained by transition points for the growth of the abdomen). In addition, the sizes of maturity estimated for each sex were identical for populations at Balneário Cassino, State of Rio Grande do Sul [associated with *Sergio mirim* (Rodrigues, 1971)] and Balneário Camboriú, State of Santa Catarina (associated with *Callichirus major*), located farther south in Brazil (Alves & Pezzuto, 1999; Alves *et al*., 2005).

Finally, the influence of the host on crab maturity size and maximum size of the species is not totally clear and is still under evaluation. To better understand the causes and the role played by host characteristics in the natural history of *A. aidae*, different studies will be necessary, such as: comparing this natural species relationship in different areas, as well as observations of pinnotherids interacting with the host in a controlled laboratory setting, in order to check if crabs are attracted to host odors during the larvae or megalopae settlement and subsequently if they do or do not lose this ability during the adult stage.

ACKNOWLEDGMENTS

This study formed part of a Master's degree thesis by DFP, and was supported by a fellowship from CAPES. FLM and DFP are grateful to CNPq for a research and PhD fellowships, respectively. Part of this study was supported by funding from the CNPq (grants 471794/2006-6 and 473050/2007-2) to FLM. Special thanks to all members of the Laboratory of Bioecology and Crustacean Systematics of FFCLRP/USP for their help during field and laboratory work, especially to Ivana Miranda for suggestions, and to anonymous reviewers for their suggestions and contributions toward the improvement of this paper. The support of the Postgraduate Program in Comparative Biology of FFCLRP/USP, and of the Centro de Biologia Marinha (CEBIMar/USP) during the collections are also acknowledged. We also thank Dra. Janet Reid (JWR Associates) for revision on English and Luis M. Pardo and Patricio Hernáez for Spanish revision. All data collection was conducted according current applicable state and federal laws of Brazil.

REFERENCES

Abele, L.G. 1982. Biogeography. In: D.E. Bliss (ed.). The biology of Crustacea: systematics, the fossil record, and biogeography. Academic Press, London, pp. 242-292.

Alves, E.S. & P.R. Pezzuto. 1998. Population dynamics of *Pinnixa patagoniensis* Rathbun, 1918 (Brachyura: Pinnotheridae) a symbiotic crab of *Sergio mirim* (Thalassinidea: Callianassidae) in Cassino Beach, southern Brazil. Mar. Ecol. P.S.Z.N.I., 19(1): 37-51.

Alves, E.S. & P.R. Pezzuto. 1999. Crescimento relativo de *Austinixa patagoniensis* (Rathbun, 1918) (Decapoda: Pinnotheridae), simbionte de *Sergio mirim* (Rodrigues, 1971) (Decapoda: Callianassidae) na praia do Cassino, RS. Nauplius, 7(1): 83-92.

Alves, E.S., S.A. Rodrigues & P.R. Pezzuto. 2005. Estudo do crescimento relativo de *Austinixa patagoniensis* (Rathbun) (Decapoda, Pinnotheridae) simbionte de *Callichirus major* (Say) (Decapoda, Callianassidae) no mesolitoral da praia de Balneário Camboriú, Santa Catarina, Brasil. Rev. Bras. Zool., 22(3): 784-792.

Bell, J.L. 1988. Distribution and abundance of *Dissodactylus mellitae* Rathbun (Pinnotheridae) on *Mellita quinquiesperforata* (Leske) (Equinodermata). J. Exp. Mar. Biol. Ecol., 117(2): 93-114.

Biagi, R. & F.L. Mantelatto. 2006. Relative growth and sexual maturity of the hermit crab *Paguristes erythrops* (Anomura, Diogenidae) from South Atlantic. Hydrobiologia, 559(1): 247-254.

Campos, E. 2006. Systematics of the genus *Scleroplax* Rathbun, 1893 (Crustacea: Brachyura: Pinnotheridae). Zootaxa, 1344: 33-41.

Costa, R.C., A. Fransozo, F.L. Mantelatto & R.H. Castro 2000. Occurrence of shrimp species (Crustacea: Decapoda: Natantia: Penaeoidea and Caridea) in Ubatuba Bay, Ubatuba, SP, Brazil. Proc. Biol. Soc. Wash., 113(3): 776-781.

Grove, M.W. & S.A. Woodin. 1996. Conspecific recognition and host choice in a pea crab, *Pinnixa* *chaetopterana* (Brachyura: Pinnotheridae). Biol. Bull., 190: 359-366.

Harrison, J.S. & P.W. Hanley. 2005. *Austinixa aidae* Righi, 1967 and *A. hardyi* Heard and Manning, 1997 (Decapoda: Brachyura: Pinnotheridae) synonymized, with comments on molecular and morphometric methods in crustacean taxonomy. J. Nat. Hist., 39(42): 3649-3662.

Hartnoll, R.G. 1974. Variation in growth pattern between some secondary sexual characters in crabs (Decapoda, Brachyura). Crustaceana, 27(2): 131-136.

Hartnoll, R.G. 1978. The determination of relative growth in Crustacea. Crustaceana, 34(3): 282-292.

Hartnoll, R.G. 1982. Growth. In: D.E. Bliss (ed.). The biology of Crustacea, embryology, morphology, and genetics. Academic Press, New York, pp. 11-196.

Heard, R.W. & R.B. Manning. 1997. *Austinixa*, a new genus of pinnotherid crab (Crustacea: Decapoda: Brachyura), with the description of *A. hardyi*, a new species from Tobago, West Indies. Proc. Biol. Soc. Wash., 110(3): 393-398.

Hines, A.H. 1982. Allometric constraints and variables of reproductive effort in brachyuran crabs. Mar. Biol., 69: 309-320.

Manning, R.B. 1975. Two methods for collecting decapods in shallow water. Crustaceana, 29(3): 317-319.

Manning, R.B. & D.L. Felder. 1989. The *Pinnixa cristata* complex in the Western Atlantic, with a description of two new species (Crustacea: Decapoda: Pinnotheridae). Smith. Contr. Zool., 473: 1-26.

Mantelatto, F.L. & J.A. Cuesta. 2010. Morphology of the first zoeal stage of the commensal southwestern Atlantic crab *Austinixia aidae* (Righi, 1967) (Brachyura: Pinnotheridae), hatched in the laboratory. Helgol. Mar. Res., 64(4): 343-348.

Mantelatto, F.L., L.C. Fernandes-Góes, M.Z. Fantucci, R. Biagi, L.M. Pardo & J.M. Góes. 2010. A comparative study of population traits between two South American populations of the striped-legged hermit crab *Clibanarius vittatus*. Acta Oecol., 36(1): 10-15.

McDermott, J.J. 2006. The biology of *Austinixa gorei* (Manning & Felder, 1989) (Decapoda, Brachyura, Pinnotheridae) symbiotic in the burrows of intertidal ghost shrimp (Decapoda, Thalassinidea, Callianassidae) in Miami, Florida. Crustaceana, 79(3): 345-361.

Melo, G.A.S. 1996. Manual de identificação dos Brachyura (Caranguejos e Siris) do litoral brasileiro. Plêiade/FAPESP, São Paulo, 604 pp.

Narchi, W. 1973. Crustáceos: estudos práticos. Editora Polígono e Editora da Universidade de São Paulo, São Paulo, 116 pp.

Negreiros-Fransozo, M.L. & V. Fransozo. 2003. A morphometric study of the mud crab, *Panopeus austrobesus* Williams, 1983 (Decapoda, Brachyura) from a subtropical mangrove in South America. Crustaceana, 76(3): 281-294.

Ng, P.K.L., D. Guinot & P.J.F. Davie. 2008. Systema Brachyurorum: Part 1. An annotated checklist of extant brachyuran crabs of the world. Raffles Bull. Zool., 17: 1-286.

Palacios-Theil, E., J.A. Cuesta, E. Campos & D.L. Felder. 2009. Molecular genetic re-examination of subfamilies and polyphyly in the family Pinnotheridae (Crustacea: Decapoda). In: J.W. Martin, K.A. Crandall & D.L. Felder (eds.). Crustacean Issues, 18: Decapod Crustacean phylogenetics. Taylor & Francis/CRC Press, Boca Raton, pp. 423-442.

Peiró, D.F. & F.L. Mantelatto. 2011. Population dynamics of the pea crab *Austinixa aidae* (Brachyura: Pinnotheridae): a symbiotic of the ghost shrimp *Callichirus major* (Thalassinidea: Callianassidae) from the southwestern Atlantic. Iheringia, 101(1/2).

Peiró, D.F., J.A. Baeza & F.L. Mantelatto. Host-use pattern and sexual dimorphism suggest a polygynandrous mating system in the symbiotic pea crab *Austinixa aidae* (Brachyura, Pinnotheridae). Mar Biol Assoc UK (Submitted).

Pezzuto, P.R. 1993. REGRANS: a “BASIC” program for an extensive analysis of relative growth. Atlântica, 15: 93-105.

Pohle, G. & M. Telford. 1982. Post-larval growth of *Dissodactylus primitivus* Bouvier, 1917 (Brachyura: Pinnotheridae) under laboratory conditions. Bull. Mar. Sci., 33(2): 257-273.

Reid, D.M. & S. Corey. 1991. Comparative fecundity of decapod crustaceans, II. The fecundity of fifteen species of anomuran and brachyuran crabs. Crustaceana, 61(2): 175-189.

Rodrigues, S.A. 1966. Estudos sobre *Callianassa*: sistemática, biologia e anatomia. Tese de Doutorado. Universidade de São Paulo, São Paulo, 168 pp.

Schmitt, W.L., J.C. McCain & E.S. Davidson. 1973. Decapoda I. Brachyura I. Family Pinnotheridae. In: H.E. Gruner & L.B. Holthuis (eds.). Crustaceorum catalogus. W. Junk N.V, Den Hague, pp. 32-37.

Valença-Silva, G., G.L. Hirose, P. Hoffmann & M.L. Negreiros-Fransozo. 2008. Crescimento relativo e maturidade sexual de *Austinixa patagoniensis* (Rathbun, 1918) (Decapoda, Pinnotheridae) da praia de Ubatumirim, Ubatuba, SP. In: E.S. Braga (ed.). Oceanografia e mudanças globais. Instituto Oceanográfico da Universidade de São Paulo, São Paulo, pp. 245-256.

Valenti, W.C. 1984. Estudo populacional dos camarões de água doce *Macrobrachium acanthurus* (Wiegmann, 1836) e *Macrobrachium carcinus* (Linnaeus, 1758) do Rio Ribeira de Iguape (Crustacea, Palaemonidae). Dissertação de Mestrado, Instituto de Biociências da Universidade de São Paulo, São Paulo, 149 pp.

Zar, J.H. 1996. Biostatistical analysis. Prentice-Hall, New Jersey, 662 pp.

Zmarzly, D.L. 1992. Taxonomic review of pea crabs in the genus *Pinnixa* (Decapoda: Brachyura: Pinnotheridae) occurring on the California Shelf, with descriptions of two new species. J. Crust. Biol., 12(4): 677-713.

Received: 15 June 2010; Accepted: 09 May 2011