MORPHOLOGICAL MATURITY OF THE KNOBBED SPIDER CRAB, *LEUROCYCLUS TUBERCULOSUS* (H. MILNE EDWARDS & LUCAS, 1842) (BRACHYURA, MAJIDAE) IN THE NORTHERN PATAGONIAN GULFS

BY

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ABSTRACT

Sexual maturation in brachyurans has three different components: physiological, morphological, and functional. The second is visualized by examining changes in the morphometric relationships between some dimensions of the organs involved in mating and egg incubation, relative to a standard measure of size. Aiming to establish the size at morphological maturity for the Patagonian knobbed spider crab, *Leurocyclus tuberculosus*, a morphometric analysis was conducted on specimens sampled in the northern Patagonian gulfs (41°-43°S). Discontinuities were detected in ln transformed relationships of abdomen width on carapace width of females, and right chela length on carapace width of males. For females, estimated $CW_{morph}50\%$ (carapace width at which 50% of the individuals attains morphometric maturity) was 47.9 mm, and CW of the smallest ovigerous female observed in the samples was 42.7 mm. For males, a change in the growth rate of ln(ChL) relative to ln(CW) was detected at 48.9 mm CW.

RÉSUMÉ

La maturation sexuelle des brachyoures présente trois composantes différentes: physiologique, morphologique et fonctionnelle. On peut visualiser la seconde en regardant les changements dans les relations morphométriques entre certaines dimensions des organes impliqués dans la reproduction et l'incubation des oeufs par rapport à la mesure standard de la taille. Afin d'établir la taille à la maturité morphologique du crabe araignée noueux de Patagonie, *Leurocyclus tuberculosus*, une analyse morphométrique a été conduite sur des spécimens des golfes du nord de la Patagonie (41°-43°S). Des discontinuités ont été détectées avec la transformation ln de la relation entre la largeur de l'abdomen (LA) sur la largeur du céphalothorax (LC) des femelles, et la longueur de la pince droite (LPD) sur la largeur du céphalothorax (LC) des mâles. Pour les femelles, la $LC_{morph}50\%$ estimée (largeur du céphalothorax pour laquelle 50% des individus atteignent la maturité morphométrique)

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a été 47,9 mm, et LC de la plus petite femelle ovigère observée dans les échantillons a été de 42,7 mm. Pour les mâles, un changement dans le taux de croissance de ln(LPD) en relation avec ln(LC) a été détecté à 48,9 mm du LC.

INTRODUCTION

The attainment of puberty in crabs and lobsters is frequently accompanied by changes in size and form of organs involved in mating and breeding, allowing researchers to recognize reproductive phases and eventually to determine the size at morphometric maturity (Du Preez & McLachlan, 1984; Jewett et al., 1985; Plaut, 1993; Alunno-Bruscia & Sainte-Marie, 1998; García-Madrigal & Bastida-Zavala, 1998; Watters & Hobday, 1998; Sampedro et al., 1999; Schejter & Spivak, 2005; Conan et al., 2006; Hall et al., 2006). Within the brachyurans, spider crabs (Majoidea sensu Martin & Davis, 2001) have become an interesting subject to study morphometric changes associated with reproduction, since analysis of abdomen and chela allometry has revealed three or more distinct developmental phases in some species (Alunno-Bruscia & Sainte-Marie, 1998; Carmona-Suárez, 2003). This group has also captured the attention of researchers due to several particularities of their mating systems: (1) Females display a terminal puberty moult occurring at a widely variable size or even in-between different instars (Hartnoll et al., 1993; Alunno-Bruscia & Sainte Marie, 1998; López-Greco et al., 2000), but the existence of a male terminal puberty moult shows exceptions within the group (Dawe et al., 1991). (2) Mating occurs while the female's exoskeleton is calcified (hard-shell mating) (Hartnoll, 1963), still in some species the first mating event occurs immediately after the puberty moult, before the female's exoskeleton has hardened (soft-shell mating) (Donaldson & Adams, 1989). (3) After the puberty moult, males display a disproportionate enlargement of their chelae, achieving their "morphometric maturity"; yet, in natural populations, a proportion of the "morphometrically immature" males can be physiologically and behaviourally apt for mating (Sampedro et al., 1999).

The "knobbed spider crab", *Leurocyclus tuberculosus* (H. Milne Edwards & Lucas, 1842) is an amphioceanic majoid, distributed in Atlantic and Pacific waters off the coast of southern South America, living on soft bottoms with heterogeneous grain composition, from the intertidal to depths close to 60 m (Boschi et al., 1992; Spivak, 1997; Braga et al., 2002; Vinuesa, 2005). It is a conspicuous species among the brachyurans of the region (maximum carapace width $>$ 88 mm), recognized as a prey item in the diet of sharks (Capitoli et al., 1995) and octopuses (Iribarne et al., 1991). Nevertheless, no study has been published on its reproduction and very little is known about its biology (Braga et al., 2002; Santana & Marques, 2004).

The primary objectives of this work are: (1) to establish the size at morphological maturity for both sexes by analysing the allometric discontinuities of *L. tuberculosus*; and (2) to report the first estimations of size at functional maturity for females of the species.

MATERIAL AND METHODS

Leurocyclus tuberculosus specimens were collected in the northern Patagonian Gulfs, Argentina (41°-43°S 64°-65°W) from October 2002 to February 2006 using baited collapsible traps (diameter: 260 mm; length: 500 mm; mesh size: 10 mm) at depths ranging from 5 to 90 m, by SCUBA diving in the subtidal (1 to 25 m) and by manual collection in the intertidal. Sex was determined by direct observation of the abdominal region. In both sexes, maximum carapace width (CW) between two lateral protrusions of the carapace projecting over the coxae of the 2nd walking legs, and maximum length of the manus of the right chela (ChL) were measured with digital callipers to the nearest 0.01 mm. In females, the maximum width of the 4th abdominal somite (AW) was also registered. A total of 303 females (CW range = 10.24-77.32 mm) and 116 males (CW range = 12.38-88.00 mm) were used for morphometric analysis. In females, the presence of recently extruded eggs, developing embryos, or broken chorionic capsules was determined by observation under a dissecting microscope. For females, size at maturity, expressed as $CW_{morph}50\%$ (carapace width at which 50% of individuals attain morphometric maturity) was determined by analysis of a discontinuity in the relationship ln(AW) on ln(CW) using the method developed by Somerton (1980). For males, size at maturity was determined as an allometric discontinuity in the growth of ln(ChL) relative to ln(CW), detected by breakpoint regression analysis using Statistica 6.0. Additionally, CW at which the male's chelae become longer than those of the female was determined by plotting the difference between ln(ChL) observed for males and ln(ChL) estimated for females, both on ln(CW).

RESULTS

In female *Leurocyclus tuberculosus*, ln(AW) on ln(CW) displayed two distinct phases of allometric growth, corresponding to juveniles and adults (fig. 1). The smallest adult female measured 42.7 mm CW and the largest juvenile was 53.2 mm in CW. $CW_{morph}50\%$ estimated for females was 47.9 mm. The smallest and largest ovigerous females found during the study measured 42.7 and 77.3 mm, respectively.

In males, two phases of allometric growth, corresponding to juveniles and adults were delimited by a breakpoint in ln(ChL) on ln(CW) at 48.9 mm CW (fig. 2). No

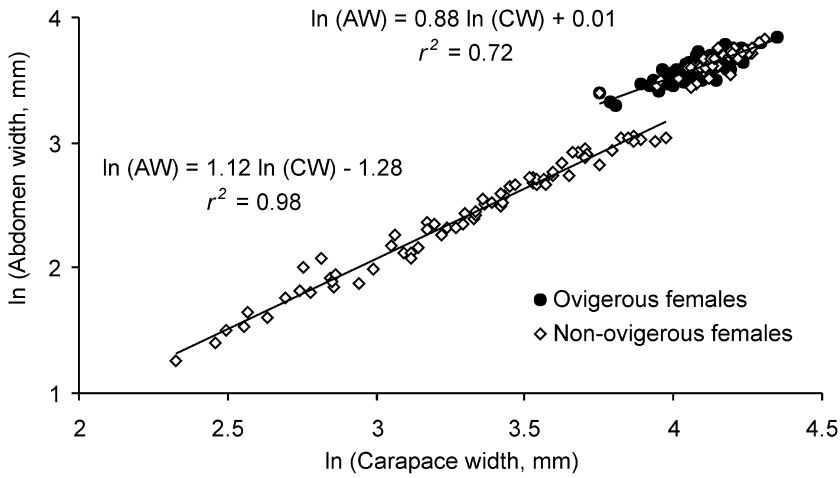

Fig. 1. Allometric discontinuity of ln(AW) on ln(CW), and regression lines fitted to data from morphologically immature and mature *Leurocyclus tuberculosus* (H. Milne Edwards & Lucas, 1842) females. AW, abdomen width; CW, carapace width.

breakpoint was found for this relationship in females. Divergence of ln(ChL) on ln(CW) of males relative to that expected for females approximately coincided with that size (fig. 2).

DISCUSSION

The estimates for size (CW) at morphological maturity reported here for *Leurocyclus tuberculosus* are similar for males (48.9 mm CW) and females (47.9 mm CW), representing 56% and 62% of the maximum observed CW for each sex, respectively. This pattern is common in several other majoid species in which transition from the juvenile to the adult phase occurs at similar or relatively close sizes in both sexes, including *Maja squinado* (Herbst, 1788) (cf. Sampedro et al., 1999), *Maja crispata* Risso, 1827 (cf. Carmona-Suárez, 2003), *Microphrys bicornutu* Latreille, 1825 (cf. López-Greco et al., 2000), and *Libidoclaea granaria* H. Milne Edwards & Lucas, 1842 (cf. Schejter & Spivak, 2005).

In our samples, the largest ovigerous female was 81% larger in CW than the smallest. Similarly, the CW of the largest male was 80% larger than our estimation of CW at maturity. Data available for other majids suggest that CW increments at the maturity moult do not exceed 40%, for both males and females (Tunberg & Creswell, 1991; González-Gurriarán et al., 1995; Paul & Paul, 1996; Hartnoll & Bryant, 2001; Hébert et al., 2002). Therefore, size differences between the largest and smallest mature individuals are large enough to suspect that these hardly belong to the same instar. This seems to contradict the generally accepted notion

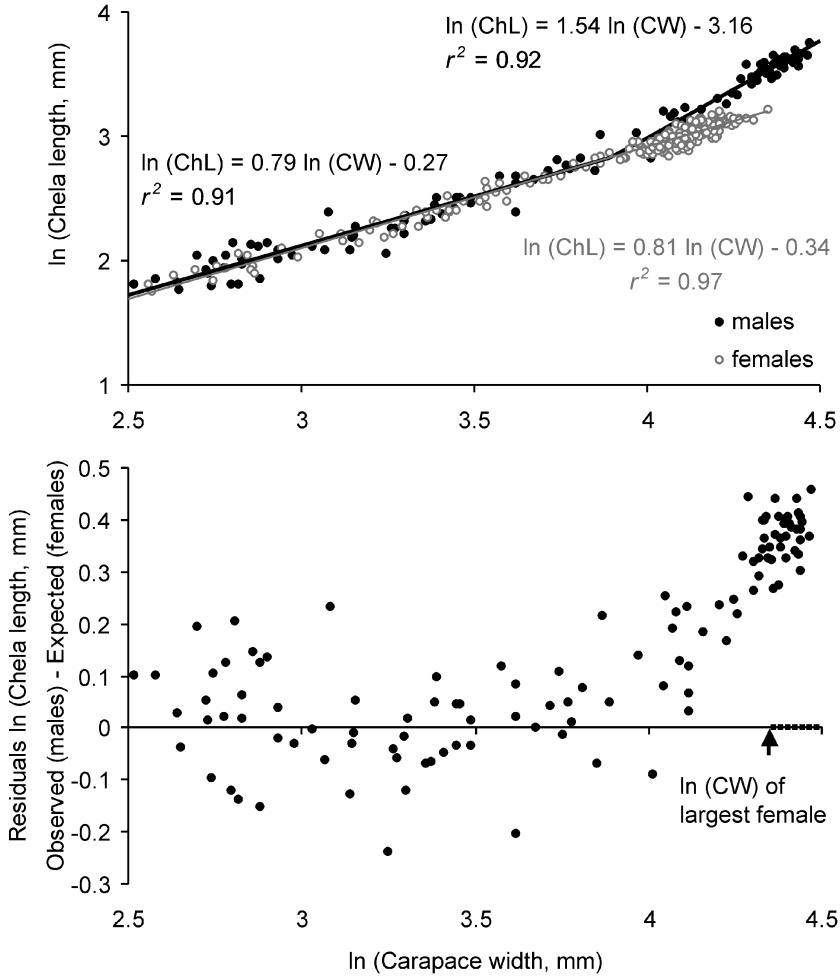

Fig. 2. Top, allometric discontinuity of ln(ChL) on ln(CW), and regression lines fitted to data from morphologically immature and mature *Leurocyclus tuberculosus* (H. Milne Edwards & Lucas, 1842) males (black lines and dots) and from females (grey line and dots); bottom, deviations of observed male ln(ChL) on ln(CW) relationship data from expected values obtained for females by fitting a rectilinear regression model to the data. ChL, chela length; CW, carapace width.

that within the Majoidea individuals reach maturity at their terminal pubertal moult (Hartnoll, 1963; Alunno-Bruscia & Sainte-Marie, 1998; Sampedro et al., 1999). Still, in some spider crabs the transition from juvenile to adult occurs when the animals are moulting to different instars, resulting in a wide size range of mature individuals being found in the population. This is the case in the snow crab, *Chionoecetes opilio* (O. Fabricius, 1788), in which the terminal puberty moult can occur when females moult to instar VIII, IX, or X (Alunno-Bruscia & Sainte-Marie, 1998). Whether *Leurocyclus tuberculosus* reaches its puberty when

moulting to one particular instar or not is still to be established. However, if the species has a terminal pubertal moult, the wide size range found in this study for ovigerous females and morphometrically mature males suggests that variation in the instar at the puberty moult is the most likely.

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