Growth Patterns of *Portunus spinicarpus* (Stimpson, 1871) (Decapoda, Portunoidea) from Ubatuba region (SP), Brazil.

Corbi-Corrêa[2], E. and Fransozo[1], A.

[1] NEBECC (Group of Studies on Crustacean Biology, Ecology and Culture) Departamento de Zoologia, IBB/UNESP, 18618-000 Botucatu (SP), Brasil
[2] e-mail: yaralu@ig.com.br

Abstract

The allometric growth of secondary sexual characters in *Portunus spinicarpus* is investigated from early juvenile stages. The specimens were collected monthly using a shrimp fishery boat and measurements of carapace width (CW) and length (CL), width of female fifth (5FW) and sixth (6SW) abdominal somites, chela carpus plus spine length (CS), and chela propodus length (PL) were taken. Regressions were performed according to the formula $Y=aX^b$ and student´s t-test was applied to evaluate the allometric growth constant. Size at puberty molt in both sexes was estimated using Somerton´s software. This technique detected a puberty molt at 27.15 CW and 27.30 of CW for females and males, respectively. Visible sexual dimorphism is restricted to abdominal morphology, but ANCOVA analyses showed that PL for males become larger after the puberty molt. An intermediate morphology of the female abdomen, between the triangular juvenile formt and the adult form was identified. Only the measurement of female fifth abdominal somite identified this intermediate form.The difference in size at onset of sexual maturity of specimens from Brazil and other regions is discussed in light of heterochronic processes, environmental conditions and misidentification.

Key words: relative growth, sexual maturity, Decapoda, Portunoidea.

Introduction

During growth, organisms exhibit changes in the proportions of some structures as a response to differential growth rates; this is relative, allometric or heterogonic growth (Hartnoll, 1985). In crustaceans, these changes may occur gradually throughout ontogeny or abruptly over a single molt, such as that between the final larval and the first post-larval instar, or between the final immature and first mature instar in Brachyurans.

The first studies concerning relative growth in crustaceans date from the early decades of last century (*e.g.,* Huxley and Richards, 1931). Since then, many ecological and fishery studies of brachyurans have provided estimates of size at onset sexual maturity (*e.g.,* Hartnoll, 1972; Campbell and Eagles, 1983; Gherardi and Micheli, 1989; Haefner, 1990; Pinheiro and Fransozo, 1993). Those studies provide the data required to estimate potential breeding stocks and the time necessary to produce them. This information is important not only for commercially exploited species, but also for the conservation and management of stocks in nature.

Allometric trends characteristic for higher taxonomic groups (*i.e.,* genus and families) are usually established after analyzing of a few species only within such a group. However there is considerable variation in relative growth patterns within the groups for which a given "trend" has been postulated. The same limitation is applicable to species analyzed from just one or a few populations, especially when they share the same environment. This may obscure population changes due to different environmental conditions (*e.g.,* Reilly, 1987). To date, although we have considerable amount of information on relative growth in decapod crustaceans, allometric trends will only be understood, and could only be postulated in respect to pattern analyses within a phylogenetic context. Additionally, relative growth could be applied to systematics, since morphometric analyzes allows quantitative estimation of morphological disparity, which could be used as cladistic characters.

The relative growth of *Portunus spinicarpus* (Stimpson, 1871) is investigated herein, and the evidence of the size at onset of sexual maturity among populations is also considered. Comparisons are made with previous descriptions, sexual dimorphism is evaluated, and differences in relative growth and maturity among populations are interpreted in the light of intraspecific heterochronic processes.

Materials and Methods

Specimens of the swimming crab *P. spinicarpus* were obtained during monthly collections over a one-year period (from July 2000 to August 2001), using a fishery boat provided with a double rig net, in the Ubatuba region of Brazil (23° 32´ S, 44° 44´ W). Seven transects were covered monthly at depths of 5, 10, 15, 20, 25, 30, and 35 m. The total area sampled in each transect was 18.000 m^2.

Larger crabs were easily sexed by abdominal shape while smaller crabs (10 mm CW= carapace width), were examined under a dissecting microscope for presence of pleopods or gonopods. Measurements were taken (Table I) using calipers with a accuracy of 0.01 mm. Measured dimensions are illustrated in figures 1 and 2. All crabs had their gonads observed for preliminary inferences on physiological sexual maturation.

The allometric equation, $Y = aX^b$ (Huxley, 1950 *apud* Hartnoll, 1974), was used to estimate the allometric growth of all the dimensions with respect to carapace width. The relationships obtained were linearized to the form $\ln Y = \ln a + b \ln X$, and the computer programs Mature I (Somerton, 1980) and Mature II (Somerton 1983) were used to delimit growth phases in those cases where fitting more than a single regression line provided a significant decrease of total residual sum of squares. Determination coefficients and Student's *t*-test for departures from isometry (Sokal and Rohlf, 1979) were calculated for all relationships obtained. Analyses of covariance (ANCOVA) were performed to compare slopes in neperian logarithm (ln) data of all regressions among males and females different phases of life. Significance of F ratios was determined at the 0.05 level.

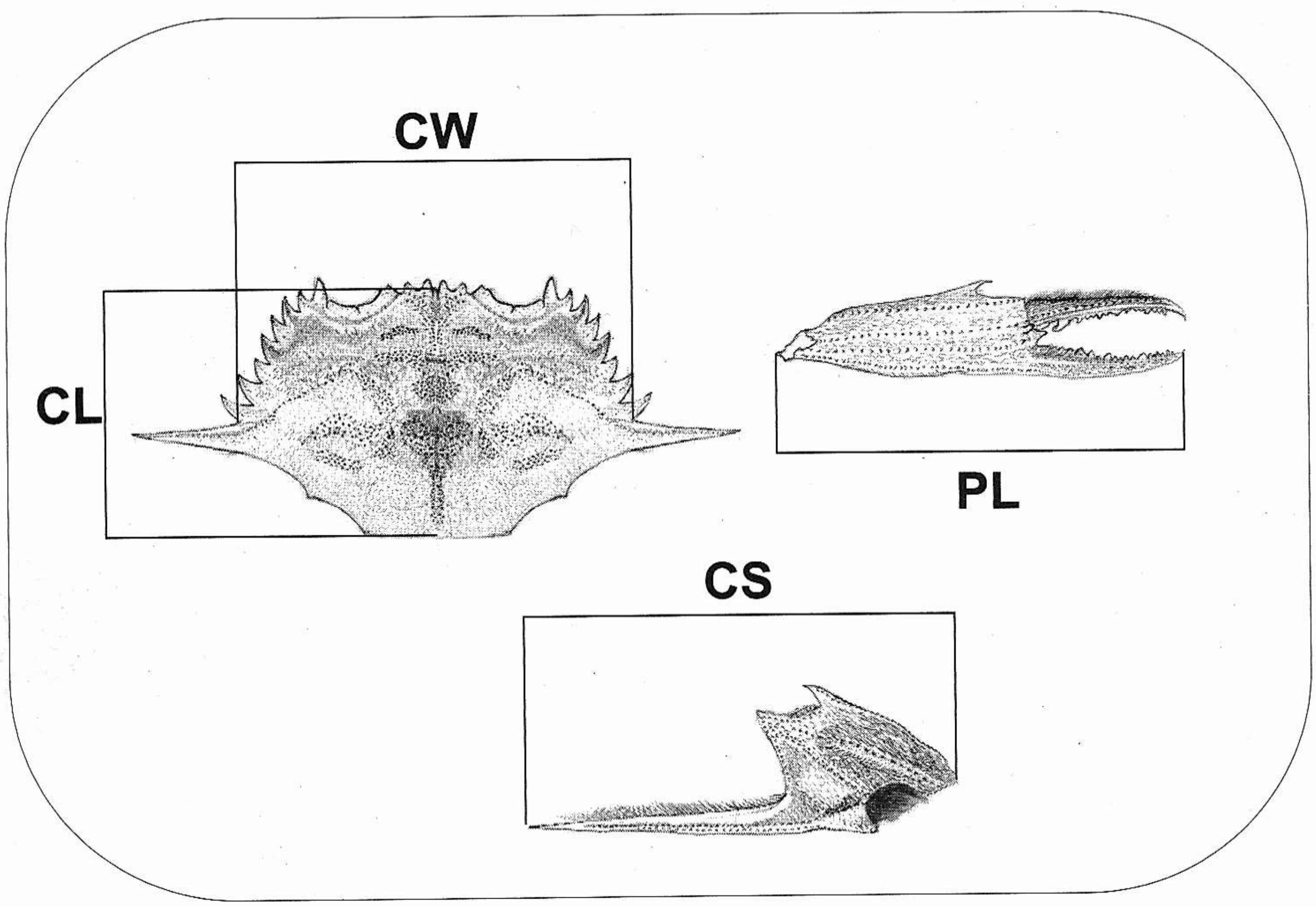

Figure 1: *Portunus spinicarpus* (Stimpson, 1871). Illustrated dimensions propodus length (PL), carpus length (CS), carapace width (CW), carapace length (CL).

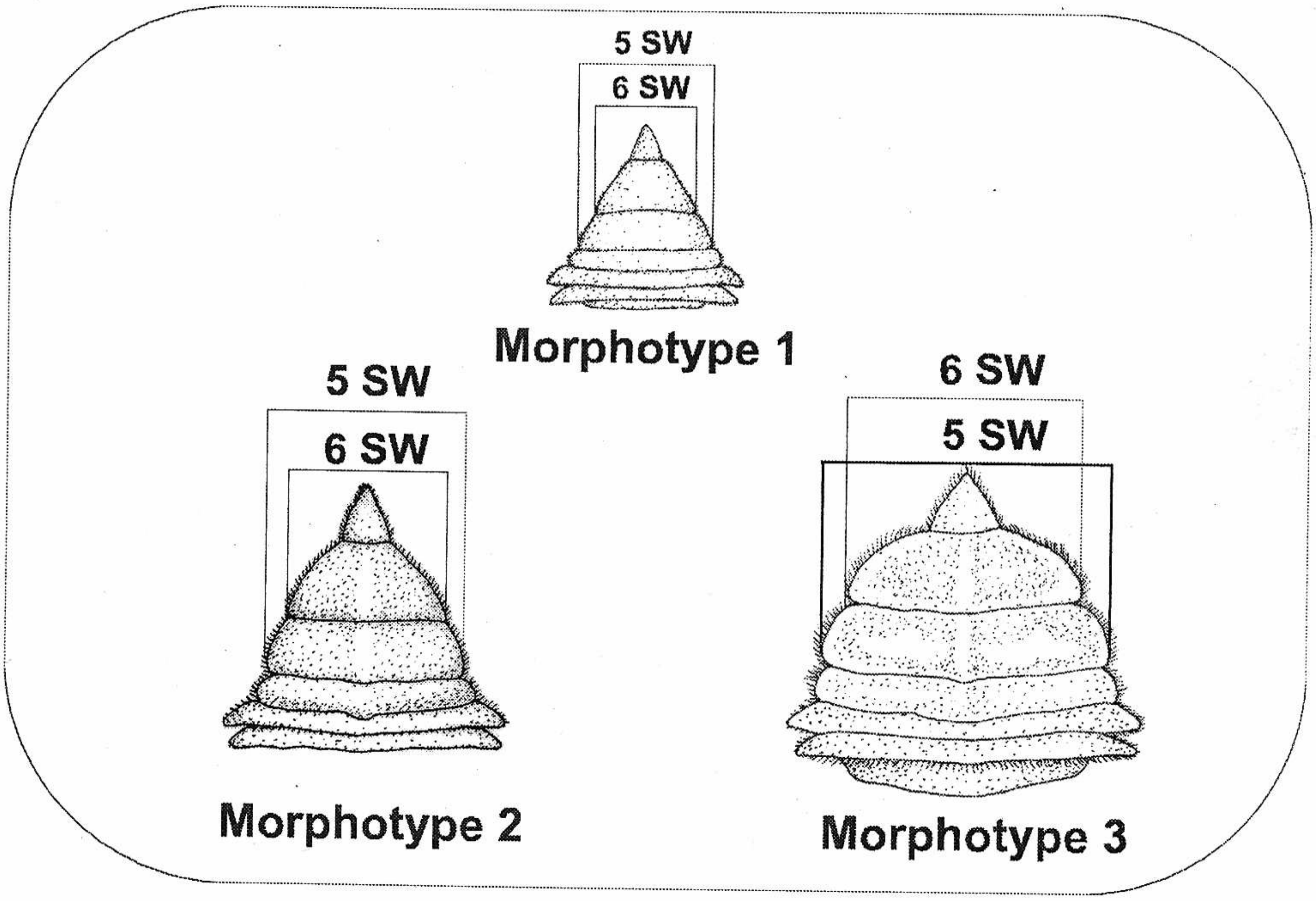

Figure 2: *Portunus spinicarpus* (Stimpson, 1871). Illustration of the three abdominal morphotypes found in females of *Portunus spinicarpus*. (5SW, fifth somite width; 6SW, sixth somite width)

Table I: Morphometric dimensions measured in each specimen of *P. spinicarpus*

SYMBOL	DESCRIPTION
CL	Carapace length, measured from basal region between frontal teeth until the post - median margin
CW	Carapace width , measured between the bases of lateral spines
5SW	Greatest width of fifth abdominal somite
6SW	Greatest width of sixth abdominal somite
PL	Length of right propodus
CS	Length of the right carpus from the base to the top of its spine

Results

A total of 529 males and 497 females over a wide size range (from 8.00 mm to 52.00 mm of CW) was analyzed. All relations, numbers of specimens and linearized allometric expressions followed by the power functions, the r^2 (%) values, and the allometric level of each relation are given in table II.

The application of Mature software I and II demonstrated the attainment of morphological sexual maturity for females and males at 27.15 mm and 27.30 mm CW, respectively. Three morphotypes of female abdominal shape were observed in the field and used in this study: morphotype 1 (m1) – from the smallest female to 21.00 mm CW; morphotype 2 (m2) – from 21.00 mm to 27.15 mm CW; and morphotype m3 (m3) – those with CW greater than 27.15. This distinction was corroborated by morphometric relationships between CW *vs.* CL and CW *vs.* 5SW; the latter distinguishing all three phases. Crabs with initial gonad development measured around 29.00 mm CW for both sexes. The size range of ovigerous females was 29.50 mm to 45.4 mm CW.

Carapace length (CL) – Overall allometric growth in males, this relation was the only one isometric. As far as females are concerned, morphotype 1 (m1) showed positive allometric growth with b = 1.34, while in morphotypes 2 (m2) and 3 (m3) growth was isometric, with b = 1.05.

Carpus plus spine length (CS) – Males and females showed positive allometric growth with the allometry level increasing from pre-puberal specimens to mature ones. Males presented a higher increase of slope (17 %) when compared to females (12 %). The inflection point for females and males followed Somerton´s results (figures 3 and 4).

Propodus Length (PL) – This dimension showed no modification in growth rate for females and a positive allometry through the analyzed size range. As for males, it was observed an inflection in the scattered data plot where CW = 27.30 mm as given by Mature II (figure 5).

Abdominal Width (5SW and 6SW) – The size of the fifth abdominal somite in females was the most useful for estimating morphological sexual maturity and differences in growth rates before the puberty molt. Rates for all morphotypes were different with an increase in the allometry level from morphotype 1 to 2, and from 2 to 3. The smallest mature female and the biggest immature one measured the same in both relations. Nevertheless, 6SW morphotype 1 and 2 females showed no statistical differences in growth rates and a positive allometric growth. At puberty molt, the rate of 6SW is increased with slopes going from 1.41 to 1.53 (figure 6).

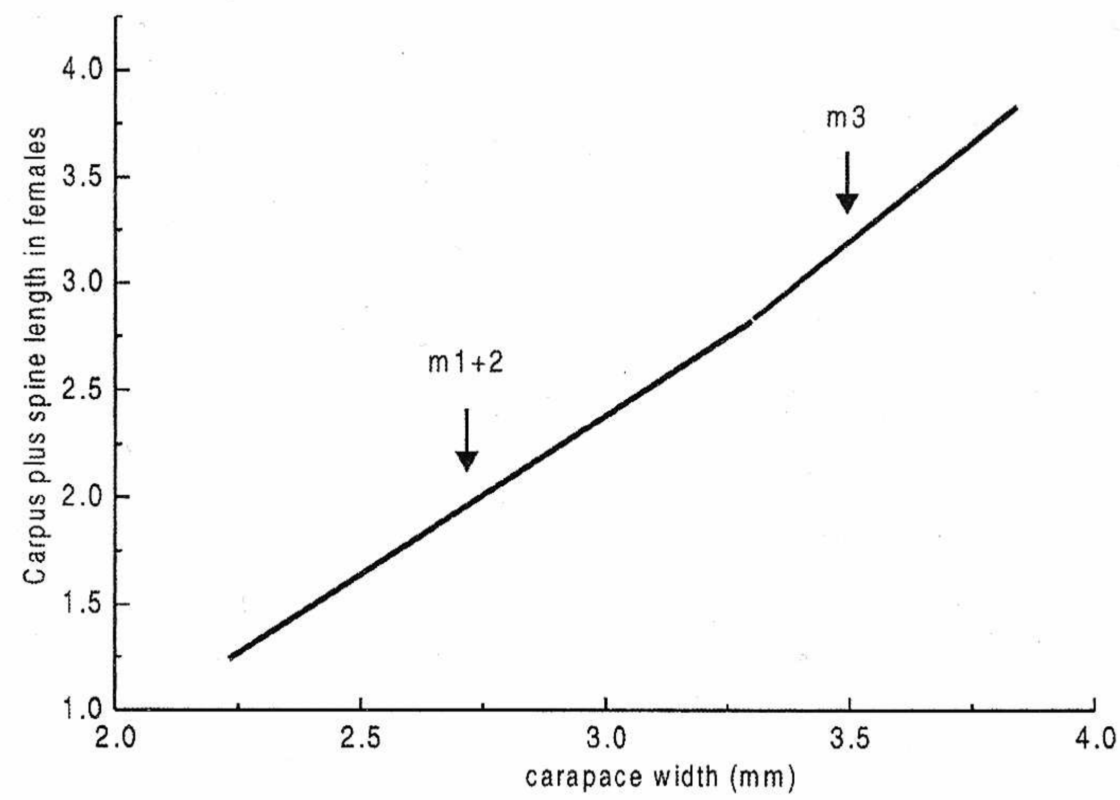

Figure 3: *Portunus spinicarpus* (Stimpson, 1871). Allometric relationship between CW and CS in females.

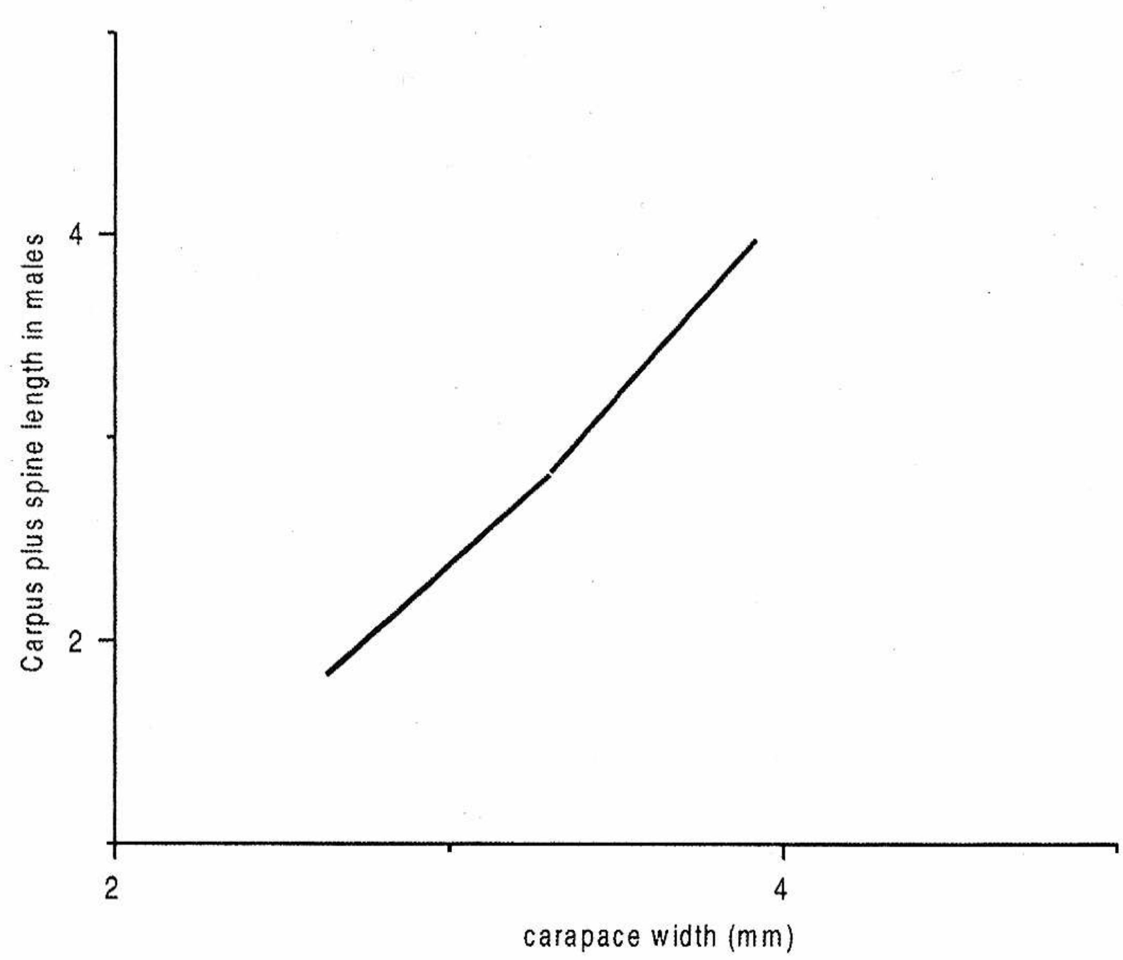

Figure 4: *Portunus spinicarpus* (Stimpson, 1871). Allometric relationship between CW and CS in males.

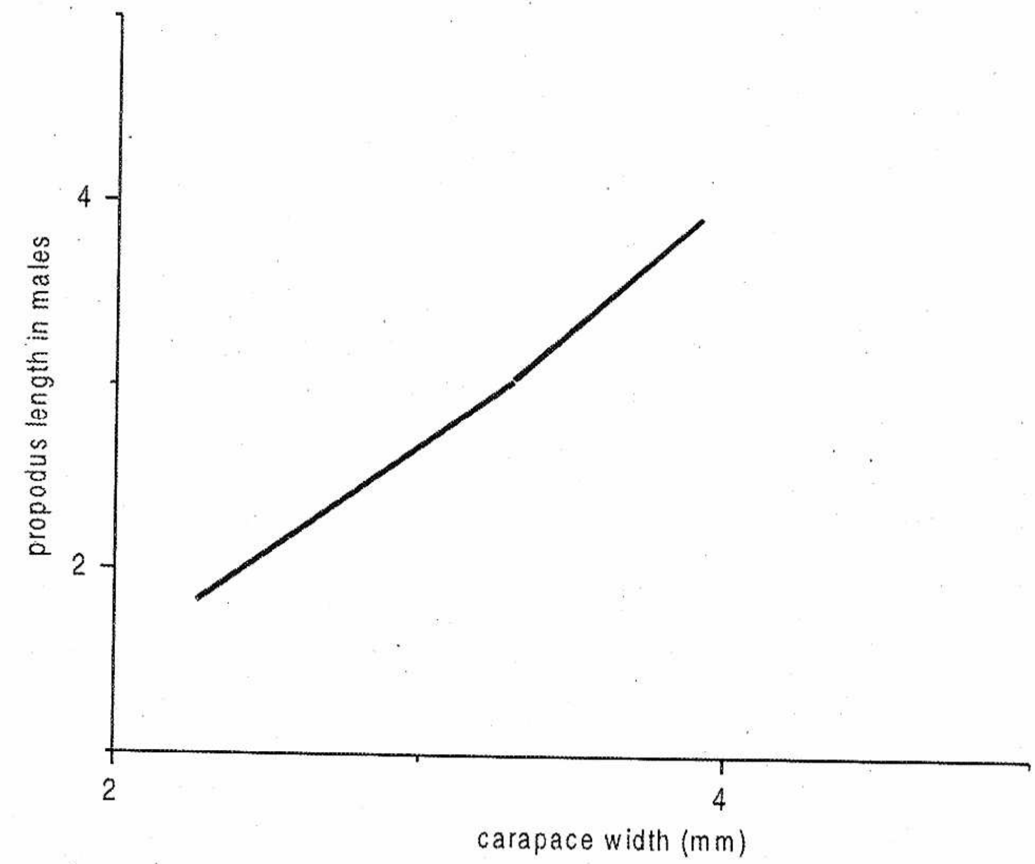

Figure 5: *Portunus spinicarpus* (Stimpson, 1871). Allometric relationship between CW and PL in males.

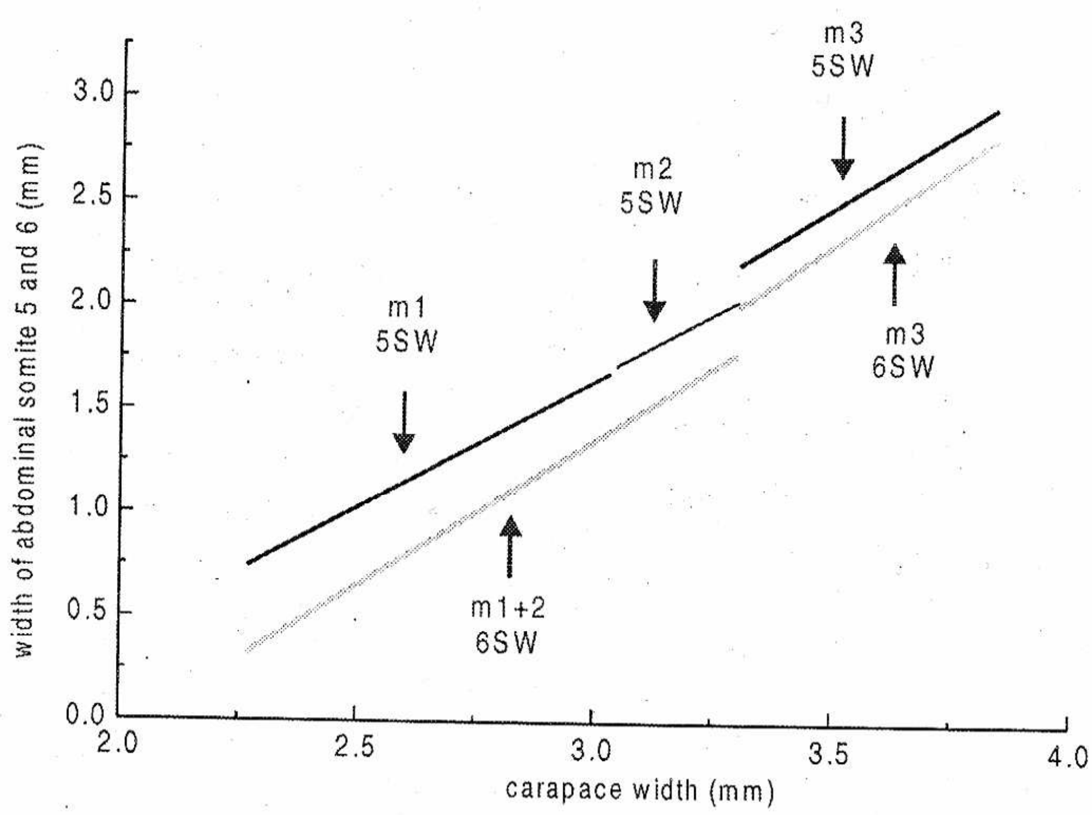

Figure 6: *Portunus spinicarpus* (Stimpson, 1871). Allometric relationship between CW and 5SW and between CW and 6SW in females.

Table II: Regression analysis of morphometric data of *Portunus*, in Ubatuba region, SP/ Brazil.

Variable	Group	N	lnY=lna+b.lnx	Power Function	R^2 (%)	Allometry
	M (T)	527	$CL = 0.60\ CW^{1.00}$	lnCL = 1.00lnCW - 0.50	99	=
CL	F (m1)	112	$CL = 0.10\ CW^{1.58}$	lnCL = 1.58lnCW - 2.24	88	+
	F (m2) + (m3)	381	$CL = 0.50\ CW^{1.05}$	lnCL = 1.05lnCW - 0.67	96	=
	M (J)	198	$CS = 0.14\ CW^{1.44}$	lnCS = 1.44lnCW - 1.95	95	+
	M (AD)	128	$CS = 0.02\ CW^{1.93}$	lnCS = 1.93lnCW - 3.55	94	+
CS	F (m1) + (m2)	197	$CS = 0.12\ CW^{1.48}$	lnCS = 1.48lnCW - 2.06	93	+
	F (m3)	129	$CS = 0.03\ CW^{1.86}$	lnCS = 1.86lnCW - 3.31	93	+
	M (J)	194	$PL = 0.43\ CW^{1.17}$	lnPL = 1.17lnCW - 0.83	96	+
PL	M (AD)	123	$PL = 0.18\ CW^{1.43}$	lnPL = 1.43lnCW - 1.68	95	+
	F (m1) + (m2) + (m3)	437	$PL = 0.50\ CW^{1.11}$	lnPL = 1,11lnCW - 0.67	98	+
	F (m1)	49	$5SW = 0.12\ CW^{1.23}$	Ln5SW = 1.23lnCW - 2.05	93	+
FW	F (m2)	191	$5SW = 0.11\ CW^{1.26}$	ln5SW = 1.26lnCW - 2.12	86	+
	F (m3)	137	$5SW = 0.08\ CW^{1.42}$	ln5SW = 1.42lnCW - 2.48	95	+
SW	F (m1) + (m2)	214	$6SW = 0.05\ CW^{1.41}$	Ln6SW = 1.41lnCW - 2.87	96	+
	F (m3)	132	$6SW = 0.04\ CW^{1.53}$	ln6SW = 1.53lnCW - 3.05	94	+

F, female; M, male; T, total; m1, m2, m3, morphotypes 1, 2, and 3, respectively; J, juvenile; AD, adult.

Discussion

Abdominal morphology is clearly the best character for observing sexual dimorphism in *P. spinicarpus*. However, the propodus length in males and the carpus plus spine length in both sexes should also be considered as a secondary sexual characteristic, changing proportions after the maturation molt. Crabs smaller than 20.00 mm CW cannot be sexed unambiguously unless they have their abdomen opened and the presence or absence of pleopods observed.

It has been inferred that the lack of clearly dimorphic chelae might be related to particular patterns of intraspecific interactions (*e.g.*, Flores and Negreiros–Fransozo, 1999). Also, the larger chelae of males and the more rounded abdomen of females have been considered as adaptations to agonistic and mating behavior for males and for carrying eggs in females (see Swartz, 1972 *apud* Lewis 1977; Hartnoll,1974; Finney and Abele, 1981; Gherardi and Micheli, 1989; Santos *et al.*, 1995). Nevertheless, although allometric growth of chelae of males and abdomen of females may provide selective advantages, they also may reflect adaptations and should to be tested in context of a phylogenetic hypothesis.

The relations, CW *vs.* CS, CW *vs.* 5SW and CW *vs.* 6SW were the most useful for the identification of morphological sexual maturity in females. The relation CW *vs.* 5SW was the only one allowing for the differentiation of three growth models with an increase of allometry from m1 to m3. This indicates females of *P. spinicarpus* go through a pre-puberty molt in the size range from CW = 21.00 to CW = 27.15 mm. The three phases observed in this relation, showed three different abdominal morphotypes. The small range in which the lines established for 5SW growth overlap, indicates that the relation with CW was an accurate indicator of morphological sexual maturity. As for males (figures 4 and 5), the relations CW *vs.* CS and CW *vs.* PL clearly showed the inflection point at which males attain maturity.

It is not yet clear when *P. spinicarpus* becomes physiologically sexually mature, however, field observations and dissection of many specimens (in order to observe gonad maturation) suggest it is achieved around 30.00 mm CW in both sexes. Hence, morphological and physiological sexual maturation occur virtually simultaneously. On the other hand, Williams (1984) reported ovigerous females of *P spinicarpus* of 18.00 mm CW. This suggests either the existence of a sibling species or that physiological maturation of gonads is achieved at a different CW among populations. Consequently, either abdominal morphotype 2 is suppressed from ontogeny or it acts as a mature morph in these populations.

These changes can be attributed to differences in environmental conditions such as water temperature (Campbell and Fielder, 1986). Nevertheless, irrespective of the cause, the result is an alteration of a heterochronic pattern. The process involved is isogenesis, which is characterized by individuals, usually from different populations, achieving a certain offset shape over different trajectories (Reilly *et. al.*, 1997). In this case, gonad maturation is attained by all organisms, but through different pathways.

Further studies on allometric growth of *P. spinicarpus* are required in order to establish growth patterns and variation ranges between different populations. Identifying the main factors, which are affecting the achievement of maturity, will be of great value in understanding the reproductive biology of these organisms.

Acknowledgements

We are grateful to the "Fundação de Amparo à Pesquisa do Estado de São Paulo" (FAPESP) for providing financial support (≠ 94/4878-8; 98/3134-6) and BIOTA/FAPESP (≠ 98/07090-3). We are also thankful to the NEBECC co-workers for their help during field work.

References

Campbell, A. and Eagles, M. D., 1983. Size at maturity and fecundity of rock crabs, *Cancer irroratus*, from the Bay of the Fundy and Southwestern, Nova Scotia. Fishery Bulletin, 81 (2): 357 – 362.

Campbell, G. R. and Fielder, D. R., 1986. Size at sexual maturity and occurrence of ovigerous females in three species of commercially exploited portunid crabs in S. E. Queensland. Proceedings of Biological Society of Queensland. 97: 79 – 87.

Flores, A. and Negreiros-Fransozo, M. L. 1999. Allometry of the secondary sexual characters of the shore crab *Pachygrapsus transverses* (Gibbes, 1850) (Brachyura, Grapsidae). Crustaceana 72 (9): 1051 – 1066.

Finney, W. C. and Abele, L. G. 1981. Allometric variation and sexual maturity in the obligate coral commensal *Trapezia ferruginea* Latreille (Decapoda, Xanthidae). Crustaceana 41(2): 113 – 130.

Gherardi, F. and Micheli, F. 1989. Relative growth and population structure of the freshwater crab, *Potamios palestinensis*, in the Dead Sea area (Israel). Israel Journal of Zoology, 36: 133-145.

Haefner, P. G. Jr. 1990. Morphometry and size at maturity of *Callinectes ornatus* (Brachyura, Portunidae) in Bermuda. Bulletin of Marine Science., 46(2): 274-286.

Hartnoll, R. G. 1972. The biology of the burrowing crab, *Corystes cassivelaunus*. Bijdragen tot de DierKunde, 42(2): 139-155.

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. 1985. Growth, sexual maturity and reproductive output. In: Wenner, A. M. (ed.). Factors in adult growth. A. A. Balkema/ Rotterdam/ Boston. , 1: 101-128.

Huxley, J. S., 1950. Relative growth and form transformation. Proceedings of the Royal Society of London. 197: 465 – 469.

Huxley, J. S. and Richards, S. O. W. 1931. Relative growth of abdomen and the carapace of the shore-crab *Carcinus maenas* fourn. Marine Biology Association, XVII (3): 1001-1015.

Lewis, E. G. 1977. Relative growth and sexual maturity of *Bathynectes superbus* (Costa) (Decapoda: Portunidae). Journal of Natural History, 11: 629-643.

Magniez-Jannin, F., David, B., Dommergues, J., Zhi-Hui, S. and Osawa, S. 2000. Analyzing disparity by applying combined morphological and molecular approaches to French and Japanese carabid beetles. Biological Journal of the Linnean Society, 71: 343 – 358.

Pinheiro, M. A. A. and Fransozo, A. 1993. Relative growth of the speckled swimming crab *Arenaeus cribrarius* (Lamarck, 1818) (Brachyura, Portunidae), near Ubatuba, state of São Paulo, Brazil. Crustaceana, 65 (3): 377 – 389.

Reilly, S. M. 1987. Ontogeny on the hyobranchial apparatus in the salamanders *Ambystoma talpoideum* (Ambystomatidae) and *Notophthalmus viridescens* (Salamandridae): The ecological morphology of two neotenic strategies. Journal of Morphology, 191: 205 – 214.

Reilly S. M., Wiley E. O. and Meinhardt D. J. 1997. An integrative approach to heterochrony: the distinction between interspecific and intraspecific phenomena. Biological Journal of the Linnean Society, 60: 119 – 143.

Santos, S., Negreiros-Fransozo, M. L. and Fransozo, A. 1995. Morphometric relationships and maturation in *Portunus spinimanus* Latreille, 1819 (Crustacea, Brachyura, Portunidae). Revista Brasileira de Biologia, 55 (4): 545 – 553.

Sokal, R. R. and Rohlf, F. J. 1979. Biometria. Princípios e métodos estadísticos en la investigación biológica. H. Blume Ediciones, Madrid. 832p.

Somerton, D. 1980. A computer technique for estimating the size of sexual maturity in crabs. Canadian Journal of Fishery and Aquatic Science., 37: 1488 – 1494.

Somerton, D. 1983. The size at sexual maturity of the blue king crab, *Paralithodes platypus*, in Alaska. Fishery Bulletin. 81 (3): 621 – 628.

Williams, A. B. 1984. Shrimps lobsters, and crabs of the Athlantic coast of the eastern United States. Main to Florida. Smithsonian Institution Press – Washington. 550p.

Zar, J. H. 1996. Biostatistical Analysis. Third Edition. Prentice Hall, New Jersey, 607p.

Received: 04th Dec 2002
Accepted: 13th Feb 2003