Morphometry and relative growth of *Corystoides abbreviatus* (A. Milne Edwards, 1880) (Decapoda: Brachyura: Belliidae) in marine waters of Argentina

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Abstract

Corystoides abbreviatus is a littoral crab species endemic of the southwestern Atlantic Ocean, present in Argentina, Uruguay and southern Brazil. The population structure, morphometric relationships, relative growth and sexual dimorphism in the coastal population close to Mar del Plata (38°S), Argentina, were analyzed. A total of 259 specimens (157 males and 102 females) were measured. Sex ratio was skewed toward males (χ^2 test =86.2). Males were larger (up to 30 mm CW) than females (up to 24.9 mm CW). Minimum size for ovigerous females was 16.8 mm CW while the smallest female with presence of spermatozoa in their spermatheca measured 12.8 mm CW. Growth of the abdomen in females was positively allometric. Males showed fusion of the III-V abdominal somites. The 75.6% of the males had the right cheliped larger than the left one and it grew in positive allometry. Females were isochelic while males were heterochelic. These results will provide basic information useful for future biological, behavioral and ecological studies of this species with the aim to compare it with the closest species *C. chilensis* from Southeastern Pacific Ocean.

Key words: *Corystoides*, allometry, heterochelia, sexual dimorphism

Introduction

Corystoides abbreviatus A. Milne Edwards, 1880 is a littoral brachyuran crab species belonging to the Bellidae family. It is found buried in muddy-sand substrates in marine coastal waters up to 18 m depth, being Uruguay its type locality (Guinot, 1976; Boschi *et al.*, 1992; Melo, 1996). This species is endemic of the Southwestern Atlantic Ocean and it is present in the Argentinean Province (Boschi, 2000) from Rio de Janeiro, Brazil (Melo, 1996), Uruguay (Zolessi and Philippi, 1995) to the Buenos Aires Province in Argentina (Boschi, 1964). Larval development of *C. abbreviatus* (as *C. chilensis*) includes four zoeae and the megalopa (Boschi and Scelzo, 1970). According to Guinot (1976) the genus *Corystoides* is characterized by a strong heterochelia in males, and heterodontia, but no specific information was found for females.

Hartnoll (1982) divided post-larval brachyuran growth into three phases (undifferentiated, juvenile and adult) based on the differentiation of secondary sexual characters, which may occurs gradually (after various molts) or abruptly. In a number of brachyuran crab species, the most obvious morphological change throughout the male growth is the development of chelipeds and gonopods. In females, by contrast, observable morphological changes occur in the abdomen where the embryonic eggs are attached to the pleopods until hatching. Those changes are quantified throughout morphometric studies based primarily on changes in relative growth rates or allometric levels of different variables. Studies are mostly based on morphological, morphometric, physiological (gonad maturation) and behavioral criteria (Sampedro *et al.,* 1999).

The family Bellidae has few members (Guinot, 1976) and unfortunately, no morphometric studies on other species are available to the present. The present study analyzes the relative growth and morphology of males and females, and size-weight relationships of *C. abbreviatus*. The proposed analysis will contribute to determine pattern of relative growth and to define the morphometric and/or morphological criteria necessary to assign individuals to the different phases in the population of the species that inhabits the Southwestern Atlantic coastal waters of the Buenos Aires Province, Argentina. These results will also provide basic information useful for future biological, behavioral and ecological studies of this species with the aim to compare it with the closest species *C. chilensis* from the Southeastern Pacific Ocean.

Materials and methods

Specimens were obtained in the Mar del Plata - Mar Chiquita coastal area, Argentina (38°S), between years 1998-2002 (Scelzo *et al.*, 2002). Individuals were captured by means of a beam trawl at depths between 4 - 15 meters. Crabs were transported to the laboratory, individually numbered and preserved in 10% formalin. Sea water temperature was measured using a mercury thermometer (±0.1°C) and salinity with a compensated salinity refractometer (±1 psu). Granulometry of the substrate was made by sieve analysis (Ingram, 1971). Organic matter was determined according to Walkley and Black (1965).

Biological variables analyzed: Variables measured in both sexes (Figure 1 A, B, C, D) were: Carapace width (CW), the widest part of the carapace behind the latest lateral spine on the carapace cephalotorax; Carapace length (CL), measured from the tip of the rostral spine to the posterior edge of the cephalotorax; Cheliped length (ChL) as the propodus length of the right and left chelipeds, measured from the base of the carpal insertion to the apex of the fixed finger. Cheliped height (ChH), maximum propodus height from the point immediately posterior of the insertion of the dactylus. In males, discriminated between major (MChH) and minor (mChH); Cheliped width (ChW), the greatest width of the propodus width. In males, discriminated between major (MChW) and minor (mChW); Abdomen width (AW) in males, the narrowest part of the fused pleonites III-V, around the limit between IV and V segment. In females, the widest part located in the distal border of pleonite IV.

According to Harnoll (1982), heterochelia is the situation where the claws on opposite sides of the body differ in size, shape, and often in function. Heterodontia was defined by the presence of molar tooth in the major cheliped. Number of teeth of molar tooth (MT) was counted as the individual numbers of teeth that compose the molar tooth. Individuals with missing chelipeds or pereiopods were not considered.

Body dimensions were measured using an ocular piece on a microscope and/or a vernier caliper (± 0.1 mm accuracy), and the wet weight (WW), by means of a digital balance 0.001 g accuracy. Besides gonopods, males were differentiated from females by the presence of a narrow abdomen and fused pleonites III-V (Boschi, 1964). Females were divided into ovigerous and non-ovigerous subsets based on the presence or absence of eggs masses.

According to Emmerson (1994) and López-Greco and Rodriguez (1999), functional maturity is here defined by the presence of eggs in females and spermatophores in the *vasa deferentia* of males. Crabs were dissected under a binocular microscope and the *vasa deferentia* were stained with toluidine blue or Rose Bengal solution. Squash preparations of *vasa deferentia* were microscopically observed for the existence of sperm cells in males to correlate their presence with morphological data as a sign of (physiological) maturity (Haley, 1973; Haefner, 1990). Size classes were grouped in 2 mm interval, starting at 6 mm CW, the minimum size of specimens captured. Sexual dimorphism was assessed comparing the major cheliped (right or left) of males to those of females.

Regression equations (log-transformed data) were calculated for both sexes on abdomen width and length, height and width of chaelipeds as function of CW. Allometry was tested by Student's t-test (Clayton, 1990). The allometry was detected based on a relative growth constant, and was defined as isometry (b= 1), positive allometry (b>1) and negative allometry (b<1). The allometry of weight was tested against a constant= 3 (Mantelatto and Martinelli, 1999). Regression parameters were compared by analyses of covariance (ANCOVA) (Zar, 1999) using CW as the covariate. Differences in size and laterality between chelipeds in females were tested using Wilcoxon Signed Rank Test (Zar, 1999). Significance was determined at α= 0.05 level for all tests.

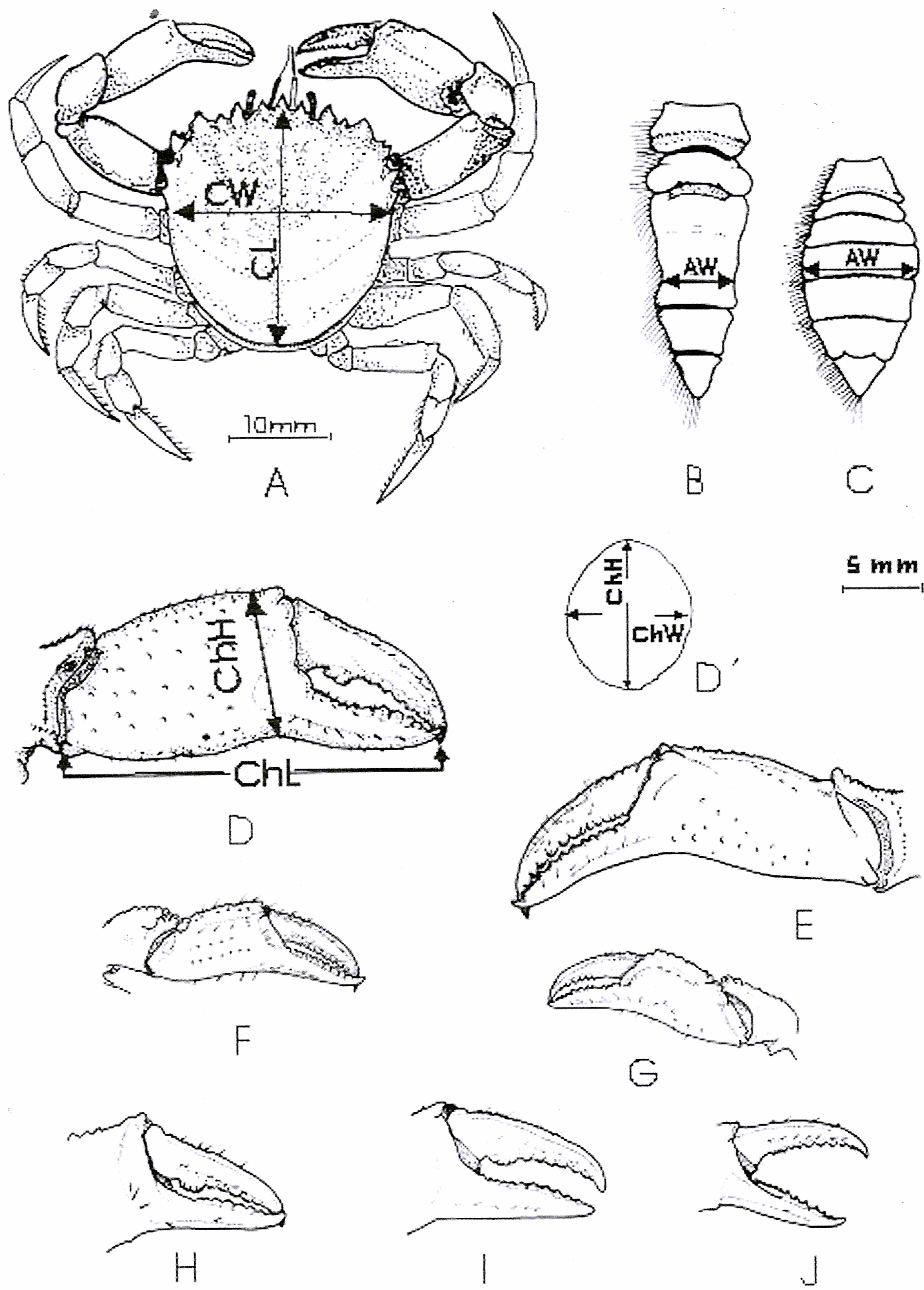


Figure 1: *Corystoides abbreviatus* measurements: A: Male specimen (CW= carapace width, CL= carapace length). B: Male abdomen. C: Female abdomen (AW= abdomen width). D: Male right cheliped (CW= 27.1 mm), (ChL= cheliped length, ChH= cheliped height). D´: Cross section (ChW= cheliped width, ChH= cheliped height). E: Male left cheliped (CW= 27.1 mm). F: Right and G: Left female cheliped, (CW= 18.7 mm). H: Male major (right) cheliped (CW= 13.5 mm). I: Male major (right) cheliped (CW= 19.9 mm). J: Male major (right) cheliped (CW= 19.1 mm). Scale bar fig A = 10mm, Scale bar figs. B, C, D, E, F, G, H. I. J = 5 mm.

Results

Environmental conditions:

The substrate was sandy bottom composed by 90% of psamites, 50% of them of fine sand, and 0.38% of organic matter. Recorded superficial water temperatures oscillated between 9.5 °C in winter (June-July) and 21 °C during summer (January-February). Salinity values fluctuated between 33 – 34 psu.

Population structure:

Of the 259 specimens measured, 157 were males (60.6%) and 102 females (39.4%). Thirteen ovigerous females accounted for the 12.74% of total females (Figure 2). Overall sex ratio showed males more abundant than females (proportion=1.5:1) been significantly different from the expected 1:1 sex ratio (χ^2 test =86.2). Males attained larger size than females (Figure 2, Table I). The smallest females with presence of spermatozoa in their spermatheca measured 12.8 mm CW. Presence of spermatozoa was recorded in the vas deferens of some small males of 13 mm CW and in all males larger than 18 mm CW.

Sexual dimorphism: Males were heterochelics while females were isochelics. Sexual dimorphism was also detected in the abdomen width, being wider in females than in males in the whole range of sizes sampled (Figure 1 B and C, Figure 5). Males showed fusion of the III-V abdominal somites. Suture line of the original fused pleonites are visible in small individuals but not in the largest one.

Morphometry and relative growth:

Carapace Length (CL). The carapace was slightly longer than wider (proportion= 1.2:1). Carapace growth was similar for both sexes. The relative growth of CL on CW was considered positive allometric along the size range of crabs studied (Table II).

Wet Weight (WW): Increment in body weight was different between sexes with higher slope values on males (Table II and Figure 3), while males showed positive allometry, females grew isometrically. The slopes of the regression lines between sexes were statistically different (ANCOVA, F=141.59, *df* = 1, 187).

Chelipeds. All males sampled for chelipeds size (n = 123) showed heterochelia, being the right cheliped larger than the left one in 75.6% of the individuals examined (n=93) (Figure 1 D, E). Heterochelia was present in the whole range of males sampled. Another feature is that male chelipeds were heterodontic. Teeth of the minor claw were more angular and serrate than those of the major one (Figure 1 E). The major cheliped (right or left) was longest, highest and widest than the small one. The molariform tooth present in the proximal area of the dactylus (Figures 1 A, D, H, I), is the result of the anastomosing or joining of 2-5 individual teeth, being three (35%) or four (53%) the most frequent components. That anastomosing could be distinguished in males at the minimum size of 13.5 mm CW (Figure 1 H), although it was possible to differentiate the individual teeth in some crabs of 19 mm CW (Figure 1 J). At its base, the size of the molar tooth ranged from 0.7 to 2.8 mm (mean size = 1.71 ± 0.46, n = 119). Heterochelia and heterodontia are considered secondary sexual characters.

Females were isochelics -at the whole range of sizes- and isodontics (Figure 1 F, G). No significant differences were found between left and right chelipeds (Wilcoxon Signed Rank Test, *Z*= 0.953).

Relative growth of chelipeds: The relative growth of the major cheliped in males was positively allometric (Table II, Figure 4). Considering males of similar CW, the chelipeds with molariform tooth were more robust than those lacking it. When comparing the relative growth of the cheliped of individuals with and without molar tooth, no significant differences were found between the slopes of the cheliped length. Significant differences were found in the intercepts (length F= 53.7, *df* = 1, 121, width F= 50.24, *df* = 1, 121 and height F= 4.07, *df* = 1, 121).

The minor cheliped in males was similar in shape and size to the female's one. Significant differences between sexes were found for the three dimensions of the propodus (length F= 62.396, *df*= 1, 188; height F= 4.368, *df*= 1, 188 and width F= 15.02, *df*= 1, 188). Growth of the female cheliped width was isometric while the length and height were positively allometric (Table II).

Relative growth of the abdomen: In females the relative growth of the abdomen width is positively allometric with no discontinuities (Table II, Figure 5). Some females within the range between 12.8 mm CW and 18.6 mm CW (minimum size of ovigerous females) were found to be inseminated. Only two small females of size 6.4 and 7.6 mm CW were found with undeveloped ovaries and were considered juveniles.

Regression analysis in males indicated isometric growth for the abdomen in relation to the carapace width (Table II). The scatter plot for abdomen width shows that the relative growth of the male's abdomen occurs with no discontinuities (Figure 5).

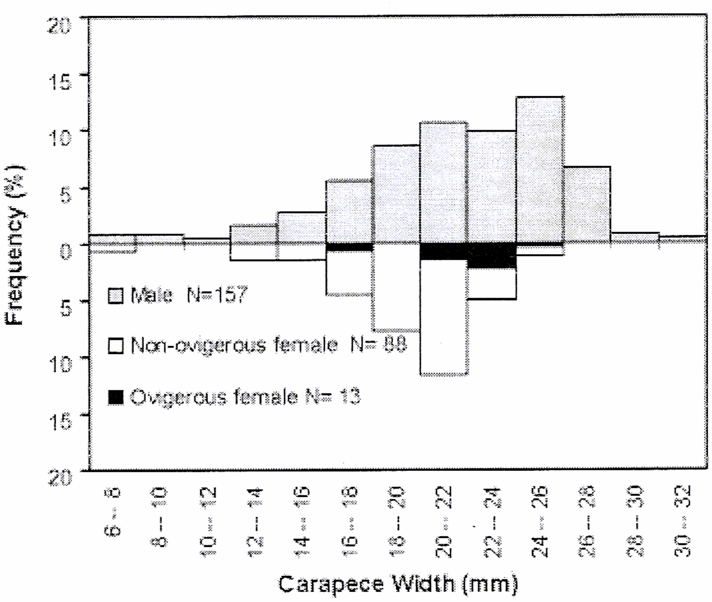


Figure 2: *Corystoides abbreviatus*. Size frequency distribution for the total of males and females sample

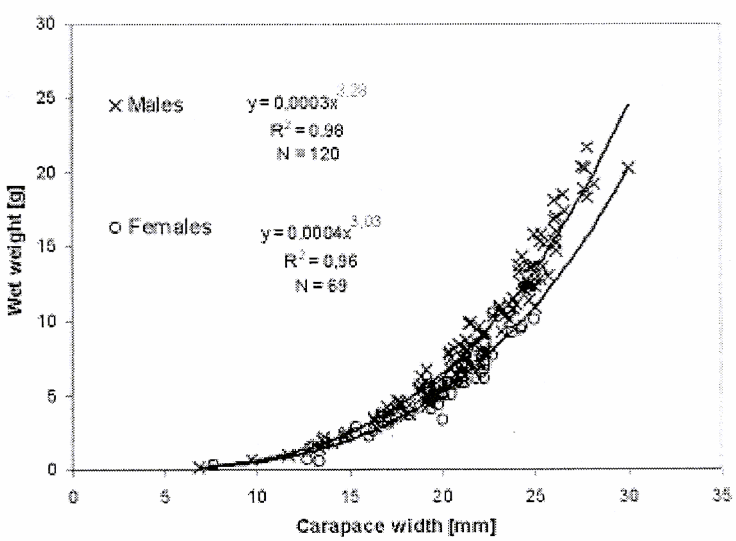
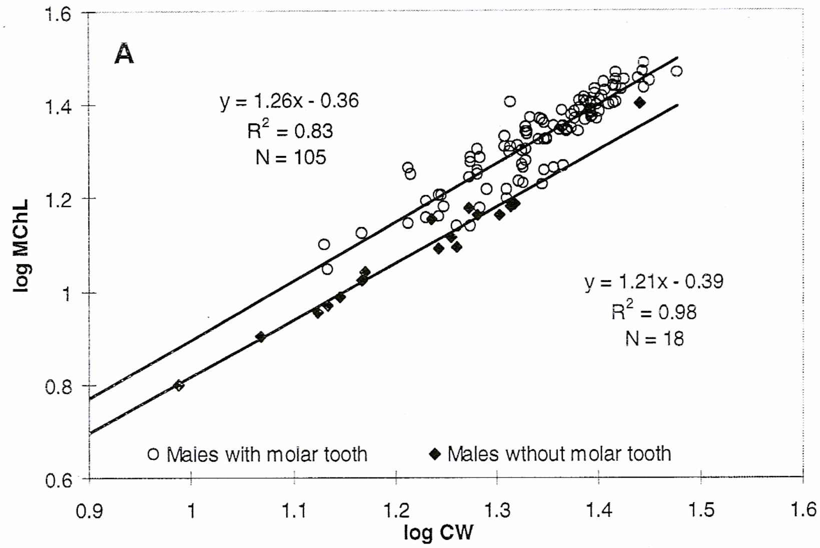
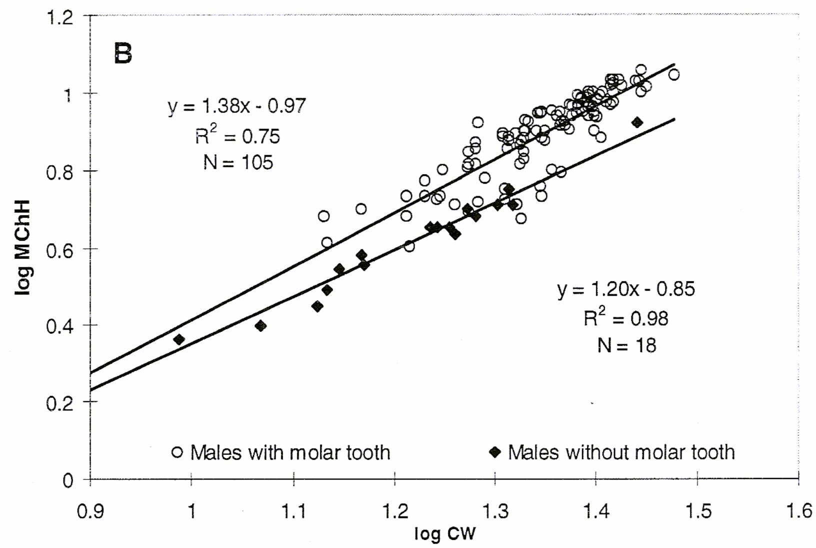


Figure 3: *Corystoides abbreviatus*. Male and female wet weight (g) plotted against carapace width (mm).





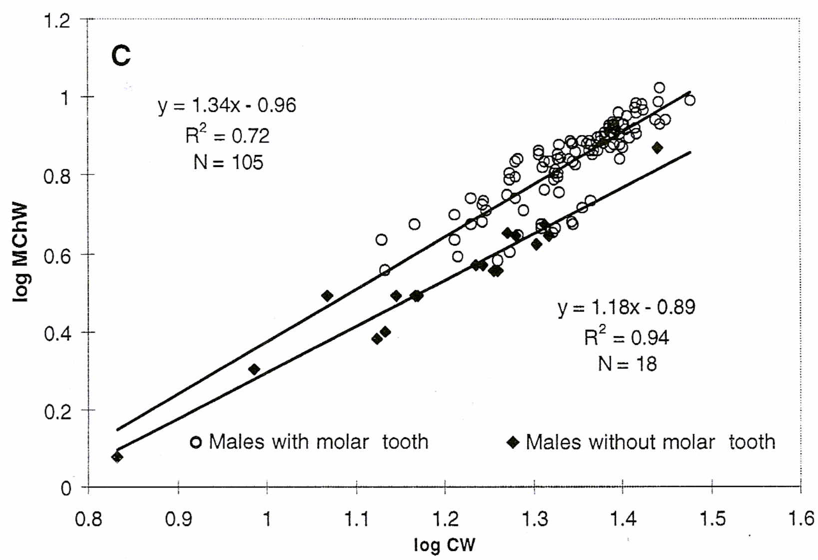


Figure 4: *Corystoides abbreviatus*. A: Major male cheliped log length, B: Major male cheliped log height, C: Major male cheliped log width plotted against carapace log width.

Table I: *Corystoides abbreviatus*. Range of sizes registered.

Sex	CW[mm]	CL[mm]	WW[mm]
Largest male	30.00	36.80	21.67
Largest female	24.90	28.90	10.61
Smallest male	6.20	7.40	0.16
Smallest female	6.40	7.50	0.16
Smallest ovigerous female	16.80	18.80	3.82

Table II: *Corystoides abbreviatus*. Results of the regression analysis and tests of allometry for the morphometric variables.

	intercept	Slope	r^2	N	t*	Allometry
All males						
WW on CW	-3.45	3.28	0.98	120	6.96	+
CL on CW	-0.33	1.18	0.97	157	11.35	+
AW on CW	-0.77	1.01	0.95	150	0.51	0
MChL on CW	-0.58	1.41	0.90	123	9.61	+
MChH ON CW	-1.12	1.49	0.74	123	6.11	+
MChW on CW	-1.21	1.51	0.83	123	8.25	+
mChL on CW	-0.56	1.35	0.70	123	4.39	+
mChH on CW	-1.00	1.31	0.89.	123	7.50	+
mChW on CW	1.08	1.33	0.88	123	7.41	+
Males with molar tooth						
MChL on CW	-0.36	1.26	0.83	105	4.49	+
MChH ON CW	-0.97	1.38	0.75	105	4.83	+
MChW on CW	-0.96	1.34	0.72	105	4.09	+
Males without molar tooth						
MChL on CW	-0.39	1.21	0.98	18	4.90	+
MChH ON CW	-0.85	1.20	0.98	18	4.72	+
MChW on CW	-0.89	1.18	0.94	18	2.32	+
All Females						
WW on CW	-3.21	3.03	0.96	69	0.32	0
CL on CW	-0.39	1.20	0.99	102	13.75	+
AW on CW	-0.98	1.46	0.95	102	13.97	+
ChL on CW	-0.38	1.18	0.90	67	3.66	+
ChH on CW	-0.78	1.11	0.88	67	2.13	+
ChW on CW	-0.74	1.01	0.87	67	0.17	0

Variables acronyms are detailed in MM: r^2 = coefficient of determination, N= sample size, t*= test of allometry, + = positive allometry, 0 = isometry.

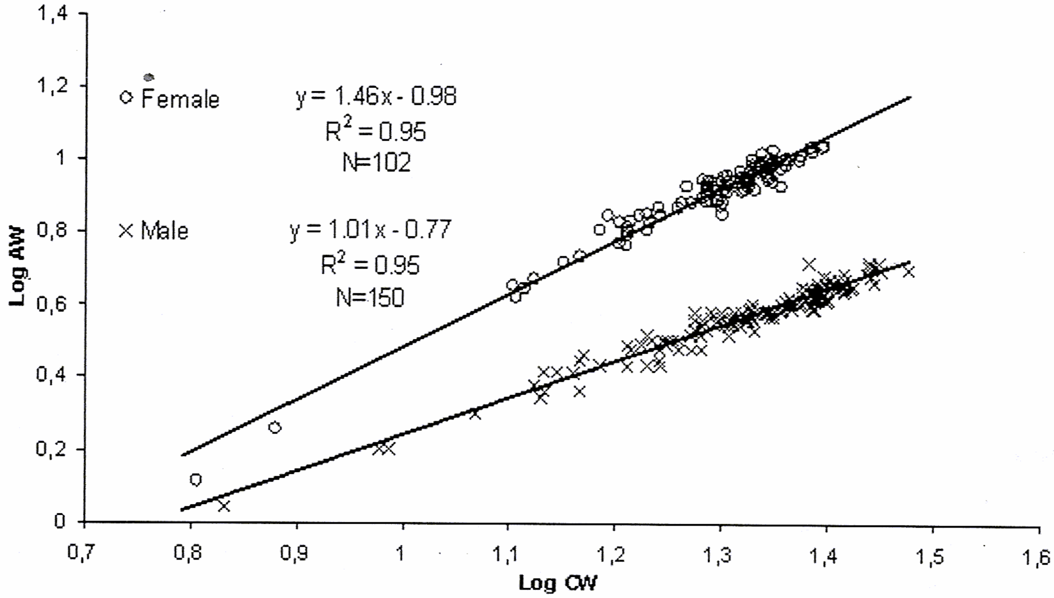


Figure 5: *Corystoides abbreviatus*. Male and female log abdomen width (mm) plotted against log carapace width.

Discussion

This study was based on morphological and morphometric criteria. Unfortunately, due to sampling methodology, our samples lacked individuals between the megalopa of 1.9 mm CL (Boschi and Scelzo, 1970 as *C. chilensis*) and the smallest crab of 6.2 mm CW captured. *Corystoides abbreviatus* is common as by-catch in the shrimp-prawn fishery in front of Mar del Plata, Argentina, but its mean relative abundance along the annual cycle is very low, oscillating between 0.26- 0.56% (Scelzo, 1999; Scelzo *et al.*, 2002). Similar to other species of brachyuran crabs (Hartnoll, 1968, 1972; Finney and Abele, 1981; Carsen *et al.*, 1996; Sampedro *et al.*, 1999), *C. abbreviatus* is a sexually dimorphic species. Heterochelia, presence of a molariform tooth in the major cheliped, and size and fusion of the III-V abdominal somites are characteristic of larger males. Although the smallest males captured had fused pleonites, it was possible to distinguish the suture line of the original fused pleonites not visible in large males. The incomplete suture of the thorax sternum was indicated by Guinot (1979) as characteristic of the Bellioidea.

C. abbreviatus shows positive allometry in the relationship CL/CW, in contrast to other brachyurans (Hartnoll, 1974; Pinheiro and Fransozo, 1993). Males show highly significant differences between the right and left chelipeds for the three chelar dimensions, as happens in the Portunidae *Callinectes ornatus* Ordway, 1863, according to Haefner (1990). When comparing the female's chelipeds to the minor cheliped of males, although they were similar in shape, the male´s one was statistically larger in size. The main function of those chelipeds could be associated to food intake. The change from the female-like form of the cheliped to the robust form is more clearly marked by the appearance of the dactylus tooth as happens in the crab *Cleistostoma kuwaitense* (Ocypodidae) (Clayton, 1990). In *C. abbreviatus*, cheliped laterality is not related to the size of the individual, and the major cheliped can be either the right or the left one independent of size. In males, major chelipeds are differentiated from minor ones in the shape of the propodus, which is more inflated and also by the presence of a molariform tooth on the dactylus of the major chela. Those characteristics are shared with other species of brachyuran crabs (Clayton, 1990). Tooth function is not clear, but as it is associated to the major cheliped in sexually differentiated males, it is possible to infer that it could participate in intra- or interspecific combats. This gives the individual crabs a disproportionately larger size, plus the advantage of adaptation that could exist during reproduction, when males compete with other males (Hartnoll, 1968; 1972; Pinheiro and Fransozo, 1993).

In males of *C. abbreviatus*, starting at 13.5 CW and along the whole range of sizes studied, we found two different forms of major chelipeds in individuals of the same body size. One of those forms was more robust, it was larger, highest and wider than the other one, and contained the molariform tooth. The other cheliped, more slender, was present in only 10% of the males captured. When the slopes of the regression lines of both kinds of males were compared, no statistical significant differences were found between them, so the growth rate is similar for both. By contrast, there were differences in the intercepts of the same dimensions considered. The low number of individuals showing the slender form could indicate that it is probably an aberrant stage in the cheliped growth due to an early loss of it in the male life. An alternative hypothesis could be that there are two coexisting "morphs" in the population, condition not related to the sexual stage of the individuals and can be attributed to a "polymorphism" in male cheliped as happens in the majid spider crabs *Pisa armata* and *Inachus leptochirus* (Hartnoll, 1982). Spermatozoa in *C. abbreviatus* were present in both males' morphs. As spermatozoa present were not encapsulated into typical spermatophores, it was not possible to distinguish between "maturing" and "mature" males as happen in other brachyuran crabs (Haley, 1973) and no correlation was possible to establish between physiological or functional and morphological male maturity. Squash preparation of male *vasa deferentia* of *C. abbreviatus* was not an adequate technique to distinguish immature from mature gonads because it did not allow recognizing the final stages of spermatogenesis, condition *sine qua non* for reproduction (López-Greco and Rodriguez, 1999). Our findings suggest that male *C. abbreviatus* would reach histological sexual maturity at sizes smaller than the functional maturity.

In larger *C. abbreviatus* males, a wide hiatus is distinguished between the two fingers of the major cheliped, characteristic similar to some majid crab species indicated by Hartnoll (1964). In the Majidae males *Mithrax sculptus* (Lamarck, 1818), *Macrocoeloma trispinosum* (Latreille, 1825), *Pelia mutica* (Gibbes, 1850) and *Stenorhynchus seticornis* (Herbst, 1788) there are differences in the shape and dentitions of the fingers, appearance of pubescence as well as the development of a single large tooth near the base of the dactylus (Hartnoll 1964). Although individual teeth could be found at the base of the dactylus in *C. abbreviatus* female cheliped, it was never found to form a molar tooth as happened in males. In some brachyuran crab species, e.g. in *Callinectes ornatus* males are also heterodontic and heterochelic and the cheliped laterality changes with age (Haefner, 1990).

The relative growth of the female abdomen follows a pattern without discontinuities. The low number of small females found in this study and the lack of data below 12 mm CW limits the actual interpretation of their size at maturity and no preliminary conclusions can be drawn. The growth of the male abdomen of most Brachyura is expected to be isometric throughout the life span (Hartnoll, 1982; Haefner, 1990). The pattern observed in *C. abbreviatus* males shows a relative growth following that for the majority of crab species.

The present morphometric study will contribute to the knowledge of some aspects of the biology almost unknown of *C. abbreviatus*. Future analyses utilizing new methodologies and modern technologies (e.g. molecular biology, genetic, spermiotaxonomy) will be necessary to differentiate the Pacific (*C. chilensis*) and Atlantic forms (*C. abbreviatus*). The present limitation to compare the "chilensis" and the "abbreviatus" forms was due to the scarce material of *C. chilensis* available from Chile, already mentioned by Rathbun (1930) and Garth (1957), except scarce material deposited in museums.

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