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Growth of the speckled swimming crab, *Arenaeus cribrarius* (Lamarck, 1818) (Crustacea, Brachyura, Portunidae), in Ubatuba (SP), Brazil

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Abstract

A total of 2629 individuals of *Arenaeus cribrarius* (1293 males and 1336 females) were captured in Ubatuba (SP), from August 1996 to July 1997. Individuals were distributed in 5 mm size class carapace width (CW), to verify sex-specific growth-age equations. The Von Bertalanffy model was chosen to determine the growth rate and expressed by $CW=120.52[1–e^{-1.80t}]$ for males and $CW=100.81[1–e^{-1.60t}]$ for females. The age estimated for the first juvenile stage (t_0) was 6.1 and 8.3 days for males and females, respectively. The maximum age determined was 1.8 years for males and 2 years for females, which correspond to a maximum size of 115.8 and 96.7 mm, respectively. The maximum size (CW_{max}) estimated using 95% of asymptotic size was 114.5 mm for males and 95.8 mm for females. Males have a precocious sexual maturity (5 months) when compared to females (6.8 months). The growth rate and size of *A. cribrarius* are higher than other portunid species, with great interest for aquaculture.

Keywords: Arenaeus, *Brachyura, Crustacea, growth, Portunidae*

Introduction

In aquatic organisms, individual growth has been determined using the increased size or weight in a specific period of time (Santos 1978; Vazzoler 1982; Fonteles-Filho 1987). In this way, crustaceans were shown to exhibit asymptotic growth, which varies according to moult frequency and somatic growth throughout ontogeny. The mathematic model developed by Von Bertalanffy (1938) has been used to determine the age of these animals. For crustaceans, the commercially important species featured in pioneer studies are, for example, the lobster *Panulirus laevicauda* (Latreille, 1817) analysed by Ivo (1975); the penaeid shrimps *Litopenaeus brasiliensis* (Latreille, 1817) and *Farfantepenaeus paulensis* (Pérez-Farfante, 1967) by Mello (1973); the freshwater prawns *Macrobrachium iheringi* (Ortmann, 1897) and *M. potiuna* (Müller, 1880) studied by Lobão et al. (1987) and Souza

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and Fontoura (1995), respectively; and the portunids *Callinectes danae* Smith, 1869 and *C. ornatus* Ordway, 1863 analysed by Branco and Masunari (1992) and Branco and Lunardón-Branco (1993), respectively. The exotic portunid species have also been studied, such as *Macropipus puber* (Linnaeus, 1767) by González-Gurriarán (1985) and *Liocarcinus depurator* (Linnaeus, 1758) by Fernández et al. (1991).

Growth rate is positively correlated to temperature (Fonteles-Filho 1987). Because of the absence of hard and permanent morphological structures in crustaceans (e.g. scales and otolith in fishes), growth has been analysed using the frequency distribution in size classes from wild populations or using aquaculture data under controlled environmental conditions (Ju et al. 2001).

Arenaeus cribrarius shows easy adaptation to culture conditions (Pinheiro and Fransozo 1999); furthermore, its high fecundity and continuous reproduction (Pinheiro and Terceiro 2000) make this species interesting for aquaculture purposes. Information on growth rate, the age at which the sexes attained the size at onset of sexual maturity, and the maximum asymptotic size have been used to study the viability of this species for aquaculture projects (Mello 1973; Lobão et al. 1987).

There are few reports which mention the relationship of weight and carapace width (Pinheiro and Fransozo 1993a) and relative growth (Pinheiro and Fransozo 1993b). Size and weight growth in relation to age have not been reported in the literature, and these are important parameters to understand better the population dynamic of this swimming crab species.

The present study investigated size and weight growth curves in relation to age for both sexes of *A. cribrarius*. The growth rate (k), the asymptotic size (CW_∞), maximum size (CW_{max}), and the age at the onset of sexual maturity have also been recorded.

Materials and methods

The swimming crabs were captured along the northern coast of São Paulo State in the Ubatuba region, Brazil, with a shrimp fishery boat equipped with two 10-mm mesh otter-trawl nets. Monthly samples were obtained in front of Toninhas and Itamambuca Beach (23°30′S) during a 1-year period (August 1996 to July 1997).

Each crab was sexed, identified according to Melo (1996), and the carapace width measured, excluding lateral spines (CW), and weighed (wet weight, WW).

Growth was analysed for each sex, using the method of monthly frequency distribution in size classes (Santos 1978). The population was represented by a polymodal frequency distribution, with modes corresponding to the mean size in each age class (Fonteles-Filho 1987). The Bhattacharya method (Bhattacharya 1967) was chosen based on the NormSep routine, to break down the monthly polymodal into "n" components using the Fisat software (Gayanilo et al. 1996). These analyses identify and determine principal monthly cohorts in each sex.

The Von Bertalanffy mathematical model was used to represent growth and was tested for both sexes using the Ford–Walford transformation (Walford 1946). The confirmation of this model was based on the best fit to the empiric points and better adjusted using determination coefficient (R^2>0.70) of the linear function $CW+\Delta t=a+bCW$. The asymptotic size (CW_∞), weight (WW_∞), and the growth constant (k) expressed in years were determined by Santos (1978).

Since *Arenaeus cribrarius* has an insignificant hatching size, the initial age (t_0) was not considered in the Von Bertalanffy mathematical model (Fonteles-Filho 1987).

Nevertheless, the age of the first juvenile stage (t_0 JI) was calculated using the growth curves obtained for each sex, and similar values validate their use in larval growth (Moreau 1987). The CW for JI (3.6 mm, according to Stuck and Truesdale 1988) was used for this analysis.

Maximum age or longevity (t_{max}) was estimated using the equation of Taylor (1958): $t_{max}=(3/k)+t_0$, where k is the growth constant and t_0 the initial age (in years). As the longevity values did not take into account the time from hatching to the first juvenile stage (JI) (43 days or 0.12 years), according to Stuck and Truesdale (1988), this value was added into the longevity analyses.

According to González-Gurriarán (1985) and Fonseca and D'Incao (1998), the maximum size (CW_{max}) corresponded to 95% of the Von Bertalanffy asymptotic size (CW_∞) and was represented by the equation $CW_{max}=0.95CW_\infty$. These values were determined for each sex and compared to the data obtained from large individuals recorded in the field by Pinheiro and Fransozo (1993b, 2002).

The age at the maximum size (CW_{max}) and the onset of sexual maturity ($CW_{50\%}$) were estimated, using in this last case, the size proposed by Pinheiro and Fransozo (1998): 63.4 mm (males) and 59.7 mm (females).

The growth curve for weight was established by deductive methods (Santos 1978), and the asymptotic weight value for each sex (WW_∞) was determined using the CW_∞ value substitution in the biometric equation (WW/CW) proposed by Pinheiro and Fransozo (1993a): $WW_{Male}=7.88.10^{-5}CW^{3.13}$ and $WW_{Female}=7.59.10^{-5}CW^{3.15}$. The growth curves were expressed by $WW_t=WW_\infty\ [1-e^{-k\Delta t}]^b$, where WW_t is the weight at age t, WW_∞ represents the asymptotic weight, and b is a constant estimated for the relationship $WW \times CW$.

Results

A total of 2629 individuals of *A. cribrarius* were captured, corresponding to 1293 males and 1336 females. The monthly frequency of each sex showed that population recruitment occurred mainly from January to February and May to June 1997, while the largest individuals were recorded in September 1996 ($CW_{male}=99.1$ mm) and July 1997 ($CW_{females}=93.6$ mm).

The monthly size class distribution for each sex is given in Figures 1 (males) and 2 (females), with their normal components.

These results were used to analyse the monthly cohort for both sexes, with males exhibiting six annual age-cohorts (Figure 3A) while in females only five were apparent (Figure 3B).

The ordinal pairs from the $CW+\Delta t$ relationship were obtained using monthly age-cohort data, and showed a linear tendency represented by the equation $CW+\Delta t=16.75+0.861CW$ ($N=24$; $r^2=0.91$; $P<0.01$) for males (Figure 4A) and $CW+\Delta t=12.62+0.875CW$ ($N=20$; $r^2=0.86$; $P<0.01$) for females (Figure 4B).

The linear fit of this relationship was used to confirm the Von Bertalanffy model to represent the growth of each sex. After the determination of growth rate (k) and the asymptotic size (CW_∞) the following equations were calculated: $CW_{Males}=120.52[1-e^{-1.80t}]$ and $CW_{Females}=100.81[1-e^{-1.60t}]$. In Figure 5A growth curves for both sexes are shown, with a high growth rate ($k=1.8$ years) and asymptotic size ($CW_\infty=120.5$ mm) for males when compared to females.

The estimated age for *A. cribrarius* in the first juvenile stage (t_0) was 6.1 days (0.017 years) for males and 8.3 days (0.023 years) for females. The maximum age attained for

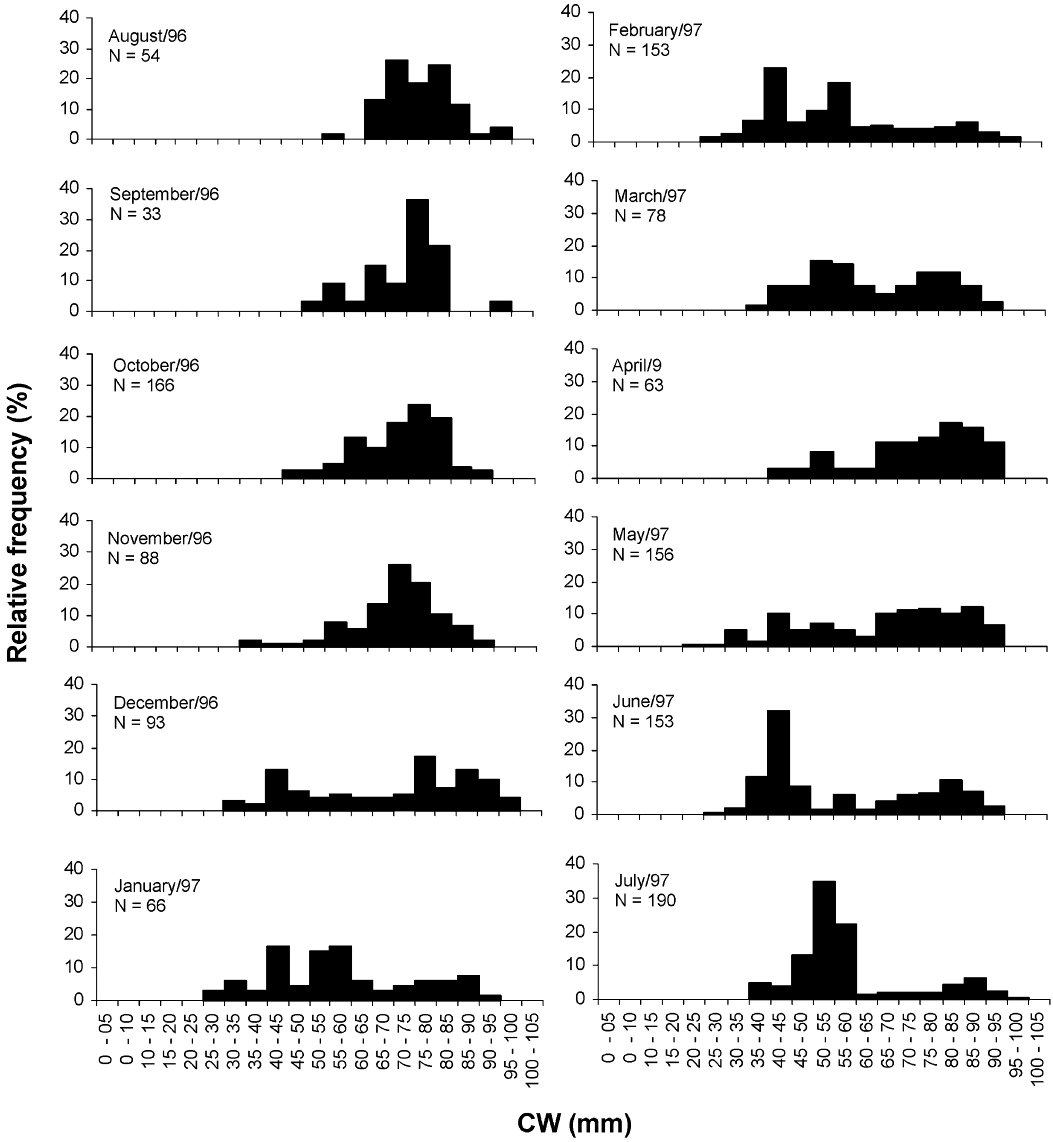

Figure 1. *Arenaeus cribrarius* (Lamarck, 1818). Monthly frequency distribution of males in class size (CW), from August 1996 to July 1997.

males was lower (1.8 years) than observed for females (t_{max}=2 years). These ages correspond to a maximum size of 115.8 and 96.7 mm, respectively. The maximum size of each sex (LCmax) in 95% of asymptotic size (CW_∞) was 114.5 mm for males and 95.8 mm for females. Males attained the size at onset of sexual maturity in 5 months (0.42 year), sooner when compared to females, which occurred in 6.8 months (0.56 years).

The weight growth of *A. cribrarius* is represented in Figure 5B, and expressed by the equations: $WW_{Male}=257.18[1-e^{-1.80t}]^{3.13}$ and $WW_{Females}=155.34[1-e^{-1.60t}]^{3.15}$. The maximum weight related to maximum age (t_{max}) was 226.9 g for males and 136.3 g for females.

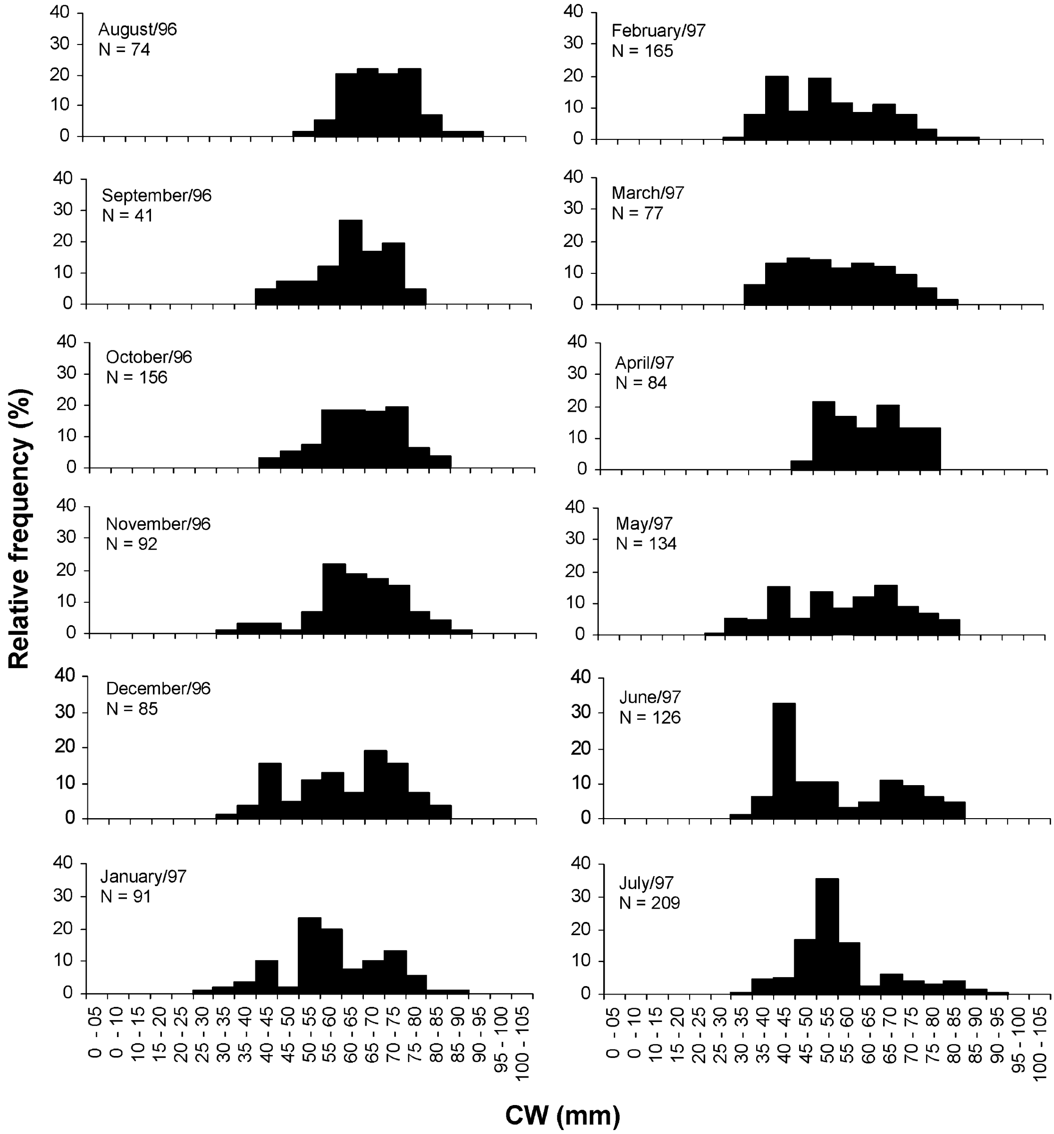

Figure 2. *Arenaeus cribrarius* (Lamarck, 1818). Monthly frequency distribution of females in class size (CW), from August 1996 to July 1997.

Discussion

In most brachyurans, males attain greater size and weight than females. *Arenaeus cribrarius* follows the same pattern, and it was confirmed by the results obtained from previous studies for the WW/CW relationship (Pinheiro and Fransozo 1993a) and the relative growth (Pinheiro and Fransozo 1993b). Males of swimming crabs ensure copulatory success by providing female protection after moult (Christy 1987). *Arenaeus cribrarius* has the same reproductive behaviour pattern (Pinheiro and Fransozo 1999), so males that attain large sizes have advantages in reproduction. The size differences among sexes permitted an easy pair formation, considered an important reproductive strategy.

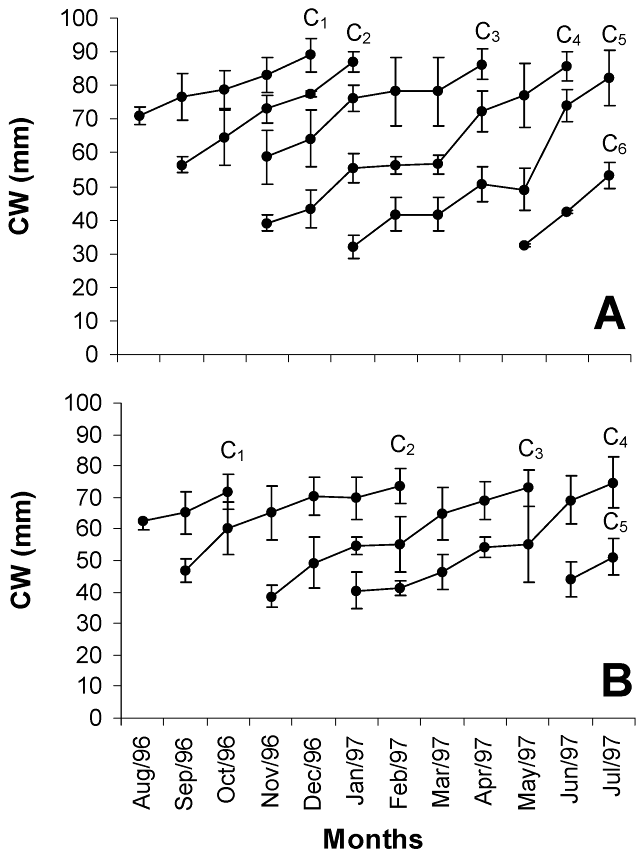

Figure 3. *Arenaeus cribrarius* (Lamarck, 1818). Annual cohort of males (A) and females (B) captured monthly during August 1997 to July 1998 in Ubatuba (SP). Values are means and standard deviations. CW, carapace width; C_1–C_6, monthly cohorts.

According to Pinheiro and Fransozo (2002), *A. cribrarius* reproduction data in the same area of this study show a seasonal-continuous pattern, occurring throughout the year, with higher activity in some months. The number of cohorts obtained was equal to that recorded for higher incidences of ovigerous females with eggs in initial development stage throughout the year, recorded by Pinheiro and Fransozo (2002).

The asymptotic size obtained in the present study was very similar to large individuals' size sampled by Pinheiro and Fransozo (1993b, 2002). Based on 4964 specimens analysed (2259 males and 2705 females), the largest specimens recorded were 112.0 mm (males) and 93.6 mm (females), which were 8 mm lower than the CW_∞ values found in the present study.

According to Fonseca and D'Incao (1998) and González-Gurriarán (1985), the maximum size in crustaceans had been estimated as 95% of the asymptotic size. For *A. cribrarius*, this size was 114.5 mm for males and 95.8 mm for females, with a reduction of 3 mm in the difference mentioned previously.

The longevity of *A. cribrarius* was similar to the values previously determined for other crustaceans (2–4 years). However, some reports published crustacean longevity values that exceed the upper limit due to the wrong estimate of the *k* constant, resulting in a

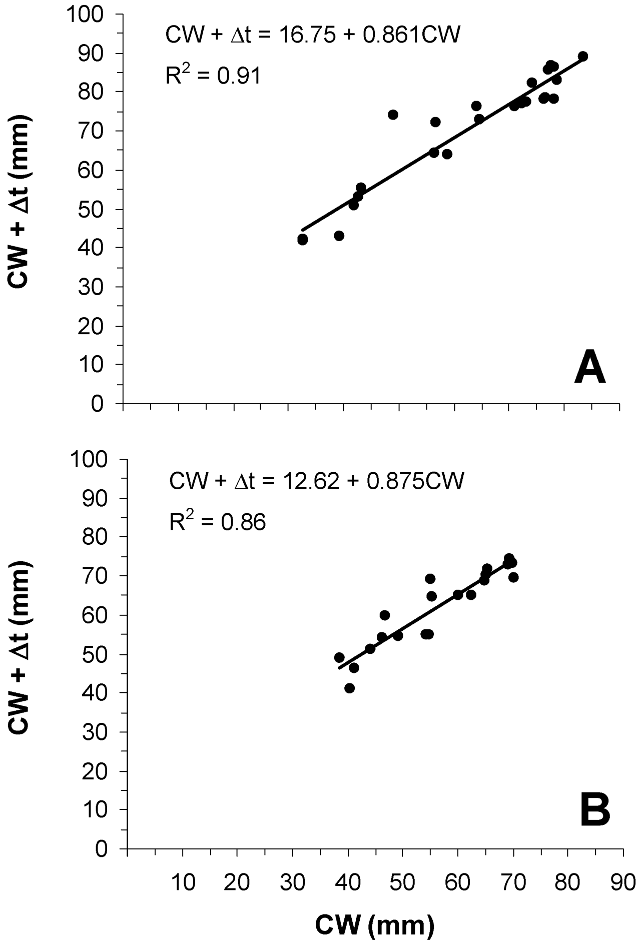

Figure 4. *Arenaeus cribrarius* (Lamarck, 1818). Ford–Walford transformation showing the best linear fit among the initial size and the final size after 1 month (CW+Δt), for males (A) and females (B) captured from August 1996 to July 1997 in Ubatuba (SP).

maximization of the t_{max} values (Fonseca and D'Incao 1998). The substitution of *A. cribrarius* maximum longevity in the respective growth equation indicated sizes of 115.8 mm (males) and 96.7 mm (females), very similar to those obtained by the CW_∞ model proposed ($\pm$4 mm of difference).

The t_0 value contrasts for JI among male (6.1 days) and female (8.3 days) curves indicated that the Von Bertalanffy model was not adequate to represent the larval growth phase, similar to the results reported for the shrimp *Penaeus paulensis* by D'Incao (1984) and for the grapsid *Chasmagnathus granulata* (Dana, 1851) by D'Incao et al. (1993).

The first zoea stage of *A. cribrarius* has a very small carapace size—0.4 mm according to Stuck and Truesdale (1988)—so the t_0 value was not used in the growth curves. Some authors used the t_0 values in the Von Bertalanffy curves to fix the size estimated for specific age (D'Incao et al. 1993).

According to Pinheiro and Fransozo (1998), the onset of sexual maturity in *A. cribrarius* was 63.4 mm for males and 59.7 mm for females, which corresponds to 5 months (0.42

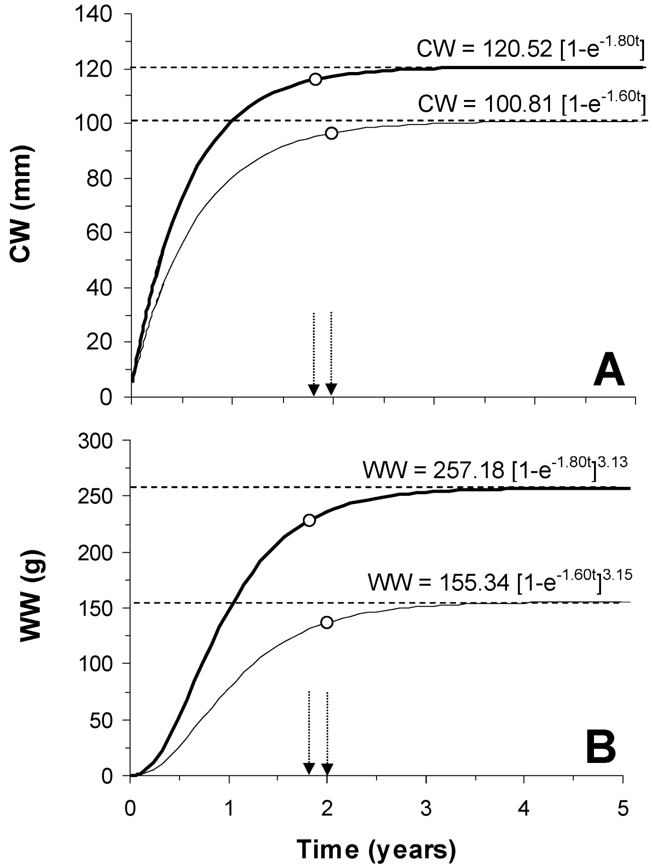

Figure 5. *Arenaeus cribrarius* (Lamarck, 1818). Growth curve in size (A) and weight (B) according to the Von Bertalanffy model, obtained from males (thick line) and females (thin line), captured in August 1996 to July 1997 in Ubatuba (SP). CW, carapace width; WW, wet weight; dotted line, asymptotic size; arrows, maximum age attained; circles, size or weight related to maximum age.

years) and 6.8 months (0.56 years), respectively. The *C. ornatus* data obtained by Branco and Lunardón-Branco (1993) revealed the first maturation size three times higher (males=1.5 years; females=1.7 years), with the same pattern observed for *C. danae* (1.6 and 1.5 years, respectively) (Branco and Masunari 1992). These results show the reproductive precocity of *A. cribrarius* when compared to the two *Callinectes* species mentioned previously.

The portunid species cited in Table I show *k* constant values lower than the *A. cribrarius* growth rate (see Figure 6). According to Millikin and Williams (1984), the growth of the swimming crab *Callinectes sapidus* Rathbun, 1896 could be influenced by the availability and quality of their food. Water temperature has also been considered an important parameter, which influenced moulting frequency and caused alteration in brachyuran growth rates (Ju et al. 2001). *Arenaeus cribrarius* attained 80% of asymptotic size in 1 year only, according to growth rates shown in the present study, while in *C. danae* it took twice as long (1.8–2.0 years) and four times as long (4.3–4.6 years) in *C. ornatus*, to reach the same size.

Table I. Growth equation of swimming crab species.

Species	Authors	Locality	Growth equation according to Von Bertalanffy model	Longevity (years)
Arenaeus cribrarius	Present study	Ubatuba (SP), Brazil	$CW_M=120.52[1-e^{-1.80t}]$	1.8
			$CW_F=100.81[1-e^{-1.60t}]$	2.0
Callinectes danae	Branco and Masunari (1992)	Florianópolis (SC), Brazil	$CW_M=140.0[1-e^{-0.697t}]$	4.3
			$CW_F=133.0[1-e^{-0.655t}]$	4.6
Callinectes ornatus	Branco and Lunardón-Branco (1993)	Matinhos (PR), Brazil	$CW_M=124.0[1-e^{-0.516t}]$	5.8
			$CW_F=91.0[1-e^{-0.655t}]$	4.6
Callinectes sapidus	Tagatz (1968)	Florida, USA	–	2.0–4.0
	Van Engel (1958)	Chesapeake Bay, USA	–	2.0–3.0
Liocarcinus puber	Borja (1988)	San Sebastián, Spain	$CW_M=112.4[1-e^{-0.535(t+0.035)}]$	5.6
			$CW_F=96.3[1-e^{-0.680(t+0.032)}]$	4.4
Macropipus puber	González-Gurriarán (1985)	Galicia, Spain	$CW_M=109.0[1-e^{-0.650(t+0.041)}]$	4.6
			$CW_F=96.0[1-e^{-0.670(t+0.048)}]$	4.5
Portunus spinimanus	Souto and Branco (1998)	Penha (SC), Brazil	$CW_M=123.0[1-e^{-0.879t}]$	3.4
			$CW_F=112.0[1-e^{-0.891t}]$	3.4

CW_M, carapace width for males; CW_F, carapace width for females.

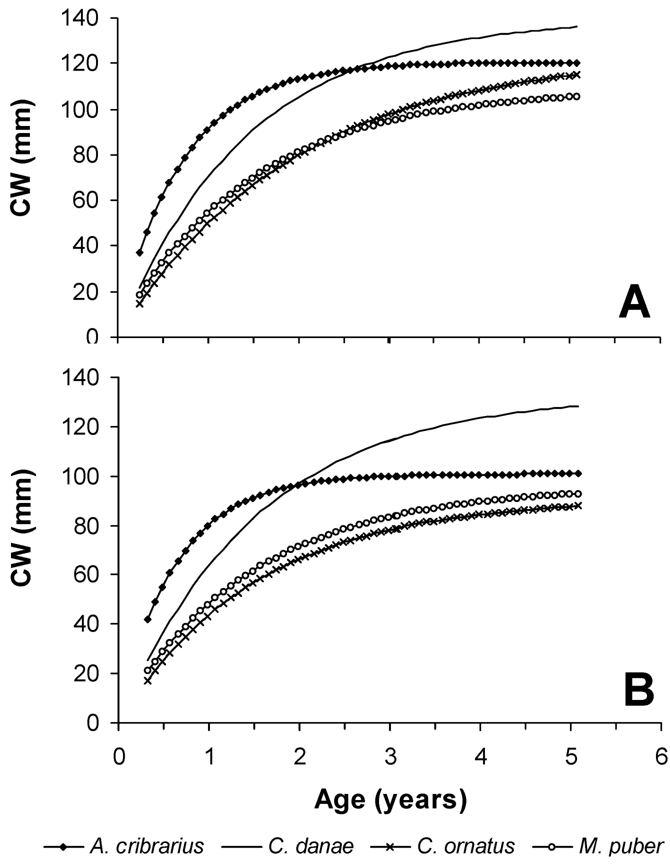

Figure 6. Comparative analyses of growth curves in size for males (A) and females (B) among portunid species. CW, carapace width.

The asymptotic weight (WW_∞) was also close to that recorded for the largest individuals of *A. cribrarius* in the environment (WW_{Males}=169.7 g and WW_{Female}=133.4 g). The weight estimate for maximum age in each sex was 226.9 g for males and 136.3 g for females, with low difference values when compared to field data, showing precision the in growth curves proposed.

The high growth rate and large size attained in the adult phase, as well the high fecundity (Pinheiro and Terceiro 2000) and easy management in captivity (Pinheiro and Fransozo 1999), gives *A. cribrarius* a future potential in aquaculture, with emphasis on meat production, the main product with high economic value.

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