



Population biology of the box crab *Hepatus pudibundus* (Crustacea: Aethridae) off the coast of Santa Catarina State, Southern Brazil

FRANCINE O. SARDÁ^{1*}, IRECE F. MACHADO¹, PEDRO F. S. PRATA¹
& LUIZ FELIPE C. DUMONT²

¹Universidade Federal de Rio Grande (FURG), Programa de Pós-Graduação em Oceanografia Biológica.
*Corresponding author: fransardah@hotmail.com

²Universidade Federal de Rio Grande (FURG), Institute of Oceanography, Av. Itália, Km 78, Caixa Postal 474, 96201-900 Rio Grande, RS, Brasil.

Abstract. The trawler fishery for the *Xiphopenaeus kroyeri* in south Brazil, affects populations of some benthic species, such as the *Hepatus pudibundus*. The goal of this study is to investigate the influence of environmental factors on abundance and spatial-temporal distribution of *H. pudibundus*, and its population structure. Samples were collected from May 2008 to April 2010 off the Balneário Camboriú coast, SC, Brazil. Three transects were established at mean depths 7, 14 and 19 m. A total of 1882 individual was collected. Higher densities were recorded in shallow waters, where the temperature is higher and the salinity is lower. The highest abundance of ovigerous females was recorded from November to April. The sex ratio was 1 male: 1.04 females. Males reached larger sizes than females, with mean sizes of 49.48 ± 17.55 mm and 47.15 ± 13.87 mm, respectively. For both sexes and ovigerous females, the mean value of the carapace width was higher at 7 m isobaths. The width-weight relationship presented a negative allometry for females ($b=2.95$) and males ($b=2.94$). The carapace length and width had a negative allometry for females ($b=0.72$) and males ($b=0.68$). The seabob shrimp closed season may be influencing negatively the *H. pudibundus* abundance, especially, upon ovigerous females and recruits.

Keywords: crab, distribution, abundance, trawling, biometric relationship

Resumo. Biologia populacional do caranguejo-baú *Hepatus pudibundus* (Crustacea: Aethridae) na costa do estado de Santa Catarina, sul do Brasil. A pesca direcionada ao camarão *Xiphopnaeus kroyeri* no sul do Brasil é realizada com redes de arrasto, afetando populações de algumas espécies bentônicas, como o caranguejo-baú *Hepatus pudibundus*. O objetivo deste estudo é investigar a influência dos fatores ambientais na abundância e na distribuição espaço-temporal do caranguejo *H. pudibundus*, e sua estrutura populacional. As amostras foram coletadas de maio de 2008 a abril de 2010, na região de Balneário Camboriú, Santa Catarina, Brasil. Três transectos foram estabelecidos nas profundidades de 7, 14 e 19 metros. Um total de 1.882 indivíduos foi coletado. A maior densidade foi registrada na profundidade mais rasa, a qual apresentou a temperatura mais alta e a salinidade mais baixa. A maior abundância de fêmeas ovígeras ocorreu de novembro a abril. A razão sexual foi de 1 macho:1,04 fêmeas. Machos alcançaram maiores tamanhos do que fêmeas, apresentando médias de tamanho de $49,48 \pm 17,55$ mm e $47,15 \pm 13,87$ mm, respectivamente. As fêmeas ovígeras apresentaram uma média de tamanho de $56,01 \pm 8,95$. Para ambos os sexos e para as fêmeas ovígeras, o valor médio da largura da carapaça (LC) foi maior na profundidade de 7 metros. A relação largura da carapaça-peso foi alométrica negativa para fêmeas ($b=2,95$) e machos ($b=2,94$), assim como a relação comprimento e largura da carapaça também foi alométrica negativa para fêmeas ($b=0,72$) e machos ($b=0,68$). A época do defeso para o camarão sete-barbas, a qual varia de março a maio, pode estar influenciando negativamente a abundância de *H. pudibundus*, atuando especialmente sobre as fêmeas ovígeras e recrutas.

Palavras chave: caranguejo, distribuição, abundância, arrasto, relações biométricas

Introduction

The majority of the commercial fishing activity in Brazil is performed by boats using trawling gear, resulting in a large capture of non-target species, that are mostly discarded (Costa & Di Benedetto 2009). The worldwide trawling for coastal shrimps is an activity that has resulted in the overexploitation of many stocks (FAO 2010). Trawlers targeting the seabob shrimp, *Xiphopenaeus kroyeri* Heller, 1862, produce an elevated and diverse incidental catch, mainly composed by fish, crustaceans, molluscs, echinoderms and cnidarians (Branco & Moritz 2001). However, due to the low economic value of most of these species, they are widely discarded back to the sea resulting in an unknown ecological impact in this ecosystem (Gasalla & Tomás 1998, Worm 2006).

Among the discarded catch, one of the most important species, when considering abundance, is the box crab *Hepatus pudibundus* (Herbst 1758). This is the most abundant crab of the Aethridae family (Dana 1851) on the seabob shrimp, *X. kroyeri* (Heller 1862) trawl fishery (Fracasso & Branco 2005). Its distribution is reported from Georgia's (USA), to Rio Grande do Sul (Brazil). The species is found inhabiting muddy, sandy or biotrititic bottoms, presenting highest abundance in neritic shallow waters, usually between 10 and 15 meters (Klôh & Di Benedetto 2010), although there are records of its occurrence in depths of 2-40 meters (Bertini *et al.* 2004). Despite of not being a commercial valuable species (Fracasso & Branco 2005), it plays an important role in coastal ecosystems since it represents an important item on the diet of many carnivorous organisms, either in larval stage or adult form (Teixeira & Sá 1998). Furthermore, another study revealed a high level of food diversity consumed by *H. pudibundus*, suggesting that this species is omnivorous, with a strong tendency to feed on crustaceans (Mantelatto & Petracco 1997). These results support the idea, already revealed previously that Brachyurans are known to influence the abundance and distribution of prey Populations (Perez & Bellwood 1988).

Despite its wide distribution, elevated abundance and ecological role, the population biology of the *H. pudibundus* is poorly understood in the region of Santa Catarina, an area close to the southern limit of its distribution. Conversely, many studies have provided information about relative growth (Mantelatto & Fransozo 1992, 1994, Reigada *et al.* 1994), reproduction (Reigada & Negreiros-Fransozo 2000), natural diet (Mantelatto & Petracco

1997) and population dynamics (Keunecke *et al.* 2007). A limited number of investigations on population structure are available (Mantelatto *et al.* 1995, Fracasso & Branco 2005).

Thus, in order to better understand the population biology of the box crab *H. pudibundus* in South Brazil, as well as the possible impact of *X. kroyeri* fishery over this species, the goal differential of this study is to investigate the influence of environmental factors on abundance and spatial-temporal distribution of *H. pudibundus*, and analyze its population structure, including the size structure according to the season and depth, biometric relationships and sex ratio.

Material and Methods

Study area

The samples were obtained from Camboriú Beach, (26° 59' 07'' S – 48° 35' 58'' W), in the State of Santa Catarina, Brazil. This area was chosen since it is a traditional fishing site. This area is influenced by three water masses: the South Atlantic Central Water (SACW), the Tropical Water (TW) and the Coastal Water (CW), which may exert an important influence on population structure of different species, especially through the resulting upwelling, that usually occurs associated to spring and summer atmospheric and oceanographic conditions (Piola & Matano 2001). During this period, the intense NE winds push the surface coastal waters offshore, resulting in the upwelling of the SACW in the inner shelf.

Sampling strategy and biometry

Crabs were monthly obtained from May 2008 to April 2010 in the surrounding area of the Balneário Camboriú (Fig. 1), using a double rig shrimp trawler with a mesh size of 30 mm in the body and 20 mm (opposing knots) in the cod end. The first year sampling was defined from May/08 to April/09, and the second year sampling from May/09 to April/10. The seasons were defined as follows: Autumn (March, April and May), winter (June, July and August), spring (September, October and November) and summer (December, January and February). Three transects were established at depths of 7, 14 and 19 m, considering that the two nets are operated simultaneously, the two samples were pooled at each station and a second sampling at the same depth, was used as a replicate. The abundance index (CPUE) was composed by a catch unit, either weight (g) or number (n), and a standardized effort of 15 minutes trawling.

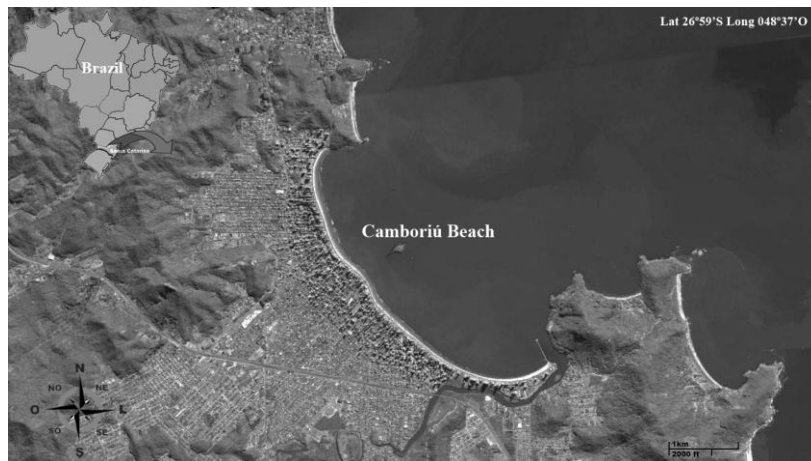


Figure 1. Map of the region of Camboriú Beach, State of Santa Catarina, South Brazil.

The crabs were identified, according to sex and determined as young and adults according to the abdomen shape (Williams 1974). The recruits were considered based on the data of first maturity obtained by Fracasso & Branco (2005) in the region of Santa Catarina. The ovigerous condition of females was determined by macroscopic observation of the presence of eggs in the pleopods. The biometry of the specimens consisted of obtaining the carapace width (CW, mm), taken between lateral spines and carapace length (CL, mm), taken between the post-orbital angle to the end of carapace.

Bottom salinity and temperature ($^{\circ}\text{C}$) were measured by using a thermosalinometer. An ecobathymeter coupled with a GPS (Global Positioning System) was used to record depth at sampling sites.

The possible influence of environmental factors (temperature and salinity) on the CPUE (g/15min; n/15min) of *Hepatus pudibundus* was assessed by a multiple regression analysis, and the significance level adopted was $p < 0.05$ (Zar 1999). A Factorial Analysis of Variance (ANOVA) was used to compare the relative abundance (females and males) and abundance of ovigerous females (CPUE – g/15min and n/15min) of the crabs between the two years sampling, seasons and depths (7, 14 and 19 meters). The data was tested for normality and homogeneity of variances (Bartlett) prior to the ANOVA and post-hoc Fisher's test. Normality was achieved for all groups. Similarly, the possible differences in the mean carapace width according to sex, depth and season, were tested by using a Factorial Analysis of Variance (ANOVA). All statistical procedures followed Zar (1999), and the significance level adopted was ($p < 0.05$).

The sex ratio was compared according to year, seasons and depth, by using the χ^2 test

($p < 0.05$). The carapace width-weight relationship was described by the equation $W = aCW^b$ and the carapace width-carapace length relationship by the equation $CW = a + bCL$, where the W is the weight (g), CL the carapace length (mm), CW the carapace width (mm), a is the intercept with dependent variable axis and b is the slope (King 1995). Both analyses were performed for each sex separately. Points outside the 95% confidence intervals were automatically excluded since they were considered as an undetected result of a broken or deformed carapace. Differences in slopes were pair wise tested based on confidence intervals, in such way that non-overlapping intervals were considered as significantly different.

Results

Environmental Factors

A seasonal pattern in temperature trends was observed, with higher values during autumn and summer and lower values during winter and spring. There were not significant differences in the mean bottom temperature between the two years. During the first year, the highest water temperature values were recorded in February ($24.7^{\circ}\text{C} \pm 2.25^{\circ}\text{C}$) and March ($25.3^{\circ}\text{C} \pm 0.76^{\circ}\text{C}$), while the lower values were recorded in May ($18.3^{\circ}\text{C} \pm 1.15^{\circ}\text{C}$) and June ($18.3^{\circ}\text{C} \pm 0.05^{\circ}\text{C}$). In the second year, the highest values were recorded in December ($25.06^{\circ}\text{C} \pm 0.41^{\circ}\text{C}$) and February ($25.16^{\circ}\text{C} \pm 0.61^{\circ}\text{C}$), and the lower values were recorded in August ($17.86^{\circ}\text{C} \pm 0.20^{\circ}\text{C}$) and July ($18.33^{\circ}\text{C} \pm 0.05^{\circ}\text{C}$) (Fig. 2). It is also important to stress that a marked stratification was observed during the summer periods in both years, evidenced by the difference between the temperature recorded in shallow (7 m) and deeper waters (14-19 m).

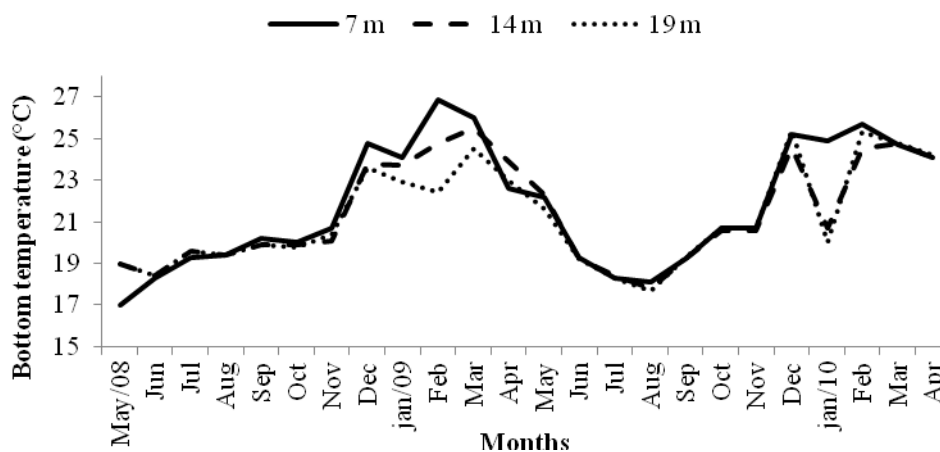


Figure 2. Variation of the mean monthly $T^{\circ}C$ for each depth (7, 14 and 19 m) from May 2008 to April 2010, in the region of Balneário Camboriú, Santa Catarina State, Brazil.

The bottom salinity presented remarkable trends during the first year, while a more stable pattern was recorded in the second year (Fig. 3). There were significant differences between the two years ($p < 0.05$). In both years, the higher average values occurred in autumn and summer and the lowest during winter and spring. In the first year, the

highest values were recorded in March (37.3 ± 0.81) and April (37.5 ± 1.97), while the lower were recorded in June (32.8 ± 0.23) and November (30.1 ± 3.43). In the second year, the highest values were recorded in May (34.9 ± 0.13) and March (34.9 ± 0.31). The lower values were recorded in August (32.8 ± 0.13) and September (33.2 ± 0.19).

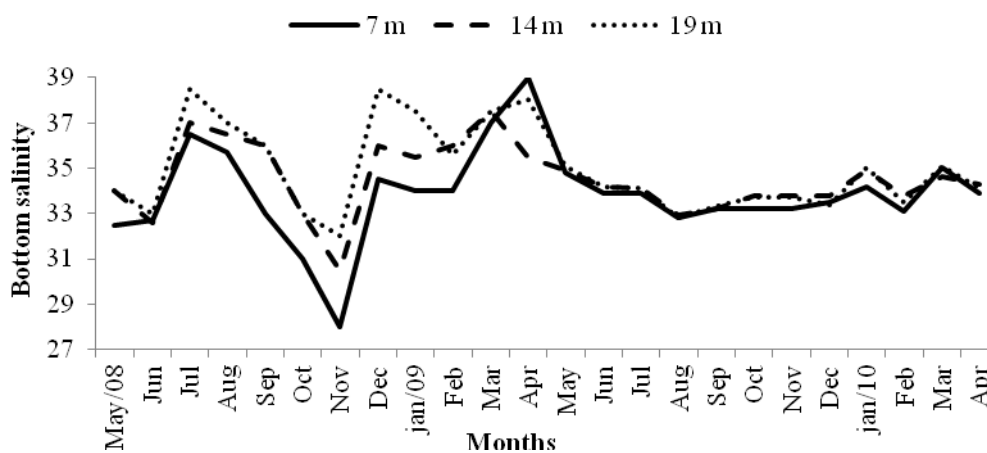


Figure 3. Variation of the mean monthly bottom salinity for each depth (7, 14 and 19 m) from May 2008 to April 2010, in the region of Balneário Camboriú, Santa Catarina State, Brazil.

Distribution and Abundance

A total of 1882 individual of *Hepatus pudibundus* was collected, 1221 during the first year and 661 during the second one. The abundance mean (CPUE N/15min) in the first year was 15.9 ± 21.8 and in the second year was 8.66 ± 11.7 (interannual differences in the mean number per trawling are statistically significant; $F=2.05$, $p < 0.01$).

Furthermore, the abundance mean in weight (CPUE g/15min) at the first year (459.3 ± 655.9) was significantly higher than the second year (276.8 ± 382.7) ($p < 0.05$). The highest average abundance (CPUE g/15min), in the first year, was recorded in February (777.6 ± 419.05), while in the second year highest abundance were recorded in August (646.8 ± 623.5). During the first year the highest biomass

was recorded at the depth of 7 meters (688.8 ± 799.2), when compared to 14 (149.4 ± 212.6) and 19 meters (526.9 ± 686.6), during the winter and spring, while in the second year it did not present a significant difference related to season or depth (Fig. 4).

Considering the abundance in number of individuals, the depth of 14 meters (5.52 ± 6.91) presented significantly lower values ($p < 0.01$) than the depths of 7 (15.14 ± 20.23) and 19 meters (16.18 ± 21.05). In the first year, the highest abundance was observed in February at depth of 19 meters (33.83 ± 29.96), and in all seasons the depth of 14 meters was statistically different, being always lower than the depths of 7 and 19 meters ($p < 0.01$). On the other hand, the second year presented a different pattern, with the highest abundance was recorded in August at depth of 7 meters (18.66 ± 17.79), in spite of not presenting significant difference according to season or depth ($p > 0.05$) (Fig. 5).

The highest abundance index CPUE (g/15min), of ovigerous females in the first year,

was recorded from November to April, with the highest abundance during November and January. November presented a significant greater biomass concentration of ovigerous females at depth of 7 meters (405.64 ± 304.26), when compared to the depths of 19 meters (9.07 ± 12.82) and 14 meters, where no ovigerous females were found ($p < 0.01$). January also presented a higher and significant biomass concentration at depth of 7 meters (432.58 ± 533.32), when compared to the depths of 19 meters (48.46 ± 1.25) and 14 meters, where there were not found any individuals ($p < 0.01$). In the second year the highest CPUE (g/15min) of ovigerous females was recorded in December, without a significant biomass concentration at depth of 7 meters (75.61 ± 106.92), when compared to the depths of 14 (24.72 ± 34.95) and 19 meters (15.52 ± 21.95) ($p > 0.05$).

The multiple regression analysis indicated that both the environmental factors and depth didn't regulated the abundance of *H. pudibundus* ($F=1.20$, $p > 0.05$) (Table I).

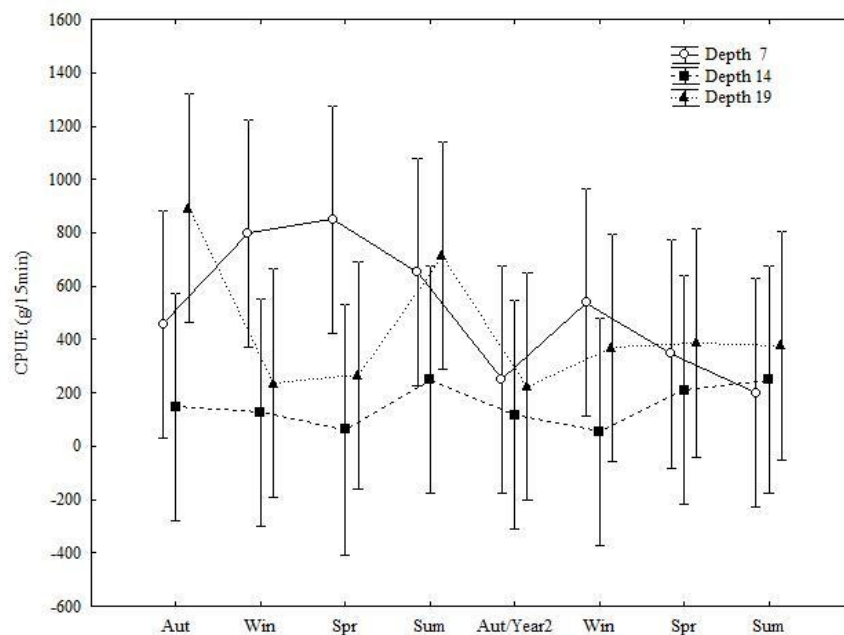


Figure 4. Seasonal variation of the CPUE (g/15min) by depth of the crab *Hepatus pudibundus*, from May 2008 through April 2010. The vertical bars indicate a confidence interval at 95%, with the minimum and maximum values.

Sex ratio

The overall sex ratio differs from the expected 1:1 equilibrium ($P > 0.05$, χ^2 test). Considering the 1853 individuals analyzed, 946 (51.05%) were females and 907 (48.95%) were males (1.04:1). During the first year, the monthly pattern indicated significant differences ($P < 0.01$) towards the females in November (72%) and January (65%). Males dominated the samples in July

(67%), September (74%) and March (75%). In the second year, the χ^2 test indicated significant differences ($P < 0.01$) toward females in August (65%) and November (67%), and towards males in May (65%) and September (86%). In deeper waters, the F:M presented values of 55% (19m) and 67% (14m) favoring males, while at a depth of 7 m, the F:M proportion was 2.39:1 (Fig. 6).

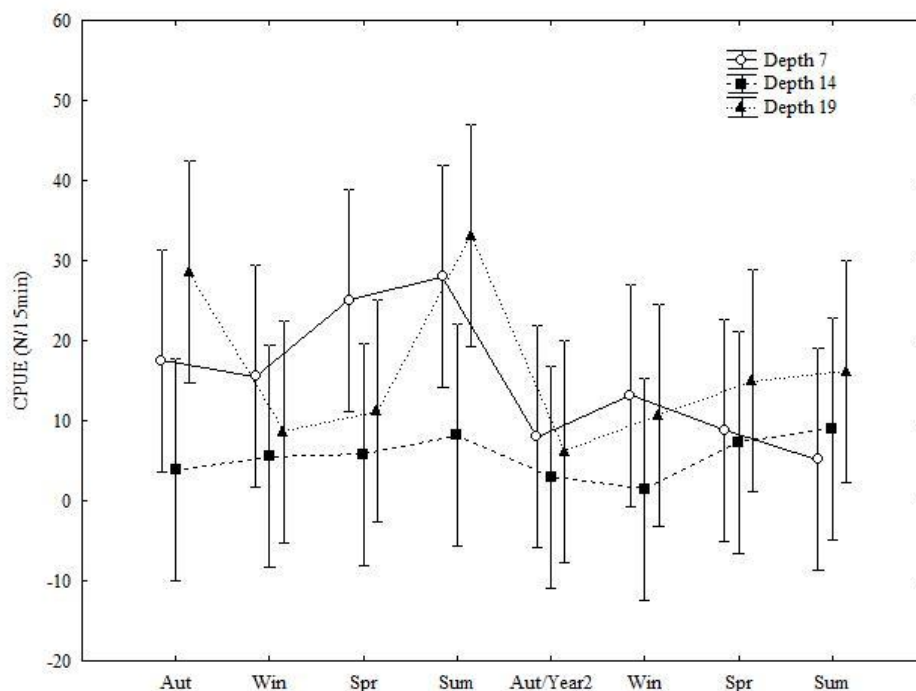


Figure 5. Seasonal variation of the CPUE (N/15min) by depth of the crab *Hepatus pudibundus*, from May 2008 through April 2010. The vertical bars indicate a confidence interval at 95%, with the minimum and maximum values.

Table I. *Hepatus pudibundus*. The multiple regression analysis, relating the abundance and environmental variables (bottom salinity and temperature) and depth, measured in the region of Balneário Camboriú ($p < 0.05$).

Environmental Factor	β	p
Depth	0.07	0.45
Bottom salinity	0.06	0.55
Bottom Temperature	-0.16	0.36

Seasonal and Spatial variation in the Carapace width

The males reached larger sizes than females ($p < 0.05$), presenting mean CW (mm) of 49.48 ± 17.55 mm, ranging from 13.5 to 96.67 mm. On the other hand, the mean size for females was 47.15 ± 13.87 mm, ranging from 16.31 to 76.99 mm. Based on the data of first maturity obtained by Fracasso & Branco (2005) in the same region, the male recruits were considered ranging from 13.5 to 35 mm, while the female recruits ranged from 16.31 to 36 mm. The mean size (CW) of ovigerous females was 56.01 ± 8.95 mm, ranging from 37.84 to 68.74 mm, this average was superior than the CW mean for males due to the low number of samples of ovigerous females. For both sexes and for ovigerous females, the mean value of the carapace width (CW) was

higher at 7 m isobath than at the other two 14 m e 19 m ($p < 0.01$) (Table II).

The analysis of seasonal trends in the mean carapace width of females showed that, analyzing both years, the larger individuals occurred in spring (52.30 ± 12.19) in the 7 m isobaths, while the smaller were recorded during the winter (27.39 ± 26.75) in the 14 m isobaths (seasonal differences are statistically different, $F=4.6$, $P < 0.01$), still these females may be considered as juveniles after plotted on the graph the line of size of the first maturity (Fig. 7). However, the larger ovigerous females were more abundant in summer (62.45 ± 6.86) and spring (58.34 ± 8.47) seasons, especially in the 7 m isobaths, when compared with others isobaths (seasonal differences are statistically different, $F=3.2$, $P < 0.01$).

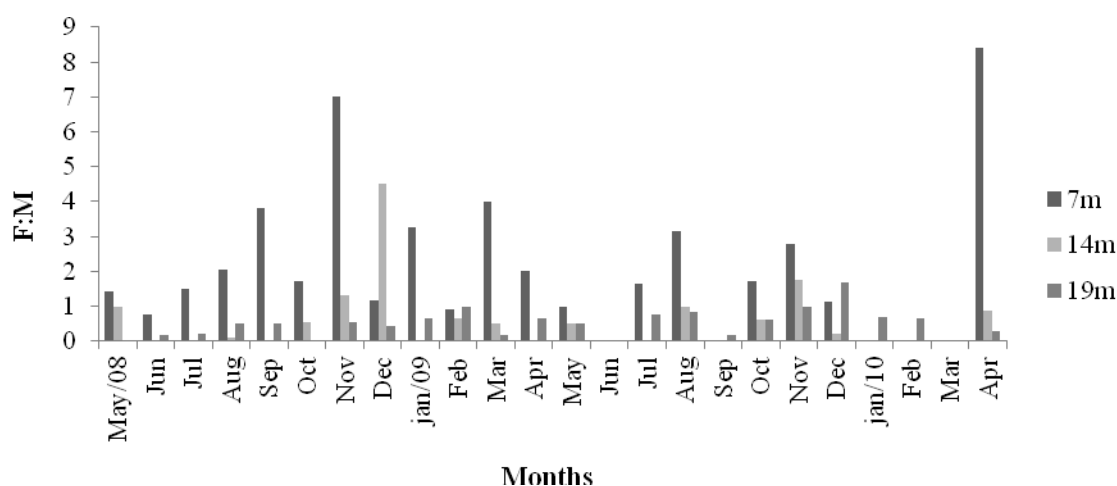


Figure 6. Monthly proportion of female and male (F: M) of *Hepatus pudibundus*, by depth (7, 14 and 19 m), during the two years of sampling, from May 2008 through April 2010.

Table II. Variation in the mean carapace width (CW), standard deviation (SD), standard error (SE) and confidence limits (95%) of females, males and ovigerous females of *Hepatus pudibundus* by depth (7, 14 and 19 m), in the region of Balneário Camboriú, Santa Catarina, Brazil, from May 2008 through April 2010. Values in the same column followed by different letters differ significantly ($p < 0.05$).

Females	Depth	CW (mm)	SD	SE	95%	
	7 ^a	50.77	12.12	9.32	41.76	78.39
	14 ^b	41.83	17.85	1.62	38.60	45.06
	19 ^b	42.01	12.98	14.27	28.16	84.37
Males	Depth	CW (mm)	SD	SE	95%	
	7 ^a	53.26	17.2	1.09	51.10	55.42
	14 ^b	47.47	19.73	1.58	44.35	50.59
	19 ^b	48.23	16.71	0.75	46.75	49.70
Ovigerous Females	Depth	CW (mm)	SD	SE	95%	
	7 ^a	59.28	8.63	1.43	56.36	62.2
	14 ^b	52.78	9.32	3.52	44.16	61.40
	19 ^b	51.86	7.47	1.55	48.63	55.1

On the other hand, the seasonal variation of the carapace width of males showed that, analyzing both years, the larger individuals occurred in the summer (58.04 ± 17.17) in the 7 m isobaths, while the smaller were recorded during the winter (41.74 ± 21.69) in the 14 m isobaths (seasonal differences are statistically different, $F=2.94$; $P < 0.05$). The graph shows the low participation of juveniles, since the mean CW during the seasons was always larger than the size stipulated for the first maturity. Still, in both years, the larger individuals, males and females,

remained in shallow areas, while the smaller ones were found in deeper waters (Fig. 8).

Biometric Relationships

The relationship between carapace width and weight presented a negative allometry for females ($b=2.95$) and males ($b=2.94$), without significant differences between the sexes. The relationship between carapace length and carapace width presented a negative allometry for females ($b=0.72$) and males ($b=0.68$), with significant differences between them (Table III).

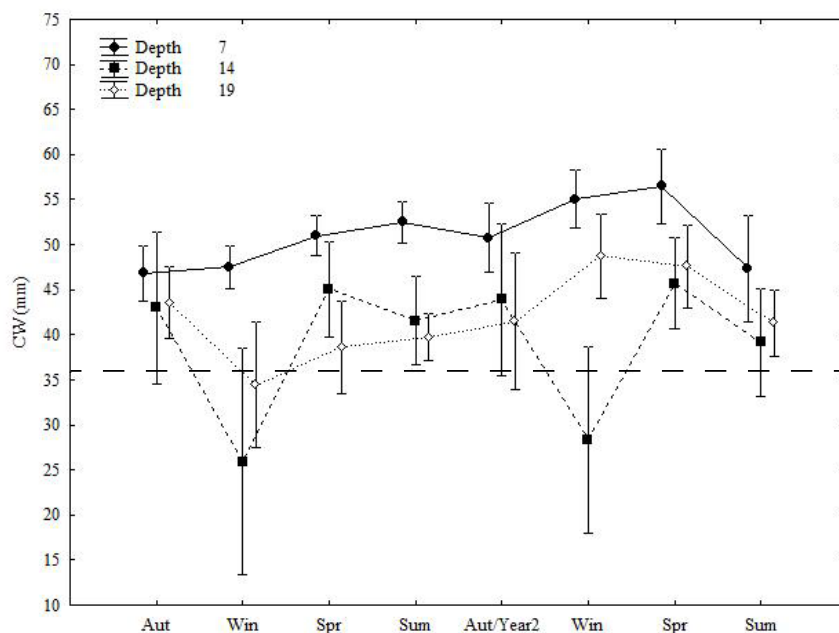


Figure 7. Seasonal variation of the mean of the carapace width (CW), for females of *Hepatus pudibundus*, by depth, from May 2008 through April 2010. The vertical bars indicate a confidence interval at 95%, with the minimum and maximum values. Dotted line: estimated sexual maturity ($CL_{50\%}$).

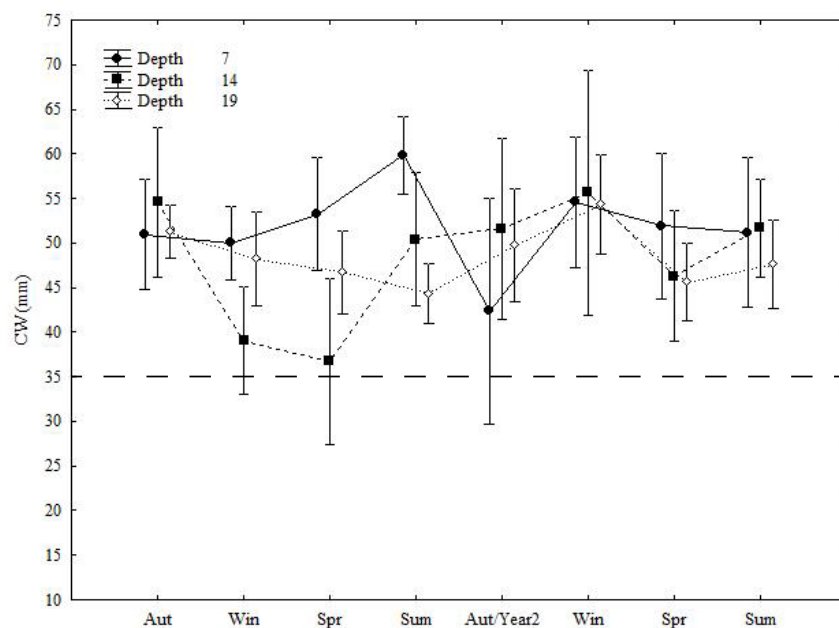


Figure 8. Seasonal variation of the mean of the carapace width (CW), for males of *Hepatus pudibundus*, by depth, from May 2008 through April 2010. The vertical bars indicate a confidence interval at 95%, with the minimum and maximum values. Dotted line: estimated sexual maturity ($CL_{50\%}$).

Discussion

Environmental parameters

During the first sampling year, a clear stratification of the water column was observed from December to March, indicated by lower temperatures and higher salinities in deeper waters. On the other hand, the second year presented a more

stable environmental pattern. Probably, this variation in the abiotic factors, in the first sampling year, is due to the influence of a local upwelling. This phenomenon is triggered when there is a predominance of northeast winds, which pushes surface waters away from the coast resulting in the

upwelling of cold and salty shelf waters (Pereira *et al.* 2009).

Distribution and Abundance

Fluctuations in abundance between both years reinforce the idea that the recruitment is influenced by environmental conditions, which directly influences the biomass available each year. It is in agreement with the biology of the brachyurans, since they present important oscillations in CPUE. A marked feature of these populations is the oscillation between high values of abundance and very subsequent low abundance periods (Fracasso &

Branco 2005), which may be related to the different requirements, during the various stages of life. In the particular case of *Hepatus pudibundus* such requirements may play an important role on the population structure (Mantelatto *et al.* 1995). This study supports the data obtained by Fracasso & Branco (2005) that using a six years temporal series sample for Santa Catarina (BR) indicate the occurrence of an interannual fluctuation at catches of *H. pudibundus*, assigned to the climatic and oceanographic conditions of the studied area, as well as the life cycle events of the species.

Table III. Descriptive statistics from size and weight relation (CWxWt) and length and carapace width relation (CLxCW) for males and females of the crab *Hepatus pudibundus* obtained in Balneário Camboriú region, State of Santa Catarina, Brazil, from May 2008 to April 2010.

CWxWt	a	b	R²
Male	0.0002	2.94	0.99
Female	0.0002	2.95	0.96
CLxCW	a	b	R²
Male	1.08	0.68	0.99
Female	0.3	0.72	0.99

Two major peaks of abundance, both in the first year sample, occurred in the spring and summer. These two peaks occurred at an average water temperature of around 20°C, indicating that the species may be adapted to a certain range of optimum temperature. Similar results were observed on the coast of state São Paulo (Mantelatto *et al.* 1995), where the studied population of *H. pudibundus* presented peaks of abundance associated with this temperature range. Additionally, a sudden decrease in the salinity of the water was observed during the transition from spring to summer, which can be related to high rainfall and thus to the transport of terrigenous nutrients fertilizing the coastal area and possibly resulting in a favorable environment for its occurrence. This abundance is explained by the fact that this species is considered euryhaline, because it is more captured in salinities of until 5 (Abreu 1980).

The monthly trends in abundance show two marked peaks of abundance, in August and November, which are likely related to mating, especially during the first year of sampling. This is confirmed by analyzing the abundance in the depth of 7 meters, but also by the larger average carapace width of the individuals. Therefore, the presence of large adult females and males indicates a migration of individuals to shallow waters, possibly for

mating. This migratory behavior can be an advantage to the species, as it can avoid competition. In January a peak in the abundance of small individuals and a low abundance in weight and carapace width of individuals, in depth of 7 meters, indicating the presence of recruits. After this period, in February and March, there are two other peaks of abundance, first in numbers then in weight, indicating the end of recruitment. This hypothesis is confirmed by analysis of the growth curve of this species, which the month of March, after the significant migration to greater depths, presented males with an average of 35 mm CW, representing around 100 days old, and females CW with an average of 28 mm, representing around 85 days old (Sardá *et al.* unpublished data). Immediately after the abundance peaks, a reduction in abundance of adults (male and female) can be observed, which may be associated to a massive mortality of individuals after the reproduction. Considering that the estimate of maximum longevity around two years is more common for decapods (Barcelos *et al.* 2007). The possible death of animals, until the age of two years, may be related to the end of the reproductive period. This longevity has been observed by Keuncke *et al.* (2007a), Sardá *et al.* (unpublished data) for *Hepatus pudibundus*. Nevertheless, Reigada & Negreiros-Fransozo (2000)

worked with *H. pudibundus* in the Ubatuba Bay (SP) found moult activity in almost all size classes, which indicates that this species does not undergo a terminal anecdisis, but continues moulting even though longer intermoult intervals.

Analyzing the three depths considered in this study, the marked difference in the *Hepatus pudibundus* abundance observed in both years on the Santa Catarina coast can be attributed to the variations in salinity and temperature, where in shallow, warmer and less saline waters; there was a higher abundance of females. On the other hand, in deeper, colder and more saline waters, there was a higher abundance of males. This preference was also observed in another study, performed in the north coast of Rio de Janeiro (Klôh & Di Benedetto 2010). During the months of February and March, there was also an abundance of males, however, concentrated at the depth 19 m. This may support the idea that mating occurs during these peaks and then immediately afterwards, there is a differential migration between sexes avoiding competition for food and space. On the other hand, females may migrate to shallower depths, attracted by the higher water temperature, to favoring egg incubation (Nagao *et al.* 1999) and also reducing competition for space. This segregation behavior has also been observed in studies with *Callinectes ornatus*, they have revealed that juveniles preferred calm and shallow waters with more organic material and low salinity (Mantelatto 2000), and later with *Callinectes sapidus* (Rodrigues & D'Incao 2008). Unlike *H. pudibundus*, after mating, females of *C. sapidus* begin to migrate to more saline areas, where the release and hatching of larvae occurs, with the males remaining in less saline areas and even able to copulate with other females. The juveniles are, therefore, using the 14 meters depth to recruitment, which can be concluded by the lower mean size observed for this depth. This idea can be sustained not only by the fact that the larger carapace width of both males and females, have been found at 7 and 19 meters depths, but also because there is a greater proportion of females at 7m depth and males at 14 and 19 meters depths. The results found on this study are consistent with those obtained by Mantelatto *et al.* (1995) on the coast of São Paulo, which also have not found a relationship between the abundance of *H. pudibundus* with the variation of environmental factors, in this case temperature and salinity.

Sex ratio

Hepatus pudibundus showed a sex ratio around 1:1.04 in favor of females, despite of having

months with a significant difference of males over females. This pattern is similar to those found by Fracasso & Branco (2005) that also performed in the state of Santa Catarina, since both studies were marked by a predominance of males in the winter. In this study, during the first year sample, there was a significant dominance of females in the months of November and January, in the second year females predominated in November. On the coast of Guarujá (Sao Paulo), this species showed the predominance of females in the months from September to February (Severino-Rodrigues *et al.* 2002), while in the Bay of Mucuripe (CE) that predominantly occurred from December to February (Sampaio & Fausto-Filho 1984). These three studies indicate the dominance of females in the warmer months, which may be related to reproduction.

When the results were analyzed by depth, this predominance of females was not constant over the two years of sampling. The deviation from the expected 1:1 sex ratio is very common in decapods (Wenner 1972), and may be attributed to spatial segregation (Jesse & Stotz 2003) and/or temporal variations in sexual composition of the population (Wenner 1972, Bas *et al.* 2005).

Seasonal and Spatial variation in the Carapace width

Hepatus pudibundus presents sexual dimorphism related to size, with males larger than females, indicating a different growth rate between the sexes (Keunecke *et al.* 2007a). Mantelatto & Fransozo (1994) and Reigada *et al.* (1994) point out that the factors that explain this difference in *H. pudibundus* are likely to be: i) the pressure of reproductive selection acts favorably in relation to larger males, which then would leave more descendants, and ii) the female, after sexual maturity, invests more in reproduction metabolism and maturation of the gonads than in its own growth.

The analysis of the mean variation of carapace width of females, males and ovigerous females of *H. pudibundus*, by depth and season, indicated that the largest individuals are concentrated in shallow water (7m) during the summer of first year and autumn of second year, indicating that reproduction takes place in shallow waters. However, the smaller individuals are concentrated in the intermediate depths (14m) during both analyzed years, suggesting that it represents a recruitment zone.

Biometric Relationships

According to Hartnoll (1982), growth in crustaceans occurs as a consequence of a sequence

of phases, and within there are variables that can be explained by allometric models (linear or power). In this study, the size-relationship between carapace width (CW) and Weight (Wt) of females ($b=2.95$) had a slope close to males ($b=2.94$). For females, the negative allometry indicates that the gain of biomass is reduced when the animal reaches maturity. For males, it can be related to the need of maximize the size, investing less at weight, in order to assure a successful reproductive strategy, in search for food and territory defense. The same result was obtained by Mantelatto & Fransozo (1992), in a study on the northern coast of São Paulo and Fracasso & Branco (2005) in Santa Catarina. The results by Klôh & Di Benedetto (2010), revealed a isometry on the relation weight and CW of males from this specie, indicating a proportional increase of these variables while the individual is growing. According to these authors, the variations between the studies may reflect the biometric characteristics of the populations of *H. pudibundus* along the distribution areas, or just temporary differences on the individuals ontogeny that compose these populations. The relationship between carapace length (CL) and carapace width (CW) of females had a higher CW slope ($b=0.72$) than males ($b=0.68$), indicating a pattern of higher relative growth in CW for females. This result confronts the results obtained for this species on the coast of São Paulo, since it was observed an isometry on the relation CL and CW, which may be related to latitudinal variations of the areas studied (Bueno *et al.* 2009). Biometric relationships can provide important on biological events occurring in a population, such as length-weight relationship variation during reproductive season or unfavorable environmental conditions (King 1995). Additionally, these biometric relationships can provide an easy way of estimating width and weight in the case if some data was not obtained during the performance of biometrics, also allowing comparison with previous investigations (Ragonese *et al.* 1997).

In some areas of Brazil the numerical contribution of *Hepatus pudibundus* often does not exceed 10% of total brachyuran recorded in shrimp fishery (Severino-Rodrigues *et al.* 2002, Branco & Fracasso 2004, Costa & Di Benedetto 2009, Klôh & Di Benedetto 2010). However, a study showed that *H. pudibundus* was the most abundant species representing 20% of the whole crustacean catch in the pink shrimp trawling fishery in Rio de Janeiro (Keunecke *et al.* 2007b).

Thereby, the continuous action of the shrimp fishery activity in coastal areas can influence the size and structure of the Brachyura populations from the systematic removal of individuals, leading

to changes in recruitment rate and population size (Klôh & Di Benedetto 2010). The closed season for seabob shrimp in the region of Santa Catarina occurs annually during the months of March, April and May, this was established based on the life cycle of the pink shrimp (*Farfantepenaeus paulensis* e *F. brasiliensis*), however, the largest catches of seabob shrimp occurring on this period (Bail & Branco 2007), leading to increase the bycatch. Given the marked presence of ovigerous females from November to April, this would be the most important time to ensure the preservation of the species, however, the closed season for seabob shrimp covers only two months of this period. Also, another period of interest in preservation of *H. pudibundus* would be the recruitment, which begins in February, just before the start of closed season for seabob shrimp and probably should present an intensive fishing, providing any profit to fishermen during the closed season. Considering that the fecundity of *H. pudibundus* is not one of the highest and the hard competition in the planktonic life (Reigada & Negreiros-Fransozo 1995), the recovery of the biomass removed by fisheries is slow if compared with shrimps, for example. Therefore, to overexploit a shrimp stock, would be needed a higher fishing effort if compared to the bycatch. Nowadays there is international consensus that the bycatch is an important part, and that requires attention from both researchers and fisheries administrators (Worm *et al.* 2006), so this information can be used to ensure the protection of this important species in the trophic ecology of this environment.

References

- Abreu, J. 1980. Distribuição e ecologia dos Decápodos numa área estuarina de Ubatuba (SP). **Boletim do Instituto Oceanográfico**, São Paulo, 29 (2): 1-3.
- Barcelos, D.F., Castiglioni, D.S., Barutot, R.A. & Santos, S. 2007. Crescimento de *Chasmagnathus granulatus* (Crustacea, Decapoda, Varunidae) na Lagoa do Peixe, Rio Grande do Sul, Brasil. **Iheringia Série Zoológica**, 97(3): 263-267.
- Bail, G.C. & Branco, J.O. 2007. Pesca artesanal do camarão sete-barbas: uma caracterização sócio-econômica na Penha, SC. **Brazilian Journal of Aquatic Science and Technology**, 11(2): 25-32.
- Bas, C., Luppi, T. & Spivak, E. 2005. Population structure of the South American estuarine crab, *Chasmagnathus granulatus* (Brachyura: Varunidae) near the southern limit of its

- geographical distribution: comparison with northern populations. **Hydrobiologia**, 537: 217-228.
- Branco, J.O. & Moritz, Jr. H.C. 2001. Alimentação natural do camarão sete-barbas (*Xiphopenaeus kroyeri*) na Armação do Itapocoroy, Penha, SC. **Revista Brasileira de Zoologia**, 18: 53-61.
- Branco, J.O. & Fracasso, H.A.A. 2004. Biologia populacional de *Callinectes ornatus* (Ordway) na Armação do do Itapocoroy, Penha, Santa Catarina, Brasil. **Revista Brasileira de Zoologia**, 21(1): 91-96.
- Bueno, F.A., Severino-Rodrigues, E., Santos, J.L. & Reis Santos, P. 2009. Crescimento relativo e tamanho de primeira maturação em *Hepatus pudibundus* capturado pela pesca do camarão sete-barbas na praia do Perequê, Guarujá, São Paulo, Brasil. **Revista Ceciliana**, 1(2): 34-38.
- Costa, I.D. & Di Benedetto, A.P.M. 2009. Caracterización preliminar de los invertebrados bentónicos capturados accidentalmente en la pesca de camarones en el Norte del estado de Rio de Janeiro, Sudeste de Brasil. **Latin American Journal of Aquatic Research**, 37: 259-264.
- FAO. 2010. The State of World Fisheries and Aquaculture. Rome.
- Fracasso, H.A.A. & Branco, J.O. 2005. Estrutura populacional de *Hepatus pudibundus* (Herbst) (Crustacea, Decapoda) na Armação do Itapocoroy, Penha, Santa Catarina, Brasil. **Revista Brasileira de Zoologia**, 22(2): 342-348.
- Gasalla, M.A. & Tomás, A.R.G. 1998. Evaluation of the status of fisheries data collection and stock assessments problems in São Paulo, Southeastern Brazil. In: FUNK, F. *et al.* (eds.). Fishery Stock Assessment Models. Alaska: Sea Grant College Program Report no. AK SG-98-01, University of Alaska Fairbanks.
- Hartnoll, R. 1982. "Growth". **The Biology of Crustacea**, 2: 111-196.
- Jesse, S. & Stotz, W. 2003. Spatio-temporal distribution patterns of the crab assemblage in the shallow subtidal of the north Chilean Pacific coast. **Crustaceana**, 75(10): 1161-1200.
- Keunecke, K.A., D'Incao, F. & Fonseca, D.B. 2007a. Growth and mortality of *Hepatus pudibundus* (Crustacea: Calappidae) in south-western Brazil. **Journal of the Marine Biological Association of the United Kingdom**, 87: 885-891.
- Keunecke, K.A., Vianna, M., Fonseca, D.B. & D'Incao, F. 2007b. The pink-shrimp trawling bycatch in the northern coast of São Paulo, Brazil, with emphasis on crustaceans. **Nauplius**, 15(2): 49-55.
- King, M.G. 1995. **Fisheries biology, assesment and management**. Fishing news books. Osney Mead, Oxford, England, 341 p.
- Klôh, A.S. & Di Benedetto, A.P.M. 2010. Estrutura populacional do siri-baú, *Hepatus pudibundus* (Herbst 1785) no Norte do Estado do Rio de Janeiro, Sudeste do Brasil. **Biota Neotropica**, 10(3): 463-467.
- Mantelatto, F.L.M. & Fransozo, A. 1992. Relação peso/largura da carapaça no caranguejo *Hepatus pudibundus* (Herbst, 1785) (Crustacea, Decapoda, Calappidae) na região de Ubatuba, SP, Brasil. **Arquivos de Biologia e Tecnologia**, 35: 719-724.
- Mantelatto, F.L.M. & Fransozo, A. 1994. Crescimento relativo e dimorfismo sexual em *Hepatus pudibundus* (Herbst, 1785) (Decapoda, Brachyura) no litoral norte paulista. **Papéis Avulsos de Zoologia**, 39: 33-48.
- Mantelatto, F.L.M., Fransozo, A. & Negreiros-Fransozo, M.L. 1995. Distribuição do caranguejo *Hepatus pudibundus* (Herbst, 1785) (Crustacea, Decapoda, Brachyura) na enseada da Fortaleza, Ubatuba, SP, Brasil. **Boletim Instituto Oceanográfico**, 43: 51-61.
- Mantelatto, F.L.M. & Petracco, M. 1997. Natural diet the crab *Hepatus pudibundus* (Brachyura: Calappidae) in Fortaleza Bay, Ubatuba (SP), Brazil. **Journal of Crustacean Biology**, 17(3): 440-446.
- Mantelatto, F.L.M. 2000. Allocation of the portunid crab *Callinectes ornatus* (Decapoda: Brachyura) in the Ubatuba Bay, northern coast of Sao Paulo State, Brazil. **Crust. Issues**, 12: 431-443.
- Nagao, J., Munehara, H. & Shimazaki, K. 1999. Embryonic development of the hair crab *Erimacrus isenbeckii*. **Journal of Crustacean Biology**, 19 (1): 77-83.
- Pereira, M.D., Schettini, C.A.F. & Omachi, C.Y. 2009. Caracterização de feições oceanográficas na plataforma de Santa Catarina através de imagens orbitais. **Revista Brasileira de Geofísica**, 27 (1): 81-93.
- Perez, O.S. & D.R. Bellwood. 1988. Ontogenetic changes in the natural diet of the sandy shore crab, *Matuta lunaris* (Forskål) (Brachyura: Calappidae). **Australian Journal of**

- Marine and Freshwater Research**, 39: 193-199.
- Piola, A. R. & R. P. Matano. 2001. The South Atlantic Western Boundary Currents Brazil/Falkland (Malvinas) Currents, in *Encyclopedia of Ocean Sciences*, vol. 1, edited by J. M. Steele, S. A. Thorpe, and K. K. Turekian, pp. 340– 349, Elsevier, New York.
- Ragonese, S., Jereb P. & Morara, U. 1997. Morphometric relationships of *Spherooides pachygaster* (Pisces, Tetraodontidae) of the Strait of Sicily (Mediterranean Sea). **Carriers de Biologie Marine**, 38: 283-289.
- Reigada, A.L.D., Negreiros-Fransozo, M.L. & Mantelatto, F.L.M. 1994. Avaliação do tamanho dos quelípodos de *Hepatus pudibundus* (Herbst, 1785) (Crustacea, Calappidae) em relação ao sexo e a fase de maturação. **Arquivos de Biologia e Tecnologia**, 37: 797–807.
- Reigada, A.L.D. & M.L. Negreiros-Fransozo. 1995. Fecundidade do caranguejo *Hepatus pudibundus* (Herbst, 1785) (Crustacea, Decapoda, Calapidae) em Ubatuba (SP), Brasil. **Brazilian Archives of Biology and Technology**, Curitiba, 38 (2): 661-668.
- Reigada, A.L. & Negreiros-Fransozo, M.L. 2000. Reproductive Cycle of *Hepatus pudibundus* (Herbst, 1785) (Crustacea, Decapoda, Calappidae) in Ubatuba, SP, Brazil. **Revista Brasileira de Biologia**, 60(3): 483-491.
- Rodrigues, M.A. & D’Incao, F. 2008. Comparação do crescimento entre *Callinectes sapidus* (Crustacea, Decapoda, Portunidae) coletados em campo e mantidos em condições controladas. **Iheringia Série Zoologia**, 98(3): 372-378.
- Sampaio, C.M.S. & Fausto-Filho, J. 1984. Considerações sobre a bioecologia dos crustáceos decápodos da Enseada do Macuripe (Fortaleza, Ceará, Brasil). **Arquivos de Ciências Marinhas**, 23: 11-24.
- Severino-Rodrigues, E., Guerra, D.S.F. & Graça-Lopes, R. 2002. Carcinofauna acompanhante da pesca dirigida ao camarão sete-barbas (*Xiphopenaeus Kroyeri*) desembarcada na Praia do Perequê, Estado de São Paulo, Brasil. **Boletim do Instituto da Pesca**, 28(1): 33-48.
- Teixeira, R.L. & Sá, H.S. 1998. Abundância de macrocrustáceos decápodos nas áreas rasas do complexo lagunar Mundaú/Manguaba, AL. **Revista Brasileira de Biologia**, 58: 393-404.
- Wenner, A.M. 1972. Sex ratio as a function of size in marine Crustacea. **American Naturalist**, 106: 321-350.
- Worm, B., Barbier, B., Beaumont, N., Duffy, J.E., Folke, C., Halpern, B.S., Jackson, J.B.C., Lotze, H.K., Michelli, F., Palumbi, S.R., Sala, E., Selkoe, K.A., Stachowicz, J.J. & Watson, R. 2006. **Impacts of Biodiversity Loss on Ocean Ecosystem Services**. Science. Vol 314.
- Williams, A.B. 1974. The swimming crabs of genus *Callinectes* (DECAPODA: PORTUNIDAE). **Fishery Bulletin** 72(3).
- Zar, T.H. 1999. **Biostatistical analysis**. Fourth Edition, Prentice Hall. 663 p.

Received March 2013

Accepted May 2013

Published online June 2013