



Characterization of the occupied shells by the hermit crab *Clibanarius vittatus* (Decapoda, Diogenidae) at Baixio Mirim tideflat, Guaratuba Bay, southern Brazil

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ABSTRACT

A characterization of the occupied shells by the hermit crab *Clibanarius vittatus* was carried out. Hermit crabs were collected in the intertidal zone, during the low spring tide monthly from April 2005 to March 2006. They were sexed and their cephalothoracic shield length (CL) was measured. Shells were identified, dried, weighed and the aperture length (AL) and width (AW) were measured. 1187 crabs were collected (949 males, 216 females and 22 intersexes), which occupied 12 species of gastropod shells. *Stramonita haemastoma*, *Olivancillaria urceus* and *Dorsanum moniliferum* made up 96.55% of the total shell species. Male hermit crabs attained significantly larger sizes than females; therefore, males occupied a wider spectrum of shells in size and weight. A stronger correlation ratio was obtained between CL and AW of *S. haemastoma*. Last whorl with a rounded shape and a spacious inner area is a common feature of all shell species most frequently occupied by this hermit crab where it occurs. The successful establishment of *C. vittatus* at Baixio Mirim is mainly due to the appropriately shaped and wide range of size of *S. haemastoma* shells that were most often occupied by the hermit crabs of the studied population.

Key words: Guaratuba Bay, shell availability, shell occupation, shell size and shape.

INTRODUCTION

Hermit crabs are anomuran crustaceans that use empty shells of gastropods as a shelter. These shells can be acquired from the habitat if empty and available; if not, by removing dead or dying mollusks, once hermit crabs are unable to dislodge alive gastropods from their shells (Rittschof 1980, Bertness 1981, Tricarico and Gherardi 2006). The gastropod shells perform several important roles in the life of these crabs, mainly the protection of their uncalcified abdomen against eventual mechanical shocks and dryness.

The use of the specific shell species by a hermit crab is firstly related to the availability of these shells in the environment (see revision in Vance 1972, Turra

and Leite 2001, Meireles et al. 2003). When this availability is restricted in the habitat, hermit crabs are compelled to occupy shells that are not always appropriate in size, form or integrity, and this restriction affects reproduction (Childress 1972, Bertness 1981, Hazlett 1989, Bertini and Fransozo 2000, Hazlett et al. 2005, Turra 2005), growth (Markham 1968, Bertness 1981, Osorno et al. 1998, Bertini and Fransozo 2000) and body morphology (Turra and Leite 2002).

Secondly, the occupation of a specific shell is influenced either by the interactions among hermit crabs, such as intra-specific competition for the shell, or by other resources (Bertness 1980, 1981, Gherardi and Nardone 1997, Dominciano and Mantelatto 2004, Sant'Anna et al. 2006b), coexistence of different hermit crabs species (Kellog 1977, Bertness 1980, Gherardi and Nardone

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1997, Floeter et al. 2000, Turra 2003, Sant'Anna et al. 2006b), predation (Bertness 1982, Rotjan et al. 2004), presence of gastropods in the community (Bertness 1980, Turra and Leite 2001, Sant'Anna et al. 2006a), previous experience (Hazlett 1993, Hahn 1998, Meireles et al. 2008, Alcaraz and Kruesi 2009) and formation of aggregations (Hazlett 1981, Turra and Leite 2000a). The hermit crab ability in detecting odours of died or dying gastropods was also reported (Kratt and Rittschof 1991, Chiussi et al. 2001).

Likewise, morphometric characteristics of shells influence their occupation by hermit crabs. Among these characteristics are weight (Hahn 1998, Dominciano and Mantelatto 2004, Turra and Leite 2004), size (Bertini and Fransozo 2000, Turra and Leite 2004), opening size (Botelho and Costa 2000, Bertini and Fransozo 2000, Sant'Anna et al. 2006a) and architecture and volume (Gherardi and Nardone 1997, Floeter et al. 2000, Shih and Mok 2000).

Clibanarius vittatus (Bosc, 1802) has a wide geographical distribution in western Atlantic, from the eastern of the United States to West Indies, including Gulf of Mexico, and from Venezuela to southern Brazil, in Santa Catarina State (Melo 1999). In spite of the wide distribution, the ecological aspects of this species were only reported in the USA in North and South Carolina, Florida and Gulf of Mexico, and in Brazil these aspects are restricted to the São Paulo State coast (Turra 2003, 2005, Turra and Leite 2001, 2002, 2004, Sant'Anna et al. 2006a, b). The present study is the first research about the relationships of the hermit crab *C. vittatus* and its occupied shell from the Guaratuba Bay, Paraná State, southern Brazil.

MATERIALS AND METHODS

Baixio Mirim is a 6.300m² tideflat located within Guaratuba Bay and isolated from the continent by a narrow channel of 15-20m width. Most of its substrate is covered by the smooth cordgrass *Spartina alterniflora* Loisel, but it is also provided with sandy and muddy surface especially in the bordering areas. In spite of urban influence, this tideflat is inhabited by hundreds of fiddler crabs that constitute the main preys for sea birds that land on the sandbanks during low tides (Masunari et al. 2005).

Hermit crabs occur individually or in groups of 5-10 crabs either in the vegetated areas or in non-vegetated ones in Baixio Mirim tideflat, from where they were collected during low spring tides, monthly from April/2005 to March/2006. Each monthly sample consisted of nearly a hundred crabs collected with the following shell size frequency distribution: 25% of individuals occupying small shells, 50% medium and 25% big ones. This procedure aimed to avoid collections biased towards more visible shells because hermit crabs have a gregarious habit, and a sampling based on the area or CPUE would be improper. Furthermore, such number was sufficient or more than sufficient to represent populations of hermit crabs in other studies in the Brazilian coast (Fransozo and Mantelatto 1998, Floeter et al. 2000, Turra and Leite 2000b, 2001, Sant'Anna et al. 2006a).

Hermit crabs were packed in plastic bags and kept in a thermal box; at the laboratory, they were preserved in freezer until their handling. They were extracted by hand from the occupied shells but, when necessary, it was done with the help of a small vice. After this, the crabs were preserved in alcohol 70% while shells were dried up indoors for 24h. Hermit crabs were identified, sexed, and the length (CL) of the cephalothoracic shield was obtained with a 0.01mm precision digital caliper. Sexes were identified according to the position of genital openings; intersex individuals had both male and female genital openings. Empty shells were identified and weighted (SWE) with an electronic scale of 0.01g precision, and their aperture length (AL) and width (AW) were measured with the same caliper. Only the most occupied shells were used for comparative analysis and, therefore, those having less than 5% occupation were excluded.

Kruskal-Wallis was used for statistical comparison of the dimensions among the different shell species, and for comparison of these dimensions in the occupied shells by different sexes (these dimensions had not a normal distribution), the Dunn's test was used to locate the source of variations. The χ^2 was used to compare the shell occupation frequencies between males and females. Correlation Indices of Spearman were calculated for all correlations among dimensions: only complete and unbroken shells were used in this analysis. All tests had a confidence of 95%.

RESULTS

A total of 1187 hermit crabs *Clibanarius vittatus* were collected, out of which 949 were males, 204 non-ovigerous females, 12 ovigerous females and 22 intersexes. They occupied 12 species of gastropod shells, with the highest frequency of occupation in *Stramonita haemastoma* (Linnaeus, 1767) with 64.61%, followed by *Olivancillaria urceus* (Röding, 1798) with 26.47%, and *Dorsanum moniliferum* (Valenciennes, 1834) with 5.48%. The remainder shells were occupied with less than 1% each one, and altogether they did not sum up 4% – *Achatina fulica* (Bowdich, 1822), *Buccinanops lamarckii* (Kiener, 1834), *Cymatium parthenopeum* (Von Salis, 1793), *Chicoreus (Siratus) senegalensis* (Gmelin, 1791), *Olivancillaria steeriae* (Reeve, 1850), *Olivancillaria uretai* Klappenbach, 1965, *Semicassis granulatum* (Born, 1778), *Polinices hepaticus* (Röding, 1798) and *Zidona dufresnei* (Donovan, 1823) (Table I). Only *S. haemastoma*, *O. urceus* and *D. moniliferum* (more than 95% of occupation) were used for comparative analysis.

The shell species differed significantly in their weight ($H = 116.37$, $p < 0.0001$) and dimensions (AL: $H = 314.85$; $p < 0.0001$. AW: $H = 59.96$; $p < 0.0001$) (Fig. 1), showing that each one has its own characteristics. In this context, *D. moniliferum* had the smallest dimensions (SWE = 3.74 ± 1.24 g; AL = 16.04 ± 2.33 mm; AW = 8.32 ± 1.11 mm), while *O. urceus* the largest weight and length (SWE = 8.16 ± 4.05 g; AL = 25.82 ± 3.99 mm; AW = 8.51 ± 1.42 mm), and *S. haemastoma* the largest aperture width (SWE = 6.62 ± 4.14 g; AL = 18.77 ± 5.91 mm; AW = 9.88 ± 2.67 mm) (Table II).

Male hermit crabs ranged from 2.97 to 11.56 mm CL, females from 2.97 to 8.24 mm, and intersexes from 3.76 to 9.45 mm. The hermit crabs' CL average ranged according to the shell species occupied by them ($H = 54.91$; $p < 0.0001$): those living inside the shells of *S. haemastoma* (CL = 6.11 ± 1.39) had highest CL, while those of *O. urceus* (CL = 5.54 ± 0.90 mm) and *D. moniliferum* (CL = 5.17 ± 0.90 mm) had close CL average without statistical difference (Fig. 2). Dimensions of the shells occupied by males were statistically dissimilar to those occupied by females. On the other hand, the shells occupied by intersexes were similar to those occupied by males; this relation is the same for

non-ovigerous and ovigerous females. AL and AW of the shells occupied by the latter ones had no significant difference from those occupied by intersexes (Kruskal-Wallis, $p < 0.05$) (Table III).

The three most frequently occupied shell species were common among these sexes. Furthermore, a pattern in the shell use was observed: *S. haemastoma* shells were occupied by almost all hermit crab sizes, *O. urceus* by medium-sized crabs and *D. moniliferum* by smaller ones. However, each sex occupied these shells with distinct frequencies: 29.29% males used *O. urceus*, while 15.58% females and 18.18% intersexes did it. In contrast, only 4.52% males, 8.33% females and 13.64% intersexes occupied *D. moniliferum* (Fig. 3).

In the correlation analyses between hermit crabs CL and the shell species dimensions, *S. haemastoma* showed the higher correlation indices, followed by *O. urceus* and *D. moniliferum*. Shell SWE was the dimension with the highest correlation indices with hermit crab CL. Among the hermit crabs occupying *O. urceus* and *S. haemastoma* shells, males presented higher correlation indices than females, but the opposite was found for *D. moniliferum* shell users (Table IV).

DISCUSSION

The total number of shell species occupied by *C. vittatus* (=12) in the present study is similar to that of populations living in shallow waters of the southeast coast of Brazil (Negreiros-Fransozo et al. 1991, Reigada and Santos 1997, Sant'Anna et al. 2006a). However, this number can increase up to 16 in tropical areas such as Florida, USA (Lowery and Nelson 1988).

The dominant occupation of the gastropod shell *S. haemastoma* by *C. vittatus* observed in Baixio Mirim tideflat was also reported in previous studies on populations coming from Galveston Island, USA (Fotheringham 1975), and from São Paulo State (Negreiros-Fransozo et al. 1991, Reigada and Santos 1997, Sant'Anna et al. 2006a), excepting in Turra and Leite (2002), who found *Chicoreus senegalensis* (Gmelin, 1791) as the most frequently occupied shell by this hermit crab.

The relationships between the hermit crab populations and the occupied shells reveal that some shell features are more important than others for crab occu-

TABLE I
Clibanarius vittatus. Absolute and relative frequencies of occupation of 12 shell species by male, female and intersex hermit crabs.

Shell species	Male hermit crabs		Female hermit crabs		Intersex hermit crabs		Total		χ^2
	N	%	N	%	N	%	N	%	
<i>Stramonita haemastoma</i>	591	62.29	161	74.54	15	68.18	767	64.61	n.s.
<i>Olivancillaria urceus</i>	278	29.29	33	15.58	3	13.64	314	26.47	*
<i>Dorsanum moniliferum</i>	43	4.53	18	8.33	4	18.18	65	5.48	n.s.
<i>Semicassis granulatum</i>	9	0.94	1	0.46			10	0.84	n.s.
<i>Buccinanops lamarckii</i>	7	0.74	2	0.93			9	0.76	n.s.
<i>Polinices hepaticus</i>	7	0.74					7	0.59	n.s.
<i>Chicoreus senegalensis</i>	5	0.53					5	0.42	n.s.
<i>Cymatium parthenopeum</i>	5	0.53					5	0.42	n.s.
<i>Zidona dufresnei</i>	2	0.21					2	0.17	n.s.
<i>Achatina fulica</i>	1	0.10					1	0.08	n.s.
<i>Olivancillaria steeriae</i>			1	0.46			1	0.08	n.s.
<i>Olivancillaria uretai</i>	1	0.10					1	0.08	n.s.
TOTAL	949	100.0	216	100.00	22	100.00	1187	100.00	

N = absolute number; * = significant; n.s. = not significant.

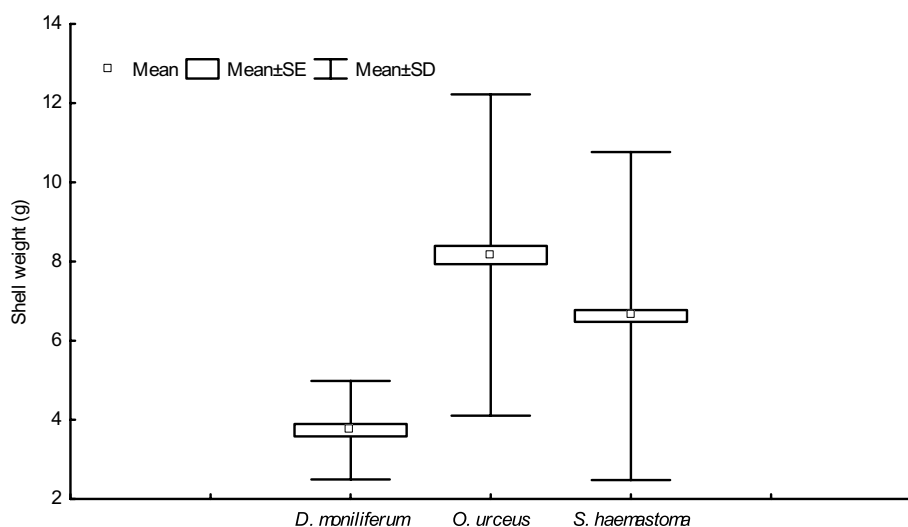


Fig. 1 – *Clibanarius vittatus*. Mean, standard deviation and standard error of the shell weight of the gastropod species more occupied by hermit crabs.

pation. Turra and Leite (2002), studying *C. vittatus*, demonstrated that the shell dimension was more important than its volume. Furthermore, in the study carried by Floeter et al. (2000) with *Calcinus tibicen* (Herbst, 1971) and *Clibanarius antillensis* Stimpson, 1859, the shell volume was more important than its weight. Bertini and Fransozo (2000) and Shih and Mok (2000), studying *Petrochirus diogenes* (Linnaeus, 1758) and

Calcinus latens (Randall, 1839), respectively, considered that the shell was the most important feature for occupation, and more recently Masunari et al. (2008) observed that *Isocheles sawayai* (Forest and Saint Laurent, 1968), living in infralittoral waters of southern Brazil, occupied predominantly *O. urceus*, a gastropod that has a heavy shell, and it may act as an anchor for this filter feeding hermit crab.

TABLE II

Clibanarius vittatus and shell species most often occupied by the hermit crabs. Dunn's multiple comparisons test ($P < 0.05$) with significant differences in the comparison of morphometric variables between pairs of shell species and average CL of the hermit crabs that occupied these shells.

Shell species pairs compared	SWE (g)	AL (mm)	AW (mm)	CL (mm)
<i>D. moniliferum</i> × <i>O. urceus</i>	***	***	n.s.	n.s.
<i>D. moniliferum</i> × <i>S. haemastoma</i>	***	**	***	***
<i>O. urceus</i> × <i>S. haemastoma</i>	***	***	***	***

SWE = shell weight; AL = aperture length; AW = aperture width; CL = cephalothoracic shield length. ** = $p < 0.01$; *** = $p < 0.001$; n.s. = not significant.

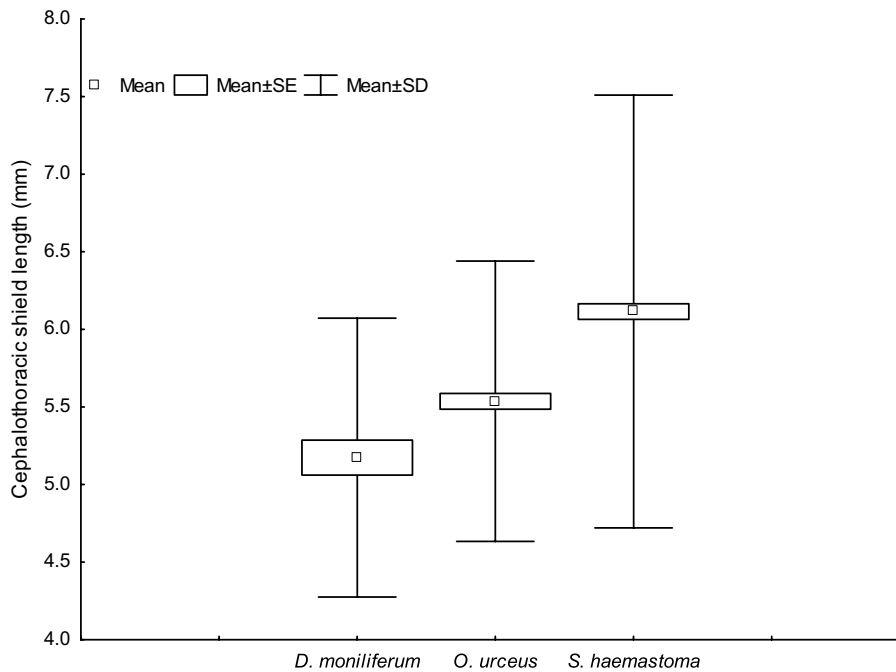


Fig. 2 – *Clibanarius vittatus*. Mean, standard deviation and standard error of the hermit crabs' cephalothoracic shield that occupied three more frequent shell species.

TABLE III

Shell species occupied by the hermit crab *Clibanarius vittatus*.
Dunn's multiple comparisons ($p < 0.05$) between the hermit crab sexes
in the morphometric variables of occupied shells (H=157.53).

	SWE (g)	AL (mm)	AW (mm)
Females × Ovigerous females	n.s.	n.s.	n.s.
Females × Intersexes	***	**	***
Females × Males	***	***	***
Ovigerous females × Intersexes	*	n.s.	n.s.
Ovigerous females × Males	***	**	*
Intersexes × Males	n.s.	n.s.	n.s.

SWE = shell weight; AL = aperture length; AW = aperture width. * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$; n.s. = not significant.

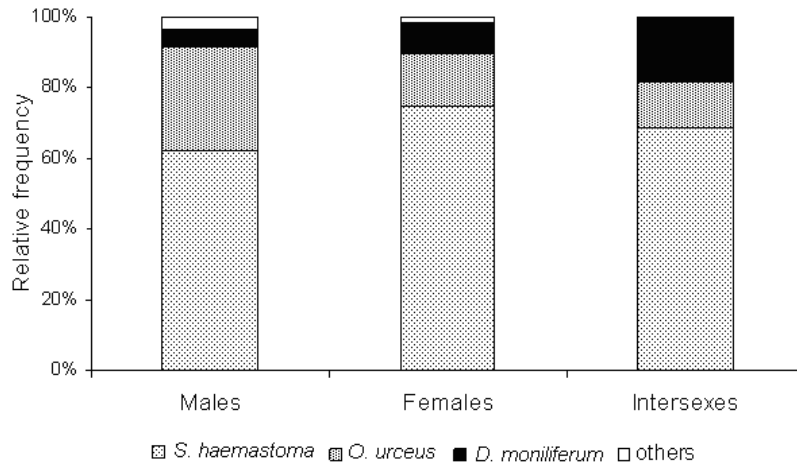


Fig. 3 – *Clibanarius vittatus*. Relative frequencies of occupied shells by males, females and intersexes.

There is a common architectural feature among the shell species occupied mainly by populations of *C. vittatus* living along the western Atlantic Ocean coast: the last whorl is globe-shaped and spacious, with shell aperture measuring 50–70% of the total length (Table V; see figures in Rios 1975 and Abbott and Dance 1998). According to Floeter et al. (2000), the preference for shells with enlarged last whorl and higher internal volume by hermit crabs of the genus *Clibanarius* is related to the maintenance of a humid microhabitat, especially during the exposed condition due to the low tide.

Stramonita haemastoma occurs in the western Atlantic Ocean coast from North Carolina, USA, to southern Brazil (Rios 1975). The almost complete overlapping in the geographical distribution of *S. haemastoma* and *C. vittatus* (compare to Melo 1999) can indicate that the shell availability is the main reason for occupying in higher frequency this shell species. Moreover, Turra and Leite (2002) demonstrated through laboratory experiment that *S. haemastoma* had been chosen among other shell species, which means that *C. vittatus* has a specific preference. The most frequently occupied shell *Chicoreus senegalensis* observed by these authors in the environment could be due to competition with other sympatric hermit crab species. Alongside the western Atlantic Ocean coast, where *S. haemastoma* is present, this hermit crab can occupy preferably another species, such as *Littorina irrorata* (Say, 1822) in North and South Carolina, USA (Mitchell 1975, Young 1979), and *Melongena corona* (Gmelin, 1791) in Florida, USA

(Lowery and Nelson 1988) (Table V). The significant occupation of other shell species with similar morphology to *S. haemastoma* (last whorl relatively enlarged than others) may indicate that the shell architecture is more important than shell species in the selection by *C. vittatus*.

Another indication that *S. haemastoma* is the suitable shell due to its shell architecture and/or general shape, is the highest correlation indices obtained between the shell dimensions and its occupier. Turra and Leite (2002) and Sant'Anna et al. (2006a) reported a strong correlation in the relationships of CL × SL (shell length) and CL × AL.

The dissimilar frequencies in the occupation of the shell species among males, females and intersexes are difficult to explain. As *C. vittatus* males attain larger sizes than females (Lowery and Nelson 1988, Sant'Anna et al. 2006a), an eventual intra-specific competition for the best shells would result in a large proportion of males occupying *S. haemastoma* shells. However, the opposite was observed: about 62% males occupied this shell species, while about 75% females did it. It is possible to conjecture that females' requirement in occupying *S. haemastoma* is the need to accommodate their eggs inside the spacious whorl of this shell species. The dominance of males in the occupation of *O. urceus* shell, the second most occupied one, supports this assumption (see Table I).

In spite of absence of an exhaustive list of gastropod species that could potentially supply *C. vittatus* with

TABLE IV
Clibanarius vittatus. Statistics for morphometric relationships ($p < 0.05$) between the hermit crab sexes and the three most frequently occupied shell species.

Shell species	Relation	Equation	r	
<i>S. haemastoma</i>	CL × SWE	$\text{LnSWE} = -0.92 + 2.16\text{LnCL}$	0.8119	
	Males	CL × AL	$\text{LnAL} = 0.39 + 1.11\text{LnCL}$	0.7849
	n = 591	CL × AW	$\text{LnAW} = 0.23 + 0.97\text{LnCL}$	0.8311
	Females	CL × SWE	$\text{LnSWE} = -0.6 + 1.62\text{LnCL}$	0.6849
	n = 151	CL × AL	$\text{LnAL} = 0.58 + 0.82\text{LnCL}$	0.6068
		CL × AW	$\text{LnAW} = 0.41 + 0.68\text{LnCL}$	0.6677
<i>O. urceus</i>	CL × SWE	$\text{LnSWE} = -0.63 + 2.04\text{LnCL}$	0.7338	
	Males	CL × AL	$\text{LnAL} = 0.88 + 0.72\text{LnCL}$	0.7739
	n = 278	CL × AW	$\text{LnAW} = 0.37 + 0.75\text{LnCL}$	0.7475
	Females	CL × SWE	$\text{LnSWE} = -0.50 + 1.73\text{LnCL}$	0.6751
	n = 33	CL × AL	$\text{LnAL} = 0.94 + 0.61\text{LnCL}$	0.7462
		CL × AW	$\text{LnAW} = 0.41 + 0.66\text{LnCL}$	0.6491
<i>D. moniliferum</i>	CL × SWE	$\text{LnSWE} = -0.08 + 0.89\text{LnCL}$	0.4985	
	Males	CL × AL	$\text{LnAL} = 1.03 + 0.26\text{LnCL}$	0.3752
	n = 43	CL × AW	$\text{LnAW} = \text{Ln}0.76 + 0.24\text{LnCL}$	0.4052
	Females	CL × SWE	$\text{LnSWE} = \text{Ln}(-0.60) + 1.65\text{LnCL}$	0.6851
	n = 17	CL × AL	$\text{LnAL} = \text{Ln}(0.80) + 0.56\text{LnCL}$	0.4796
		CL × AW	$\text{LnAW} = \text{Ln}0.42 + 0.68\text{LnCL}$	0.7187

CL = cephalothoracic shield length; SWE = shell weight; SL = shell length; SW = shell weight; AL = aperture length; AW = aperture width; r = correlation indices of Spearman.

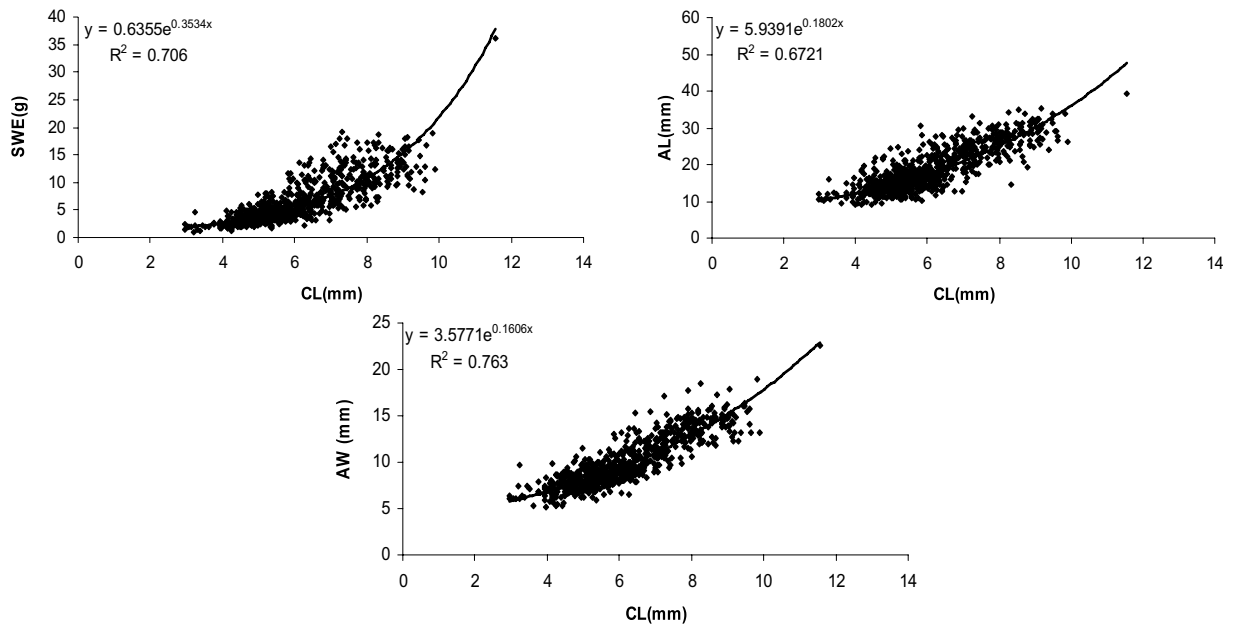


Fig. 4 – *Clibanarius vittatus*. Dispersion plots between hermit crab cephalothoracic shield length (CL) and variables of the most frequently occupied shell – *S. haemastoma*. (SWE = shell weight; AL = shell aperture length; AW = shell aperture width).

TABLE V

Clibanarius vittatus. Localities where the hermit crabs was reported, total number and most frequently occupied shell species.

Locality	Most frequently occupied shell species by the hermit crab	No. of occupied shell species	Reference
North Carolina, USA	<i>Littorina irrorata</i>	5	Mitchell (1975)
South Carolina, USA	<i>Littorina irrorata</i>	6	Young (1979)
Gulf Coast, USA	<i>Stramonita haemastoma</i>	8	Fotheringham (1975)
Florida, USA	<i>Melongena corona</i>	16	Lowery and Nelson (1988)
São Sebastião, Brazil	<i>Chicoreus senegalensis</i>	9	Turra (personal communication)
Ubatuba, Brazil	<i>Stramonita haemastoma</i>	2	Negreiros-Fransozo et al. (1991)
São Vicente, Brazil	<i>Stramonita haemastoma</i>	13	Sant'Anna et al. (2006a)
Guaratuba, Brazil	<i>Stramonita haemastoma</i>	12	Present study

empty shells, it is possible to infer that this hermit crab can find plenty of shelters at Baixio Mirim tideflat, either in abundance or in size spectrum. The morphometric dimensions of the three mostly occupied shells – *S. haemastoma*, *O. urceus* and *D. moniliferum* – that showed positive correlation with hermit crab size support this assumption.

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RESUMO

A caracterização das conchas ocupadas pelo ermitão *Clibanarius vittatus* (Bosc, 1802) foi realizada. Os ermitões foram coletados de abril/2005 a março/2006, na zona intertidal, durante a maré baixa de sizígia. Os ermitões tiveram o sexo reconhecido e foram medidos no comprimento do escudo cefalotorácico. As conchas foram identificadas, pesadas depois de secas e medidas no comprimento e na largura da abertura. Foram coletados 1187 ermitões (949 machos, 216 fêmeas e 22 intersexos) que ocuparam 12 espécies de conchas de gastrópodes. *Stramonita haemastoma*, *Olivancillaria urceus* e

Dorsanum moniliferum perfizeram 96,55% do total das conchas ocupadas. Ermitões machos atingiram tamanhos significativamente maiores do que as fêmeas; entretanto ocuparam um maior espectro de conchas em tamanho e peso. Fortes índices de correlação foram obtidos para a relação entre o escudo cefalotorácico dos ermitões e a largura da abertura de *S. haemastoma*. A última espira espaçosa e de formato globoso é um aspecto comum das conchas mais frequentemente ocupadas pelo presente ermitão em todos os locais de sua ocorrência. O sucesso no estabelecimento de *C. vittatus* no Baixio Mirim é devido principalmente ao formato e à amplitude de tamanhos das conchas de *S. haemastoma*, as quais são mais frequentemente ocupadas pelos ermitões da população estudada.

Palavras-chave: Baía de Guaratuba, disponibilidade de conchas, ocupação de conchas, tamanho e formato da concha.

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