Morphometric Relationships Between the Hermit Crab *Isocheles sawayai* (Forest & Saint Laurent) (Crustacea Anomura Diogenidae) and its Shell from Southern Brazil

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Abstract: A study on morphometric relationships between the hermit crab *Isocheles sawayai* and its shell in a population from Paraná-Santa Catarina States coast was carried out. Hermit crabs from the by-catch of shrimp fishing (4-15m depth) were collected. Cephalothoracic shield length (CL) and width (CW) from hermit crabs and total length (SL), aperture length (AL) and weight (SW) from shells were taken. A total of 266 hermit crabs occupying eight species of shell - *Buccinanops lamarckii, Dorsanum moniliferum, Oliva reticularis, Olivancillaria steeriae, O. urceus, Polinices hepaticus, Semicassis granulatum* and *Stramonita haemastoma* - were obtained. Males (N = 189) that dominated strongly (1M : 0.4 F) occupied eight shell species, while females (N = 76) occupied only six. There was only one intersex individual that occupied a *Stramonita* shell. Contrarily to intertidal populations, *O. urceus* was the most frequently occupied shell by males (57.14%) and females (62.33%) in this studied area. Due to the smaller size of females (mean CL 5.19±0.84mm), these ones occupied shells of a smaller size than males (mean CL 6.49±1.14mm). The highest *O. urceus* shell frequency of occupation is connected to the hermit crab´s life style: it is a filter feeding species and its shell remains totally buried in the sandy substratum having only its cephalothoracic appendages free. The heavy shell of this gastropod (highest SW/SL) favors the stability in strong current water conditions, as it functions as an anchorage for this semi-buried hermit crab.

INTRODUCTION

Hermit crabs are extremely dependent on empty gastropod shells, as they need to protect their delicate abdomen inside them. The capital importance of this need can be observed in times of unavailability of this resource, when the hermits are able to occupy a variety of alternative protectors such as conical shells of scaphopods, serpulid tubes, cavities of pebbles, sponges, dead corals, bamboo pieces and shells of bivalve [1]. On the other hand, there were hermit crabs occupying gastropod shells covered by alive corals, bryozoans and barnacles reported from southern Brazil [2]. The selection of the gastropod shell to be occupied by a hermit crab is related to several factors, among which the shell availability in the habitat has been considered the most important one [3] and confirmed by several authors of different countries [4]. The shell´s weight and its internal volume [5-11] and physical factors [12, 13] have been reported as a secondary factor. On the other hand, males and females can occupy different species of empty shells as reported in Brazilian hermit crab populations [7, 8, 10, 11]. In case of low availability of gastropod shells and hermit crabs were forced to occupy tight shells, negative effects such as lowered growth rates and increased susceptibility to predation by some crab species were observed [14-16]. The hermit crab *Isocheles sawayai* (Forest & Saint Laurent, 1967) has a geographic distribution restricted to the Brazilian coast, from the Ceará State to the Santa Catarina State, from shallow waters to infralittoral zones of sandy beaches [17], in abundant or small populations [18-23]. Most of this hermit crab population occupy empty shells of the gastropod *Stramonita haemastoma* (Conrad, 1837), followed by *Buccinanops* sp. and *Olivancillaria* sp. [18, 22, 24]. Morphometric relationships between the hermit crab *I. sawayai* and its shell coming from shallow waters of the southeastern Brazilian coast [24] showed that most of these hermit crabs have well fitted shells. Among several pairs of dimensions, the thickness of the hermit cephalothorax and the width of the shell aperture had the closest relationship.

Another morphometric relationship study carried out with three species of intertidal hermit crab *Clibanarius* Dana 1852 from the São Paulo State beaches [4] clearly shows that these crabs tend to take smaller and lighter shells as they increase in size. The present study aims to describe the morphometric relationships between the hermit crab *I. sawayai* and its shells, in a population living in the coast of Paraná and Santa Catarina (southern Brazil). In spite of its wide distribution along the Brazilian coast, the populations of these States were not treated in this aspect.

MATERIAL AND METHODS

Hermit crabs were obtained from by-catch of shrimp fishing that was carried out with gill nets of 2.0 to 3.0cm mesh, in depths from 4 to 15m along Paraná and Santa Catarina States coast, southern Brazil, on October, 6th, 2001, January, 20th, 2002 and October, 7th, 2002. In the laboratory, the hermit crabs were extracted from the shells, labeled, and preserved in alcohol 70%, while the properly labeled shells were dried in room temperature till their weight became constant. Crabs were identified, sexed and, ovigerous females were recorded. In the graphs of Figs. (**1**) and (**4**), the intersex crab was included to the male group, as it is a functional

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male without any indications to be hermaphroditic [25]. The length (CL-between anterior and posterior margins) and the maximum width (CW) of cephalothoracic shield were measured with a digital caliper of 0.01mm error. CL was used as a reference measurement in correlation analysis in order to do compare with results reported by previous authors [24]. In the study of the population structure, males (+ intersex) and females were distributed separately in CL classes with 0.30mm range, that were identified by respective middle values.

The shells occupied by hermits were identified and weighted (SW) with an electronic scale of 0.01g error, and their total length (SL-between both extremities), and the length (AL) and the width (AW) of the shell aperture were measured with a manual caliper of 0.05mm error. The relative length of the shell aperture was estimated as the ratio between AL and SL. Similarly, the relative weight of the shell was calculated as the ratio between SW and SL.

Average values and standard deviation were calculated and histogram construction were done with the aid of STATISTICS software for microcomputers. The frequencies of each shell occupation were compared through X^2 test. The relationships between CL and various shell parameters were calculated through linear function ($y = ax + b$) or power function ($y = ax^b$) [26].

RESULTS

A total of 266 hermit crabs of *Isocheles sawayai* were obtained, among these 189 were males, 76 females and one intersex. Six ovigerous females (three from the in October month sample and three from the January month sample) were recorded; however, due to the low frequency, they were treated without discrimination with other females. The hermit crabs occupied empty gastropod shells of eight species: *Buccinanops lamarckii* (Kinner, 1834), *Dorsanum moniliferum* (Valenciennes, 1834), *Oliva reticularis* Lamarck, 1811, *Olivancillaria steeriae* (Reeve, 1850), *Olivancillaria urceus* (Röding, 1798), *Polinices hepaticus* (Röding, 1798), *Semicassis granulatum* (Born, 1778) and *Stramonita haemastoma*.

CL and CW of the hermit crabs varied from 2.97 to 8.80mm and 2.84 to 8.86mm, respectively, in a linear relationship in the dispersion graph. The equation of this relationship is $Y = 0.9901X + 0.0082$, $R^2 = 0.98$. The average CL of males was 6.49±1.14mm while the females average was 5.19±0.84mm (Table **1**).

Males (+ intersex) were distributed into 20 CL classes, predominant in bigger CL values, while females into 14 CL classes, predominant in smaller ones (Fig. **1**). Males occupied all recorded shell species, while females, only in six of them. These shells measured from 19.85 to 60.55mm SL, among them the *Buccinanops* which was the largest one with 50.66mm mean SL, followed by *Semicassis* and *O. urceus*.

Shells occupied by male crabs had an average of 44.29±7.34mm SL (range of 19.85-60.55mm SL), while female ones had an average of 37.27±6.25mm SL (range of 23.40-53.15mm SL). Similarly, as females had a smaller size, they occupied shells with smaller mean weight (7.68±4.45g SW) than males (11.74±6.08g SW). The intersex occupied a shell of *Stramonita* with 40.30mm SL and 12.96g SW (Table **1**). The shell *O. urceus* had the highest frequency of occupation by *I. sawayai* summing up 57.14% among males and of 62.33% among females. *Semicassis* was the second more frequently occupied by males (17.98%) and *Stramonita* by females (22.07%).

Big sized shells such as *Buccinanops* and *Semicassis* were occupied exclusively by males or these ones dominated in this occupation (Fig. **1**). However, there was not any tendency of differentiated shell occupation, in function of the hermit crab sex. Males and females occupied shells in an equivalent way, proportionally to the abundance of each sex (Table **1**).

For this reason, in the shell occupation analysis both sexes were considered together.

A significant relationship (95%) was found only between the shell species *O. urceus* because it was most frequently occupied by *I. sawayai*: between SL x CL (linear function $Y = 5.4907X + 9.7051$, $r^2 = 0.71$) (Fig. **2**), and between SW x CL (power function $Y = 0.128X^{2.48}$, $r^2 = 0.75$) (Fig. **3**). The remainder relationships (AL x CL, AW x CL) were also significant ($P < 0.05$) only in the case of shell species more frequently occupied. Furthermore, all these correlations showed a tendency to negative allometry, except for AL x CL of *Stramonita* and CL x AW of *Buccinanops* (Table **2**).

There was a direct relationship between the occupation frequency of the male hermit crabs and the relative length of AL (ratio between AL and SL) of the shell species more frequently occupied: the higher the relative length of AL, the higher the occupation frequency (Fig. **4**). The relative weight (ratio between SW and SL) of most shells also showed the same tendency (Fig. **5**).

DISCUSSION

The population of *I. sawayai* recorded in Ubatuba beach [24] was composed of 288 individuals, a very close number of the present study (N=266). The hermit crab CL ranges were also similar in these two populations: from 3.40 to 8.30mm for males and from 3.50 to 7.20mm for females in Ubatuba, and 2.97-8.80mm and 3.21-7.27mm, respectively in the Paraná-Santa Catarina States coast (see Table **1**).

The linear and power relationships between several measures of the hermit crabs and the shells are in accordance with previous works [4, 27]. Additionally, the tendency for a negative allometry in the relationship between these measures (see Table **2**) is in accordance to the results obtained by former authors [4] for three species of *Clibanarius*. Therefore, the linear correlation between the shell parameters (SL, AL and AW) and the hermit crab CL, and the power correlation between CL and SW recorded for *I. sawayai* seem to constitute a general rule for the hermit crabs whose morphometric relationships are known.

The occurrence of only one intersex hermit crab confirms the rarity of this sex in the populations of *I. sawayai* observed in previous paper [25] in the São Paulo State. However, the interpretation of its role is difficult, since this intersex is a functional male, according to these authors.

In the present study, the population of *I. sawayai* occupied almost the same spectrum of the shell species compared

Table 1. ***Isocheles sawayai*. Statistics for Morphometric Relationships Between the Hermit Crab and Respective Occupied Shells**

Hermit Crab	**N**	**CL Mean**	**CL Min**	**CL Max**	**S.D.**
Males	189	6.49	2.97	8.8	1.13
Females	76	5.19	3.21	7.27	0.84
Intersex	1	5.70	5.70	5.70	0
Hermit Crab	**N**	**CW Mean**	**CW Min**	**CW Max**	**S.D.**
Males	189	6.44	2.84	8.86	1.12
Females	76	5.13	3.06	7.48	0.88
Intersex	1	5.49	5.49	5.49	0
Shells with Males (mm)	**N**	**SL Mean**	**SL Min**	**SL Max**	**S.D.**
Buccinanops lamarckii (Kinner, 1834)	15	50.66	40	58.8	5.15
Semicassis granulatum (Born, 1778)	34	45.4	31.65	56.75	5.07
Olivancillaria urceus (Röding, 1798)	108	44.06	21.65	60.55	7.3
Stramonita haemastoma (Conrad, 1837)	24	42.88	22.1	56.4	7.65
Dorsanum moniliferum (Valenciennes, 1834)	2	40.67	38.55	42.8	3
Oliva reticularis Lamarck, 1811	1	36	36	36	0
Olivancillaria steeriae (Reeve, 1850)	2	33.85	29.45	38.25	6.22
Polinices hepaticus Röding, 1798)	3	29.95	19.85	36.95	8.96
Shells with Females (mm)	**N**	**SL Mean**	**SL Min**	**SL Max**	**S.D.**
Olivancillaria urceus	48	38.43	25.25	53.15	5.51
Semicassis granulatum	7	36.9	28.9	45.75	5.34
Stramonita haemastoma	15	35.47	23.4	50.75	7.76
Dorsanum moniliferum	3	35.26	32.75	38.65	3.04
Olivancillaria steeriae	2	34.17	25.85	42.5	11.77
Polinices hepaticus	1	24.45	24.45	24.45	0
Shell with Intersex (mm)	**N**	**SL**	**SL min**	**SL max**	**S.D.**
Stramonita haemastoma	1	40.3	40.3	40.3	0
Shell Weight (g)	**N**	**SW Mean**	**SW Min**	**SW Max**	**S.D.**
With males	189	11.74	1.53	33.33	6.08
With females	76	7.54	1.33	22.19	4.3
With intersex	1	12.96	12.96	12.96	0
Shells Occupied by	**EF ♀**	**EF ♂***	**OF ♀**	**OF ♂***	**X^2 Test**
Olivancillaria urceus	47.70	108.29	48	108	0.0018NS
Semicassis granulatum	12.54	28.46	7	34	2.4463NS
Stramonita haemastoma	11.93	27.07	15	25	0.7920NS
Dorsanum moniliferum	1.53	3.47	3	2	1.4151NS
Olivancillaria steeriae	1.22	2.78	2	2	0.4932NS
Polinices hepaticus	1.22	2.78	1	3	0.0407NS

CL and CW = cephalothoracic shield length and width; SL and SW shell length and weight; N = absolute number; SD = Standard deviation; R = range; EF = expected frequency; OF = observed frequency; NS = not significant. * = included the only intersex.

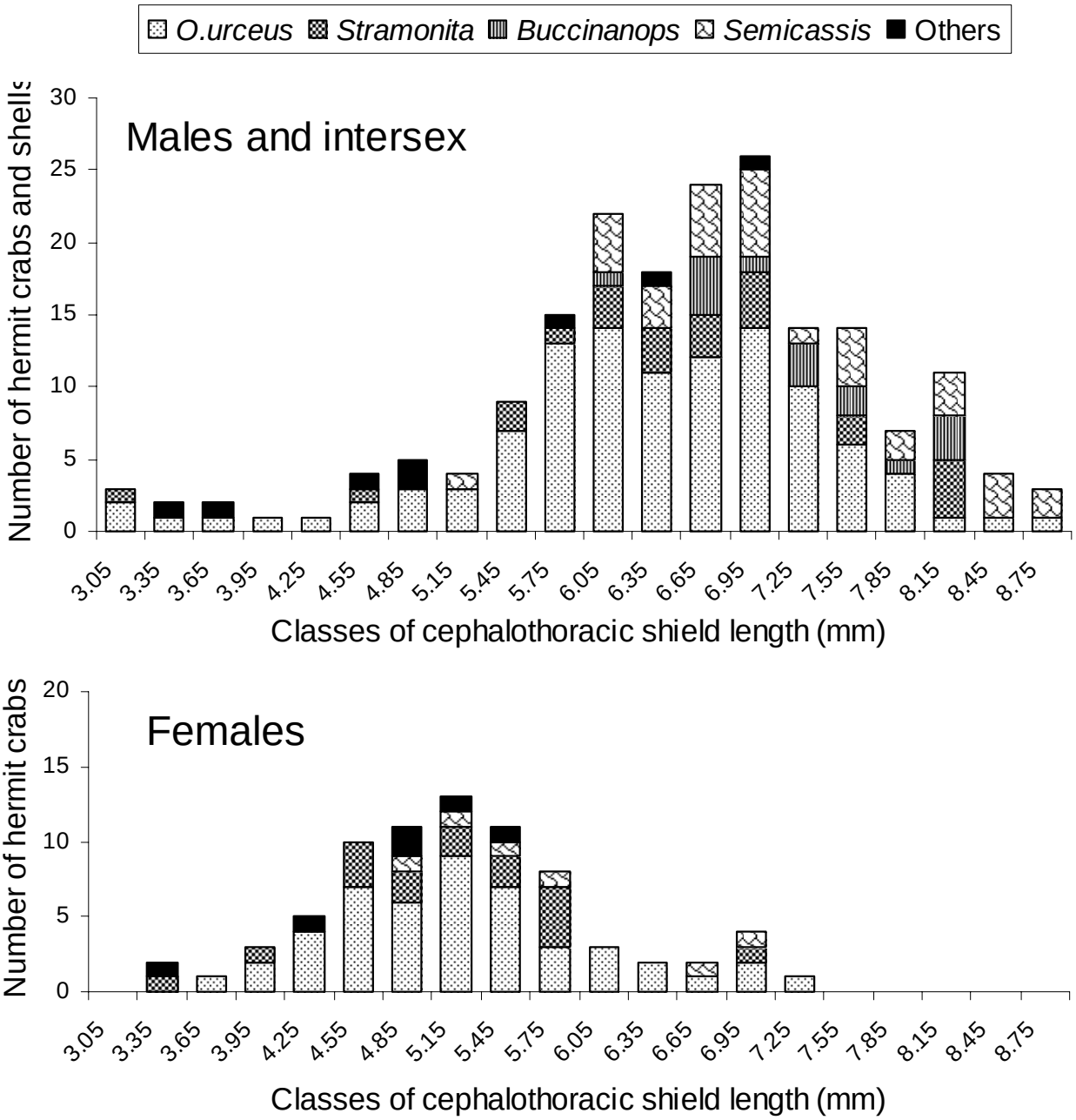

Fig. (1). Distribution of males (+intersex) and females of the hermit crab *Isocheles sawayai* absolute frequency into classes of cephalothorax shield length and their occupied shells.

to those from the São Paulo State. However, the dominance of *O. urceus* recorded in Paraná-Santa Catarina coast is unique. In that state, about 68% in Peruíbe beach [18] and about 80% in Ubatuba beach [24] of the hermit crabs occupied shells of *Stramonita*. This difference can be related with different shell availability in the intertidal areas and in deeper waters (at least 4m depth in the present study). Therefore, in higher depths, shells of *O. urceus* seem to be more numerous and consequently in higher availability than in intertidal areas.

The strong dominance in the occupation of *O. urceus* shells by *I. sawayai* in deeper waters is certainly related to the possibility of its ready occupancy. This hypothesis is based on the wide size range of these shells (see Table **1**). However, this dominance can also to be connected to the hermit life style: it is a filter feeding species and its shell remains totally buried in the sandy substratum, having only its cephalothorax appendages free [28, 29]. The relatively heavy shell of *O. urceus* can contribute favorably for the anchorage of the hermit-shell set inside the sandy substratum; this stability avoids this semi-sedentary hermit crab to be dragged by the water movement. On the other hand, shells relatively light as *Buccinanops* were chosen by big hermit crabs, probably, due to the natural shortage of larger shells than *O. urceus*. The maximum SL recorded for *O. urceus* of 60.55mm (see Table **1**) sustains this assumption. This shell occupancy contrasts with that of *Clibanarius erythropus* (Latreille 1818) from East Atlantic shores: this hermit crab

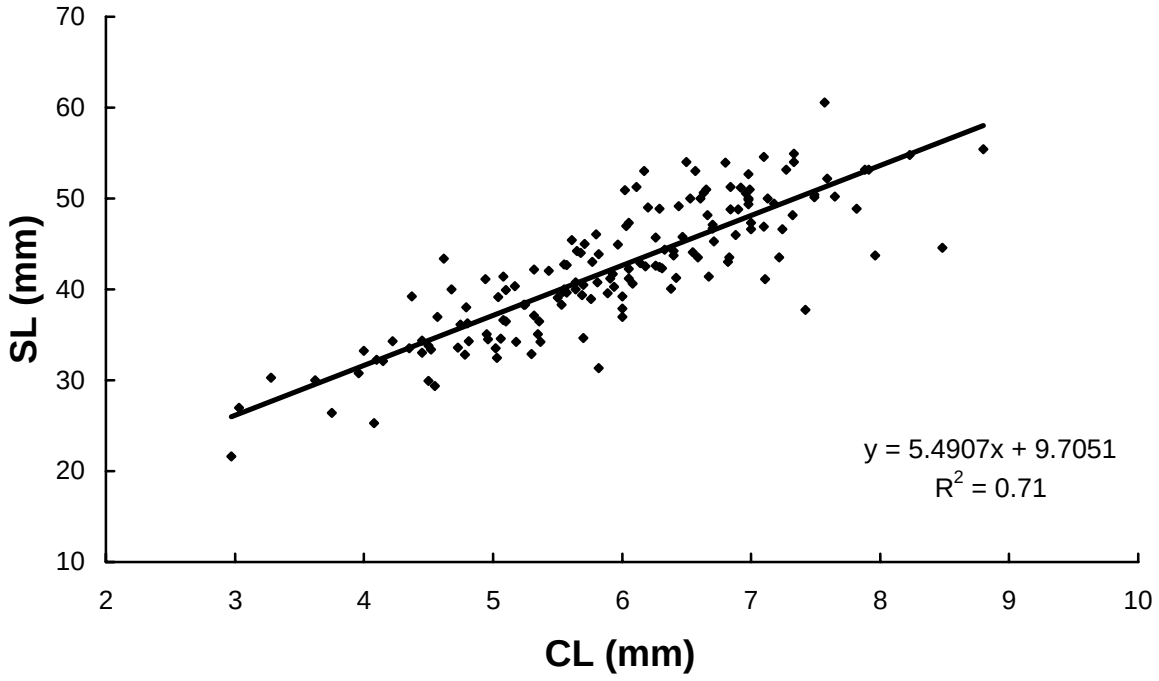

Fig. (2). Relationship between the shell length (SL) of *Olivancillaria urceus* and the hermit crab *Isocheles sawayai* cephalothorax shield length (CL).

chose elongated and lighter shells that are less energetically expensive [30].

With the exception of *Stramonita*, all gastropod shells occupied by *I. sawayai* live in sandy substratum [31]. Therefore, as soon as the shell becomes available, mainly *O. urceus*, it is immediately occupied by the sympatric *I. sawayai*. This immediate occupation can be deduced from the integrity (shell aperture without imperfections and smooth shell surface) of almost all occupied *O. urceus* shells.

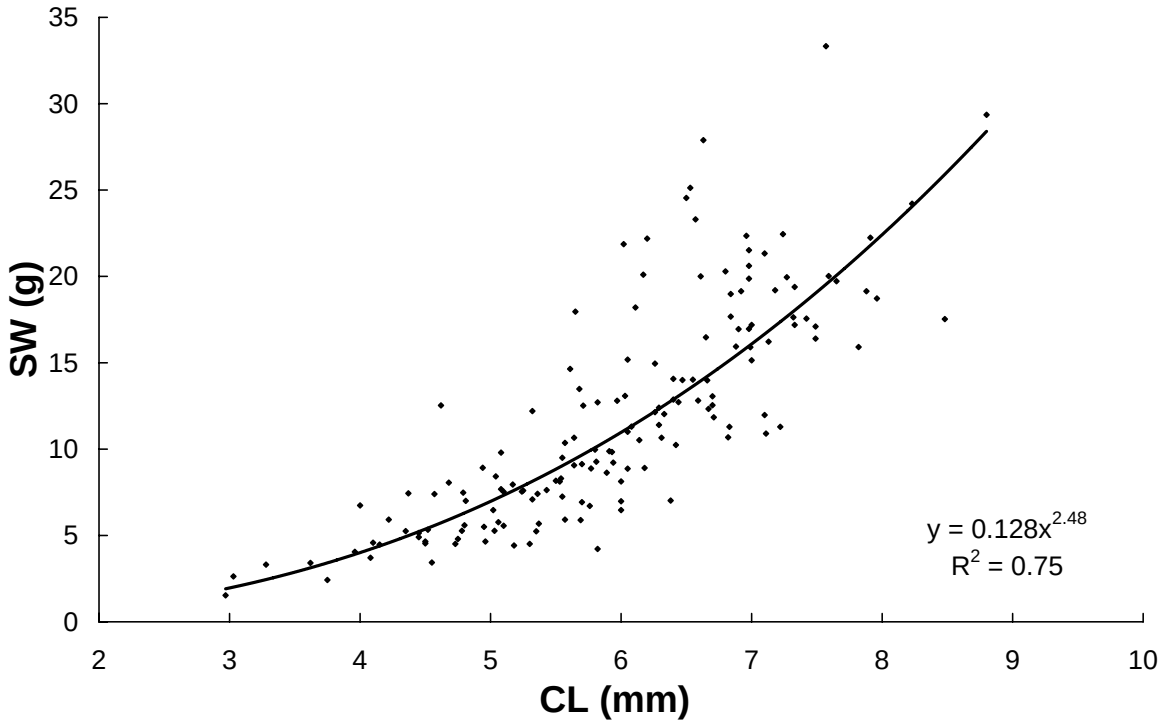

Fig. (3). Relationship between the shell weigth (SW) of *Olivancillaria urceus* and the hermit crab *Isocheles sawayai* cephalothorax shield length (CL).

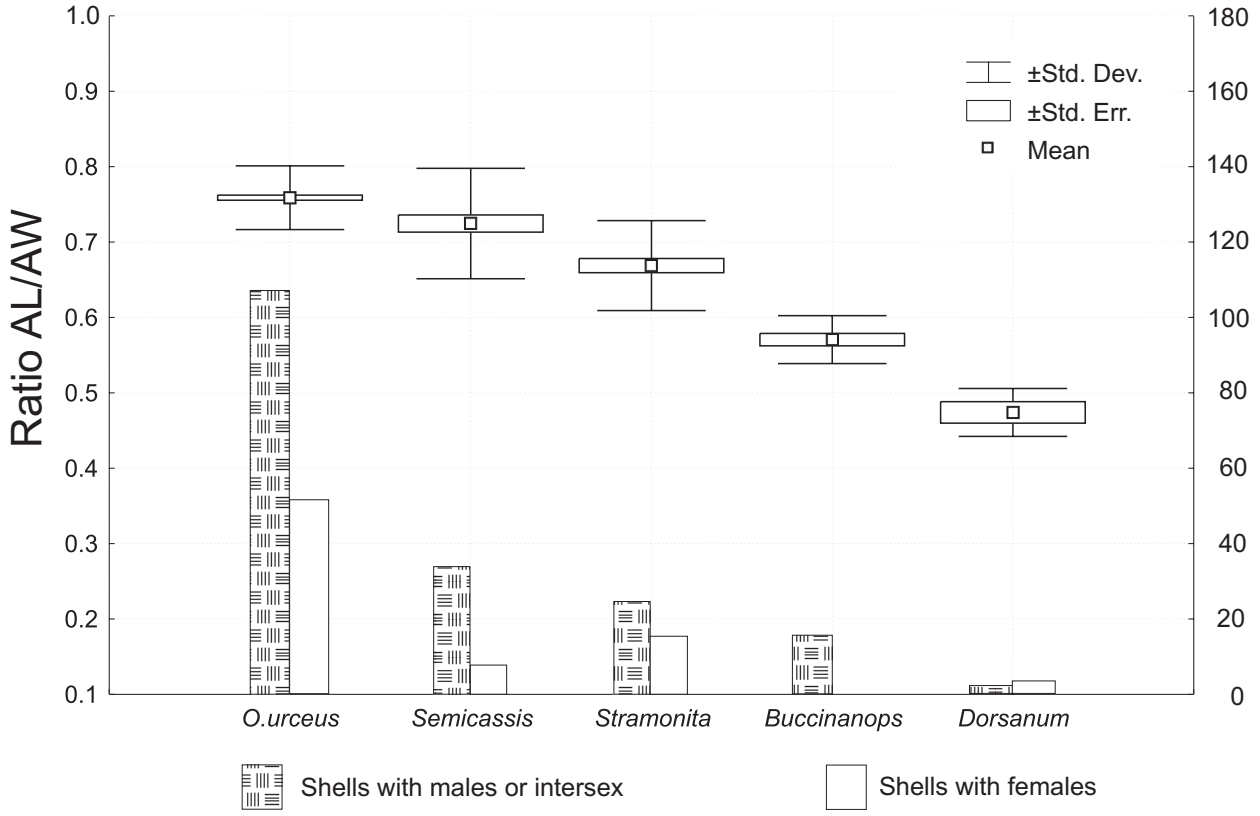

Fig. (4). Mean, standard deviation, standard error of the ratio AL/SL of the shell species more frequently occupied by the hermit crab *Isocheles sawayai* and absolute frequency of males (+ intersex) and females that was occupying these shells.

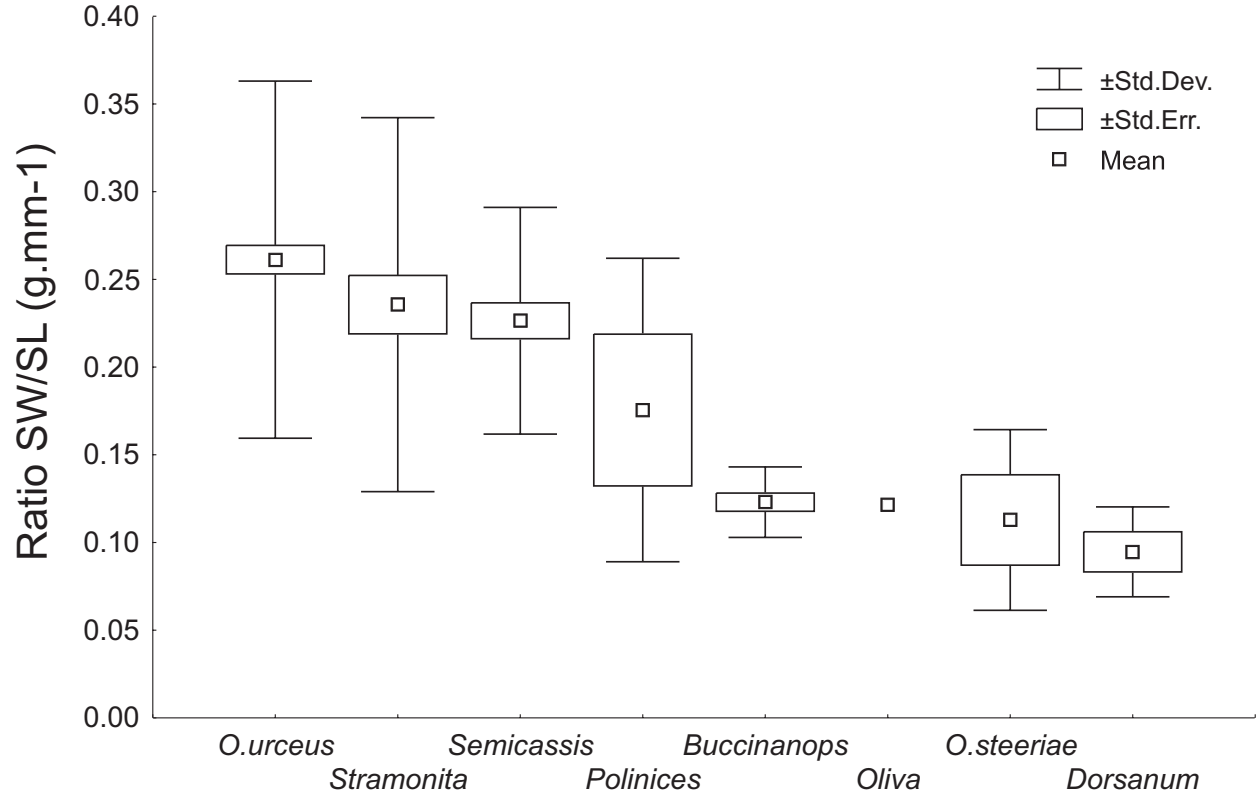

Fig. (5). Mean, standard deviation, standard error of the ratio SW/SL of the shell species occupied by the hermit crab *Isocheles sawayai*.

Table 2. ***Isocheles sawayai.*** **Regression Analysis ($y=ax^b$ Neperian Logarithm Values) Between the Cephalothoracic Shield Length (CL) (Independent Variable) of the Hermit Crab – and Shell Length (SL) and Weight (SW) and Shell Aperture Length (AL) and Width (AW) More Frequently Occupied by Hermit Crabs**

Gastropod Shell Species	Relation	Equation	r^2
Olivancillaria urceus N = 156	SL x CL	lnSL = 1.027 + 0.775lnCL	0.7137*
	SW x CL	lnSW = -0.983 + 2.484lnCL	0.7482*
	AL x CL	lnAL = 0.858 + 0.838lnCL	0.7164*
	AW x CL	lnAW = 0.320 + 0.879lnCL	0.6217*
Stramonita haemastoma N = 41	SL x CL	lnSL = 0.908 + 0.889lnCL	0.7378*
	SW x CL	lnSW = -1.049 + 2.563lnCL	0.6902*
	AL x CL	lnAL = 0.596 + 1.066lnCL	0.7848*
	AW x CL	lnAW = 0.417 + 0.867lnCL	0.5600*
Semicassis granulatum N = 40	SL x CL	lnSL =0.979 + 0.791lnCL	0.7293*
	SW x CL	lnSW = -0.874 + 2.211lnCL	0.6112*
	AL x CL	lnAL = 0.868 + 0.753lnCL	0.4554*
	AW x CL	lnAW = 0.495 + 0.651lnCL	0.4978*
Buccinanops lamarckii N = 15	SL x CL	lnSL = 0.980 + 0.843lnCL	0.5353*
	SW x CL	lnSW = -0.737 + 1.777lnCL	0.4031*
	AL x CL	lnAL = 0.785 + 0.786lnCL	0.4895*
	AW x CL	lnAW = 0.198 + 1.092lnCL	0.6037*

N = number of crabs; * = significant, $P<0.05$.

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