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Short Communication

Shell choice and occupation by the hermit crab (Crustacea: Diogenidae) in laboratory environment

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Abstract: The Neotropical hermit crabs' behaviour is rarely studied, although it is an important tool for the conservation of these invertebrates. In this context, the present study aimed to describe the hermit crab ethogram on its behaviour in the choice and dispute by shells. 60 specimens of hermit crabs were collected that were occupying mollusc shells *Cerithium atratum*, in sandstone reefs. In the laboratory, 30 hermit crabs were removed from their host shells by heating, the rest remained in their shells. The specimens were submitted to five experimental tests: (I) behaviour, (II) shell dispute, (III) shell preference, (IV) specimen behaviour with and without shell, and (V) shell contention between individuals with and without shell. The ethogram was built and evaluated by the *Ad Libitum* type of observational sampling methods and by the scanning type, for 30 uninterrupted minutes, records every two minutes, in total 15 observations per each observer. There were eight behavioural acts divided into 4 categories: immobility, interaction between specimen, environment exploration, and shell occupation. The most frequent behaviour was "walking", for both hermit crabs (54.2%) and those without shell (59.3%), followed by the rest of the individuals with and without shell, 16.9% and 12.4%, respectively. All hermits preferred mollusc shell *Bulla striata*, when offered in conjunction with the shell of *Astrea tecta*. However, all specimens returned to *C. atratum* shells when it was experimentally offered with all shells. Studies with hermits have shown that the species has preferences of gastropods shell *C. atratum*.

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Introduction

Diogenidae is a hermitages family of the Decapoda that includes approximately 425 species, making it the second most diverse of the families of the Anomura infraorder. It has a cosmopolitan distribution and is considered fragile due to non-calcification of its abdomen. Its life strategy is closely related to the use of shells, being essential to its survival (Vance, 1972; Hazlett, 1981; Matos and Couto, 2010).

The association between hermit crabs and gastropod shells is quite specific (Sant'Anna et al., 2006). Hermits can move around with their shells due to the twisting of their abdomen, which is associated with the presence of modified uropods, allowing them to attach to the shell columella (Narchi, 1973). Shells are of great importance to hermit crabs, for protection against predators, resistance to desiccation, protect against the force exerted by the waves tidal, protection of eggs in female, in some cases even against the other hermit crabs and a moderating function of environmental factors (Bach et al., 1976; Burggren, 1979; Pinheiro et al., 2005).

Most hermit crabs use shells of different gastropods. The diversity of shells used was related to the number gastropod species present. The pattern of shell utilization varies among populations, which demonstrate preference for some shell types that can bring advantages and maximize their abilities (Markham, 1968). The process of shell occupation was influenced by several factors such as availability

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in nature, weight, shape, architecture, internal volume and epibionts occurrence (Rotjan and Blum, 2004).

In this perspective, the present work aims to identify the preferred shells to be occupied by hermit crabs, as well as characterization of their behaviour aspects in the choice and dispute by shells, collected on the Jaguaribe Beach, in the Ilha de Itamaracá – PE, Brazil, observed in microcosm with the elaboration of an ethogram for the behavioural registers.

Materials and Methods

Material collection was performed in July 2016 during low tide. A total of 60 individuals of hermit crabs were randomly collected from sandstone reefs. The captured individuals were conditioned in a tray containing substrate and water from the collection environment to simulate their natural environment (microcosm). At the same time, the empty shells of the gastropods, including *Bulla striata* (Bruguière, 1792), *Astraea tecta* (Phillipi, 1846) and *Cerithium atratum* (Born, 1778) of different sizes were collected (Fig. 1). Then, the hermit crabs were removed from their host shells by heating i.e. keeping the apex of the shells on fire flame.

In the first four experiments, the ethological method of observational sampling type *Ad Libitum* (Altmann, 1974) was used based on the continuous record of what the animal does, where the rule is the absence of rules (Del Claro, 2004). In the fifth experiment, the instantaneous scanning method was used (Altmann, 1974) based on the discontinuous register, where at each predefined time interval, two minutes, all hermit crabs were observed to verify the interaction between hermit crabs with and without shell. This interval must be as small as possible, in order to act as if a photographic record was taken at each moment of observation (Del Claro, 2004). In order to compare the frequencies of the behaviours was used t-student test with significance level P=0.05 (Zar, 1996).

Experiment I: Consisted in observing how the hermit behaved when being offered a shell with aperture inferior to its size. The hermit without a shell was inserted into the microcosm before an empty shell of

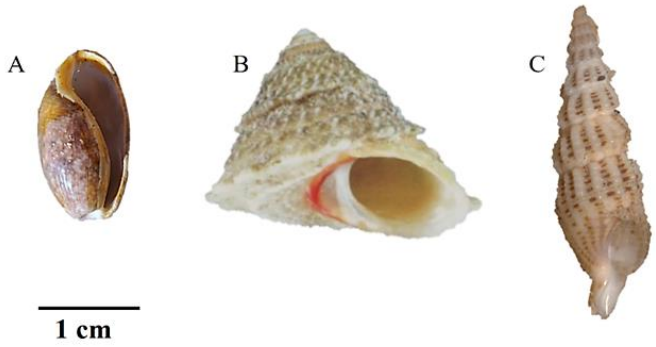

Figure 1. Gastropods' shells used in the experiment, collected in Jaguaribe beach, Ilha de Itamaracá – PE, Brazil. (A) *Bulla striata* (Bruguière, 1792), (B) *Astraea tecta* (Phillipi, 1846), and (C) *Astraea tecta* (Phillipi, 1846).

B. striata, with an opening smaller than its size. Five replicates were used, whose hermit crab behaviours were observed for five minutes in each replicate.

Experiment II: The preference of the hermit was verified by shells of different shape. Ten replicates were used with two moments and duration of ten minutes each. At the first moment, the hermit without shell was inserted with an empty shell of *B. striata* and another of *A. tecta* and observed to their choice between the offered shells. In the second moment, after the individual had stayed in one of the shells, was inserted the shell of the *C. atratum*, type of shell that normally the hermit occupies in natural environment.

Experiment III: Competition verification by shells among hermit crabs. Five specimens of hermit crabs without shell were inserted and only one shell of *C. atratum*, in the microcosm and observed the reactions. In this experiment, five replicas were used, with duration of 20 min, with the purpose of observing the competition between the individuals of hermit crabs by the shell.

Experiment IV: The behaviour among crabs with and without shells within the same microcosm was observed and thus the etogram made. Four specimens were inserted, two with and two without shell, with the use of five replicas, whose hermit crab behaviours were observed for ten minutes.

Experiment V: Was observed if there were differences in the behavioural patterns among the hermit crabs in the dispute for the shell. Five replicas were used, where each replica simulated a microcosm where it

Table 1. Description of the behavioural acts of the hermit crabs in microcosm, collected in Ilha de Itamaracá, Pernambuco, Brazil.

Category	Behavioural act
Walk	Individuals with and without shells walking in the environment.
Enter the shell	Hermit without shell trying to get into the shell.
Enter in the shell empty	Shell-less specimen when occupying shell.
Drive out the intruder	The specimen with shell expelling another without shell.
Run away with the shell	The specimen with shell escaping from another without a shell.
Run away without a shell	The specimen running away from individuals with shell.
Fight with shell	Confrontation between specimens with shell.
Fight without shell	Confrontation between specimens without shell.
Persecution	Individual chasing another.
Resting with shell	Specimen with shell still and isolated.
Resting without shell	Specimen without shell still and isolated.
Turn gravel	Individual stopped revolving the substrate.
Turn shell	The specimens looked at the shells, exploring the opening and the inner space of the shell.

contained three hermit crabs with their respective shells and three without shells. The observation time was 30 minutes, with behaviour recorded at two-minute intervals, to the total of 15 observations for each replica. T-student tests were still performed with significance level of 5%, to identify if there was significant difference in the frequency of behaviour between the individuals with and without shell.

Results and Discussion

In the first experiment, it was observed that 100% of the hermit crab turned the shells in the first contact. According Pinheiro et al. (2005), this type of behaviour is classified with specific exploratory, by which these animals analyse their conservation, size, shape, weight, size of its aperture, colouration and its internal volume. In relation to the attempt to occupy the shells, 80% of the hermits insisted two or more times, even though they did not succeed in hosting it, because they are shells smaller than their size, and 20% tried to enter only once, after examining it. Bertini and Fransozo (2000) claim that the choice of shells is not random, thus exhibiting specific exploratory behaviours such as rotating the shells with the chelipods, exploring the opening and the inner space of the shell.

For the second experiment, in the first stage it was recorded that all hermit crabs preferred the shell *B. striata,* analysing it before occupying it, clearly showing its preference rather than *A. tecta*. In the second moment, when inserted the shell that he occupied previously (*C. atratum*), they migrated to the introduced shell, thus being noticeable the preference for the latter. According to other studies (Pereira et al., 2009), the species of hermit crabs tend to prefer elongated shells narrow spirals, such as of the genus *Cerithium*.

In the five replicates of the third experiment, there were complications being that in 80% of these, three or more disputes took place by the shell and only in a replica were verified two disputes by the shell, in this have the expulsion of the first host by another greater individual, who remained until the end of the treatment. In natural environments, which offer shelter are larger, it is usually not prospective this type of competition, however, in low availability of shells may occur (Scully, 1983), being able to conclude that larger individuals stand out better than smaller specimens do.

In the fourth experiment were registered 14 behavioural acts, divided into 14 categories and built the ethogram. The categories registered were: walk, enter the shell, enter in the shell empty, drive out the intruder, run away with the shell, run away without a shell, fight with shell; fight without shell, persecution, resting with shell, resting without shell, turn gravel and turn shell (Table 1). It was found that the most common categories were those that were most frequently repeated, walking, turning shell, enter in the empty shell and resting with shell, actions classified as exploratory, corroborating with Pinheiro et al. (2005), where he mentions that the main initial

Table 2. Frequency of specimen categories, without and with shells, collected in Ilha de Itamaracá, Pernambuco, Brazil.

Category	Frequency with shell (%)	Frequency without shell (%)
Walk	54.2	59.3
Enter the shell	12.0	0.0
Run away with the shell	4.9	0.0
Run away without the shell	0.0	5.6
Fight with shell	5.8	1.4
Fight without shell	0.0	5.6
Persecution	0.9	4.5
Resting with shell	16.9	0.0
Resting without shell	0.0	12.6
Turn shell	5.3	11.0

Table 3. Level of significance between the behavioural categories of the hermit crabs, with and without shells, collected Ilha de Itamaracá, Pernambuco, Brazil.

Category	*P*-value
Walk	0.70
Run away with the shell X Run away without the shell	0.92
Fight with shell X Fight without shell	0.95
Persecution	0.16
Resting with shell X Resting without she	0.51
Turn shell	0.22

activities are to recognize the environment (walking) and beyond the search for more adequate shelter, in the case of the experiment were turn shell and enter the shell.

For the fifth experiment, a total of 11 categories was registered (Table 2). Among the behaviours registered the most frequent was the walk, with 59.3% of the without shell and 54.2% with shells, where the specimens walked on the substrate of the microcosm. Then, the most frequent was the resting of the individuals with and without shell, 16.9% and 12.4%, respectively. It is noted that individuals without shells were in greater movement, because they are in search of shells, in which it is indispensable for their survival, thus being more in movements than those that already have shell.

When analyzing the level of significance between the behavioural categories shared between the specimens with and without a shell, it was observed that none of the categories analyzed showed a significant difference between the behaviours of individuals with and without a shell (Table 3), even though they presented different frequencies. According Bertness (1981), this is because even though the specimens have shells they continue to look for new ones that best suit their size and other characteristics.

Based on the results, it was observed that there is a very strong relationship between the crabs in the choice of their shells, showing that this choice is related to the availability of the resource in the environment, and the search for a suitable shell is constant. Note that there is a preference for shells of the species *C. atratum,* however, where it is not available in the environment, it may be replaced by *A. tecta*. And that prior to occupying them, there are exploratory behaviours such as turning the shell and analyzing the opening of it. On the other hand, the shared behaviours between individuals with and without shells have little distinction, since the shell search, which is ideal for the size of the individual, is consistent for both cases.

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