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Spatio-temporal microhabitat use by two co-occurring species of scorpions in Atlantic rainforest in Brazil

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ABSTRACT

With the increasing devastation of the tropical rain forest, there is a critical need to understand how animal forest communities are structured and how habitat degradation will affect these communities. We conducted a field survey to investigate the microhabitat preferences of two co-occurring species of scorpions (*Tityus pusillus* and *Ananteris mauryi*) in a fragment of Atlantic rainforest, as well as their abundance and their ecological niche, during both the dry and rainy seasons. Behavioural aspects related to the use of the environment and the proportions of juveniles and adults are also described. The occurrence of intra- and interspecific coexistence was assessed by active search. In addition, pitfall catches were used to assess the structure of the population in the dry and rainy seasons. The differential patterns of spatial distribution in the litter layers provided evidence of partial niche partitioning between the two coexisting scorpion species depending on age and climatic conditions. Abundance, foraging behaviour and age structure (juveniles and adults) were seasonally influenced. We conclude that the diverse and subtle behaviours involved in interaction and habitat use may facilitate species coexistence. Resource partitioning and refuge sharing on a temporal and/or spatial scale, as well as predation pressure, may drive the dynamics and spatial distribution of scorpion species in the rain forest environment.

1. Introduction

Although habitat selection and species interactions are major factors that influence animal population dynamics (Gagnon et al., 2011; Schowalter, 2012), the features that affect such parameters are not fully understood for the majority of arthropod species. The processes involved in habitat selection usually involve responses to environmental conditions that promote growth, survival and reproductive success (Uetz, 1979; Polis, 1981; Schowalter, 2012). Therefore, the presence of conspecifics and heterospecifics in the environment will most likely result in substantial competition for the resources of food and shelter and may decisively influence habitat selection (Polis and McCormick, 1987; Kaltsas et al., 2009; Lankau, 2011).

Scorpions are primarily solitary and sedentary arthropods and live preferentially in microhabitats that are colonised by other arthropods on which they prey (Brownell and Polis, 2001). Intra- and heterospecific coexistence has been recorded in several species of scorpions (Shivashankar, 1994; Warburg, 2000; Kaltsas et al., 2009) and produces different levels of sociability and aggregation. Species may either co-occur in the same habitat (environment) or co-occur in the same shelter (niche) (Warburg, 2000). Age and seasonality have been shown to be important factors affecting such interactions (Polis, 1980a; Warburg, 2000; Kaltsas et al., 2009). The coexistence of specimens of *Mesobuthus gibbosus* (Brullé, 1832) in Greece, for example, was more often observed among adults on the one hand and among immature individuals on the other hand. The occasional cohabitation of mature and immature scorpions was only observed during the winter (Kaltsas et al., 2009). Similarly, *Hottentotta judaicus* (Simon, 1872) and *Compsobuthus werneri judaicus* (Birula, 1908), which colonised the same microhabitat in the Mediterranean region of northern Israel, shared the same shelter more frequently during the rainy season, whereas *Nebo hierichonticus* (Simon, 1872) and *Scorpio maurus fuscus* (Linneaus, 1758) cohabitated more often during the dry season (Warburg, 2000). These scorpions are species of the sand desert or the Mediterranean region, and only a few studies have addressed the ecology of scorpions occurring in tropical forests. This lack of previous studies is particularly surprising in view of the high biodiversity of such environments and the evidence that environmental change is transforming the ecology of tropical forests (Lewis et al., 2009).

The Brazilian Atlantic Forest is considered a hotspot of biodiversity and features a habitat that is one of the richest in animal species and has one of the highest rates of endemism in the world (Ribeiro et al., 2009). Nevertheless, ecological studies of scorpions in such environments are rare (Dias et al., 2006; Yamaguti and

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Pinto-da-Rocha, 2006). The present study investigated the population structure of two scorpion species, *Ananteris mauryi* Lourenço, 1982 and *Tityus pusillus* Pocock, 1893, which are widely distributed in fragments of the northeast Atlantic Forest (Lourenço, 2002; Dias et al., 2006; Porto et al., 2010). The focus of the study was microhabitat preference, intra- and interspecific coexistence and aspects of behaviour. We tested the prediction that co-occurring scorpion species would exploit different microhabitats to avoid intra-guild predation. We also assessed whether the dry and rainy seasons were associated with differences in the abundance of both species. Scorpions are predators, preying on a wide variety of populations of insects and spiders and affecting the energy flows of ecosystems (McCormick and Polis, 1990). Therefore, the findings of the present study on the ecology and behaviour of two widespread species can contribute to a greater understanding of the structure of arthropod communities in the Atlantic Forest of Brazil that feature scorpions as predators.

2. Materials and methods

2.1. Study area

Field work was conducted in the Campo de Instrução Marechal Newton Cavalcante (CIMNC), a military area composed of a 6280 ha fragment of semi-deciduous seasonal Atlantic Forest (07°46′55″ S, 35°09′02″ W), in the state of Pernambuco, in the northeast of Brazil. The area is characterised by a mean annual temperature of 25.2 °C and an annual rainfall of 1634.2 mm (LAMEPE, 2011). Sampling was conducted at two sites, 2.3 km apart, during the period of lowest precipitation (in October and December 2009, with rainfall of 11 and 75 mm, respectively) and during the period of highest precipitation (in May and July 2010, with rainfall of 220 and 95 mm, respectively). The area had originally been occupied by a sugar cane mill. However, it has been undergoing natural regeneration since its occupation by the military in 1944.

Because the studied scorpion species coexist in leaf litter, leaf litter depth was used as an indicator of habitat uniformity to minimise the sampling error caused by habitat diversity. Litter depth at the study sites ranged from 3.6 cm to 7.7 cm. The corresponding dry weights ranged from 0.97 kg m^{-3} to 1.39 kg m^{-3}.

2.2. Microhabitat preference

Microhabitat sampling was conducted by actively searching along four parallel transects 30 m long and approximately 20 m apart. Each transect was travelled twice (round trip) at the same time each night between 20:00 h and 01:00 h by a pair of collectors. Scorpions found up to 5 m from the transect on both sides (a sampling area of 300 m^2 per transect) were collected. The animals collected in one transect were considered to represent one sample. Sixteen samples each were collected during the rainy and the dry periods, for a total of 32 samples.

An active search with UV light was performed to visualise scorpions under the litter layer. The litter layer was subdivided into epi-leaf litter (the top layer of litter, approximately 2–3 cm thick, composed of intact leaves and fallen branches) and sub-leaf litter (the layer below the epi-leaf litter, approximately 3–4 cm thick, composed of small pieces of leaves and branches at different levels of decomposition). If necessary, dead leaves and other debris from the epi-leaf layer were carefully removed to confirm the sub-leaf location of scorpions. Logs and vegetation (up to a maximum height of 10 cm) were also investigated. During the active search, the postures of the animals (observed movements and body positions) were recorded. Data were only collected for active individuals that were either outside of their refuges or just emerging from the refuges, as suggested by McReynolds (2008).

Table 1
Microhabitats (in %) colonised by the scorpions *Tityus pusillus* and *Ananteris mauryi* in the Atlantic Forest in the northeast of Brazil. Data obtained by actively searching during the dry and rainy seasons.

	Dry season		Wet season	
	Tityus pusillus	*Ananteris mauryi*	*Tityus pusillus*	*Ananteris mauryi*
Ground	0	27	0	0
Under logs	0	0	18	0
Epi-leaf litter	67	19	73	100
Sub-leaf litter	28	54	0	0
Vegetation	5	0	9	0

2.3. Abundance

Abundance estimates were not only based on active search but also on pitfall traps to minimise differences due to variations in the activity time of the scorpion species since errant species, such as *T. pusillus*, are easier to see and to collect than humicolous species, such as *A. mauryi*.

The traps consisted of plastic bottles (9.0 cm in diameter, with a volume of 500 ml) containing 70% alcohol (200 ml) as a preservative. Drops of detergent were used to break the surface tension. The traps were buried in the ground and protected by a suspended polystyrene disc. They remained exposed for 5 days. Pitfall traps were set in the two sites, 15 pitfall traps per site. Surveys were performed during both the dry and the rainy seasons, two field trips per season. At each site, traps were deployed along three 12 m transects, 20 m apart. Each transect contained five traps, 3 m apart, for a total of 15 pitfall traps in each collection period. A total of 120 samples were obtained with this method.

2.4. Data analysis

Differences in microhabitat use were evaluated with a G-test on contingency table data (Sokal and Rohlf, 1981) from pooled samples (active search). A *t*-test was used to verify whether the abundance of the two scorpion species differed between seasons. For this analysis, the plots at the two sites were treated as a single sample, with each forest site representing four replicates. Statistical analyses were performed with Statistica v. 7 software (StatSoft Inc., Tulsa, OK, USA).

Voucher specimens of *T. pusillus* and *A. mauryi* from the field collections were deposited in the Arachnological Collection of the Universidade Federal de Pernambuco, Recife.

3. Results

3.1. Microhabitat preference

Significant differences in preference indices were found between habitats in the dry season ($G_{(5,2)} = 40.42$, $p < 0.0001$), with relative preferences observed for epi-leaf litter (*T. pusillus*) and sub-leaf litter (*A. mauryi*) (Table 1). No significant differences in preference indices between habitats were found in the rainy season ($G_{(5,2)} = 3.36$, $p = 0.499$). The spatial distribution in each microhabitat was highly dependent on developmental stage (adult or juvenile) and climatic conditions (dry or rainy season) (Tables 1 and 2).

T. pusillus was observed in all three types of microhabitats (vegetation, under logs and litter). Adults were preferentially found within the epi-leaf litter (both seasons), whereas juveniles used only the sub-leaf litter layer (100%) during the dry season but