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ORIGINAL ARTICLE

Diversity and seasonal composition of the scorpion fauna from a mountainous system on pampean grasslands in central Argentina

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ABSTRACT
Scorpions are one of the most important taxa for ecological, conservation, and biogeographic studies. Biodiversity in the pampean grassland hilly environment is relevant because of the high number of native plant and animal taxa. We studied the diversity, abundance and phenology of a scorpion community in a natural reserve from central Argentina. Samples were taken monthly using 10 pitfall traps. Five species of scorpions (269 individuals) were observed in the study site (Bothriuridae). *Bothriurus prospicuus* was the most abundant species with 40.15% of the total individuals captured. The Shannon index was H´ = 0.69 and the evenness index was 0.83. Scorpion abundance was significantly different between months and was significantly correlated with monthly mean temperature. The knowledge on the scorpion fauna in "Ernesto Tornquist" Provincial Park could help in the preservation of natural grassland habitats.

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Scorpions; Ventania; "Ernesto Tornquist" Provincial Park; diversity; phenology

Introduction

The mountainous systems of Buenos Aires province, Argentina, known as Ventania (southwestern) and Tandilia (southeastern) are hilly environments comprising mountain belts running from northwest to southwest (Selléz-Martínez 2001; Dalla Salda et al. 2006). The Ventania system has a more recent origin dating from the Paleozoic age (Selléz-Martínez 2001).

Biodiversity in the pampean grassland hilly environments is relevant because of the high number of native plant and animal taxa (Kristensen & Frangi 1995a; Zalba & Cozzani 2004). Moreover, these mountainous systems have been considered as high conservation priority areas, showing relictual genera and many endemic taxa and habitat types (Roig-Juñent & Debandi 2004; Zalba & Cozzani 2004; Ferretti et al. 2014). Also, some authors considered them as "orographic islands" (Kristensen & Frangi 1995a) and protected areas established in these hilly environments are focused on conserving the last relicts of pampean grasslands. Surveys of the invertebrate fauna in areas where conservation strategies already exist are especially important. Although not originally established to preserve invertebrates, efforts are already in place for the conservation of potentially new, rare and endemic invertebrate species that may exist in these areas (Nime et al. 2014). In addition, management plans to conserve fauna can only be developed and implemented once inventories or partial inventories are completed (Whitmore et al. 2002). Also, protection of local biodiversity is further threatened by the scarcity on ecological data on native species, mainly invertebrates, so that the actual richness of terrestrial arthropod species is likely to be underestimated (Carmo et al. 2013). Finally, observations on the ecology and geographical distribution of cryptic species, such as scorpions, frequently lack empirical support and are provided under different approaching studies, such as taxonomic or systematics. Considering that the composition of arachnid assemblages can be influenced by the degree of human activity and also by the size of native grassland fragments (Shochat et al. 2004; Carmo et al. 2013), it is unclear how these features may affect scorpion diversity.

The order Scorpiones comprises approximately 2000 described species distributed worldwide, of which more than 50% have been registered in the Neotropical region (Porto et al. 2010).

Many scorpion species have been reported in southern South America (Pocock 1898; Mello-Leitão 1931; Maury 1968, 1979; Ojanguren Affilastro 2005; Mattoni 2007; Ojanguren Affilastro & Cheli 2009). Most species are nocturnal and inhabit shelters beneath rocks or

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logs, occupy crevices under stones or even dig burrows into the substrate to spend the day (Polis 1990). Scorpions are common and ecologically important arthropods in most ecosystems throughout the world (Polis 2001; Brown 2004; Araújo et al. 2010) as they are among the most important predators in terms of density, biomass and diversity, for example in arid and semi-arid environments (Polis 1990). Many environmental factors can influence the diversity and abundance of scorpions in most ecosystems, such as the soil type, topography, hydrology, food resources, and especially, temperature and precipitation (Polis 1990; Prendini 2005; Dias et al. 2006; Araújo et al. 2010; Nime et al. 2013, 2014; Pizarro-Araya et al. 2014).

In this context, we performed a study on scorpion diversity in a natural grassland reserve from Ventania mountainous system. Specifically we aimed: (i) to determine the richness and abundance of species in a natural area representative from the pampean grassland hilly environment; and (ii) to investigate the seasonal variations in scorpion activity on the soil surface of the area mentioned above, during a period of 12 months.

Material and methods

Study site

This study was performed in an area located at southern Buenos Aires province, central Argentina. The study site was inside the "Ernesto Tornquist" Provincial Park (ETPP) (38°3′28.75" S; 61°59′20.35" W), an area of about 6700 ha in the Ventania mountainous system (Figure 1). This area is characterized by the presence of valleys and hills with heights of 450–1000 m asl. It has a humid and temperate climate with average annual rainfall of 850 mm and mean annual temperatures of about 14.5°C (Kristensen & Frangi 1995a).

Rainfall and temperature data were provided by a meteorological station located near the study area (Cerro Bahía Blanca station). Precipitation was measured daily and compiled into monthly totals while temperature values were obtained daily and compiled into monthly means.

Scorpion sampling

Samples were taken monthly over 12 months, between September 2009 and August 2010. Scorpion sampling

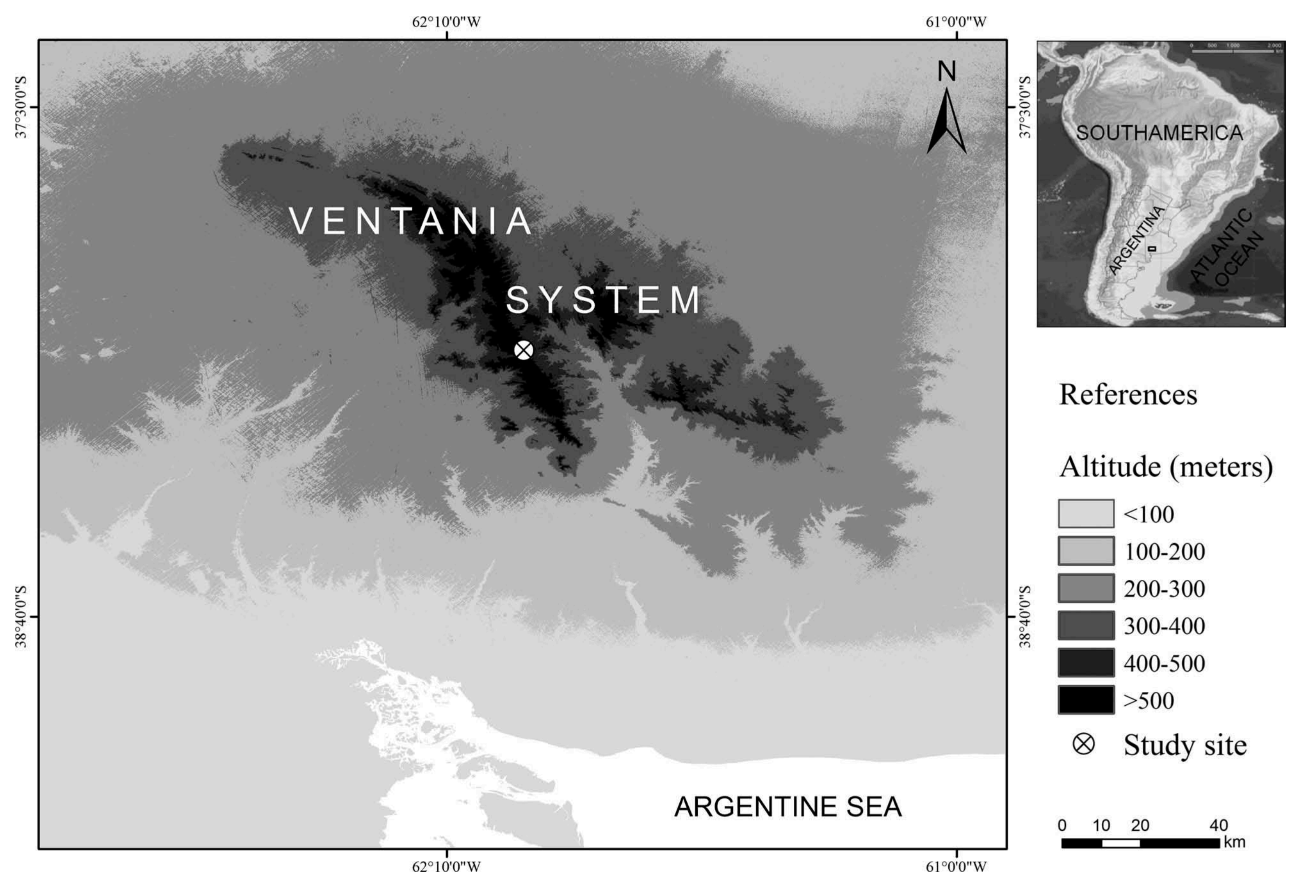

Figure 1. Location of the study site in "Ernesto Tornquist" Provincial Park (ETPP) in the Ventania mountainous system, Argentina.

was conducted with pitfall traps (23 cm diameter at ground level, 15 cm deep covered with a plastic roof supported by three metallic rods 15 cm above the soil to prevent flooding). Ten pitfall traps were placed in a straight line, distant 10 m from one another. The traps were located on a hill slope, with altitude differences of about 20 m from first to last trap (655–675 m asl). Traps were opened and active during the entire month and refilled after 30 days with 1500 ml of ethylene glycol, which prevented evaporation and acted as a preservative liquid.

All samples were studied at the Laboratorio de Zoología de Invertebrados II, Universidad Nacional del Sur, Buenos Aires, Argentina, where the arachnids were separated and preserved in 75% ethanol. The scorpions were identified to species (Maury 1973; Acosta 1988; Acosta & Maury 1998; Ojanguren Affilastro 2005) and stored in the collection of the Laboratorio de Zoología de Invertebrados II, Universidad Nacional del Sur, Buenos Aires, Argentina (LZI).

Data analysis

For each scorpion species, the abundance, dominance and constancy were estimated. Constancy was calculated as follows: $C = (p \times 100) \div N$, where C = constancy % for each species; p = number of samples in which the species is present; N = total number of samples. Species were classified as constant (when present in > 50% of samples), accessory (present from 25% to 50%) or rare (< 25% of samples) (Carmo et al. 2013). Scorpion diversity was calculated using the Shannon index (H') (Moreno 2001). To calculate whether species are distributed evenly across microhabitats, Evenness index was used (Magurran 1988). Normality and homogeneity of variances were evaluated with Levene and Shapiro–Wilk tests. An analysis of variance (ANOVA) test was made to compare the abundances of scorpions between sampling months. Correlation analyses (using the Pearson correlation) were performed between the abundance of scorpions collected on each month and total monthly precipitation (mm) and monthly temperatures averages (°C). All statistical analyses were performed using PAST version 3.02 (Hammer et al. 2001).

Results

We collected 269 individuals all belonging to the Bothriuridae family (Table 1). The genus *Bothriurus* was more abundant (84.76% of total individuals) than *Urophonius* (15.24%). At the species level, the most abundant species were *B. prospicuus* (40.15%) and *B. bonariensis* (34.94%). They were followed by *B. flavidus* (9.67%) and *U. mahuidensis* (9.29%). The least abundant species was *U. iheringi* (5.95%).

Table 1. Spectrum and abundance of scorpion species captured with pitfall traps at the "Ernesto Tornquist" Provincial Park, Argentina. *N* = total abundance; % = relative abundance.

Scorpion species	*N*	%
Bothriurus prospicuus Mello-Leitão 1932	108	40.15
Bothriurus bonariensis (Koch 1943)	94	34.94
Bothriurus flavidus Krapelin, 1911	26	9.67
Urophonius mahuidensis Maury 1973	25	9.29
Urophonius iheringi Pocock, 1893	16	5.95
Total	269	100

Bothriurus prospicuus was the only species found to be constant, with a constancy index of C = 66.66, while *B. bonariensis* (C = 41.66), *B. flavidus* (C = 41.66), *U. mahuidensis* (C = 33.33) and *U. iheringi* (C = 25) were classified as accessory. The Shannon index was $H´$ = 0.69 and the evenness index was 0.83. Scorpion abundances per month were significantly and positively correlated with monthly mean temperatures (Pearson correlation coefficient, $R = 0.63$; $p < 0.05$) and about 69% of the scorpions were collected during the warmer months (Figure 2). No significant correlation was found between scorpion abundances and rainfall. Significant differences were found regarding abundances of scorpions between months (ANOVA, $F = 16.82$, $p > 0.01$) with December and January being the months with highest abundances (Fisher, $p < 0.05$).

Bothriurus prospicuus and *B. bonariensis* showed a peak of activity during December and January (southern hemisphere summer). However, a few individuals of *B. prospicuus* were registered during October, April and June. *Bothriurus flavidus* was more abundant in January and a few individuals were registered during February, March, April and October. *Urophonius mahuidensis* presented a peak in June and July but also was reported in May and September and *U. iheringi* was more abundant in June and a few individuals in August and September (Figure 3).

Discussion

The richness values observed in our study are similar to those reported for other natural areas from southern of South America. Schwerdt et al. (2014) reported four species in a natural reserve from the Tandilia mountainous system (southeastern Buenos Aires, Argentina), Costa and Pérez-Miles (1994) and Toscano-Gadea (2002) reported five species in two mountainous systems from southern Uruguay, and Araújo et al. (2010) and Carmo et al. (2013) registered four and six species, respectively, in natural areas from southern Brazil.

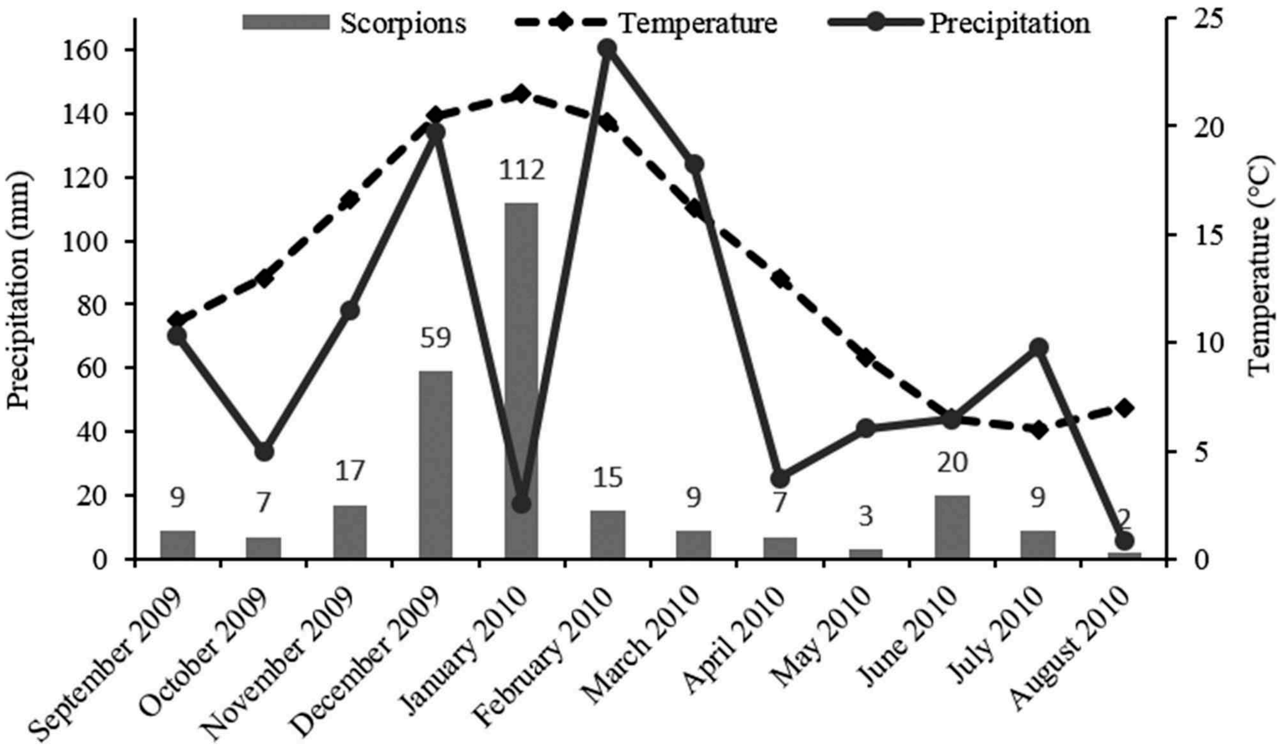

Figure 2. Variation in precipitation (mm), temperature (°C) and the total abundance of scorpions during the study period at "Ernesto Tornquist" Provincial Park, Argentina.

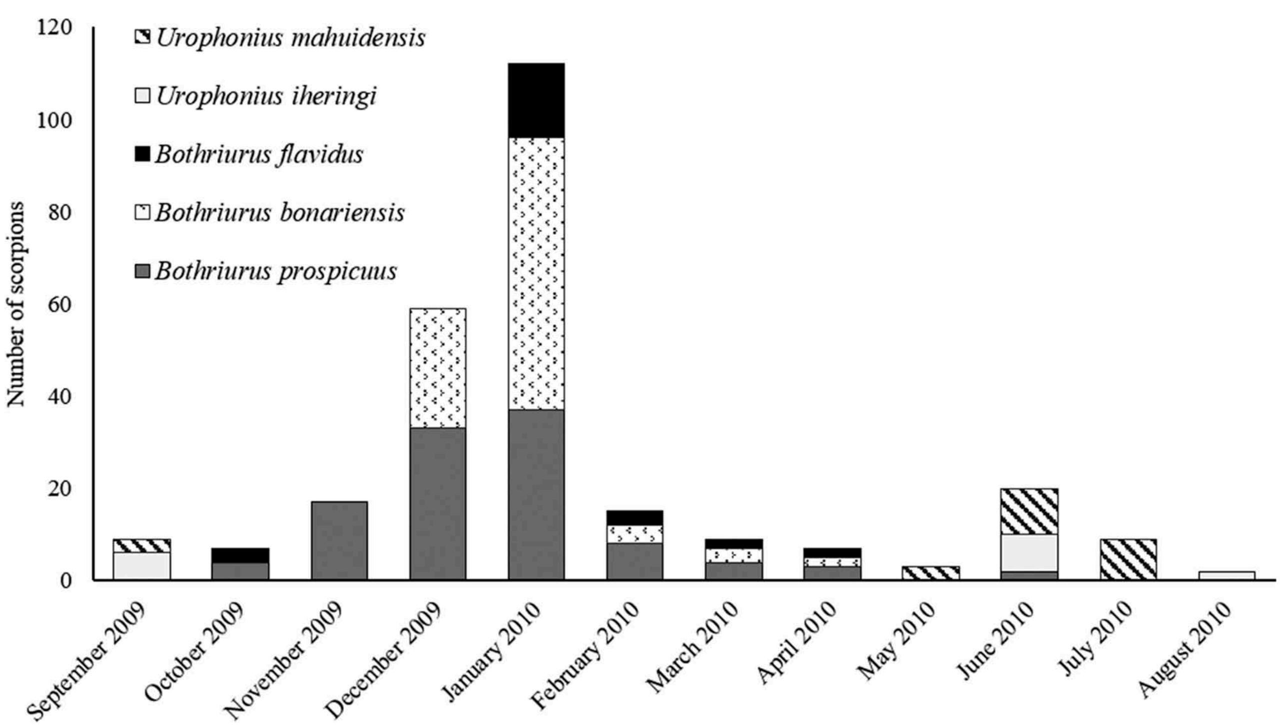

Figure 3. Comparison of number of scorpion species recorded per month with pitfall traps at "Ernesto Tornquist" Provincial Park, Argentina.

However, the richness values were higher than in the present study in Chile (nine species, Agusto et al. 2006), in the natural area of Chancaní (nine sympatric species, Acosta 1995a; and seven species, Nime et al. 2014) and in the central Andes, Mendoza, northwestern Argentina (seven species, Fernández-Campón et al. 2014).

Regarding the community composition, many differences in genera and species present in other natural areas of Argentina were found. For example, Nime et al. (2014) observed that almost 90% of the individuals belonged to Bothriuridae and *Brachistosternus* and *Timogenes* were the most dominant species, while one species of *Bothriurus, B. cordubensis* Acosta, 1995 was registered in low abundance. Fernández-Campón et al. (2014) registered *Orobothriurus* and *Brachistosternus* as the most abundant genera followed by *Bothriurus* with only one species, *B. burmeisteri* Kraepelin, 1894. The community composition observed in the present study was most similar to that found in mountainous systems from southern Uruguay and in central Argentina. This aspect could be due to historical processes that determined the distributional patterns of the scorpion species along the mountainous systems in the biogeographical province of Pampa (Morrone 2014). In agreement with this study, Costa and Pérez-Miles (1994) and Toscano-Gadea (2002) reported Bothriuridae as the most abundant genus with *B. bonariensis* being the most abundant species. Also, the genus *Urophonius* with *U. iheringi* as representative species was found by those authors. Moreover, *U. iheringi* was also registered in a natural reserve from the Tandilia system in southeastern Buenos Aires province as the more abundant species (Schwerdt et al. 2014). Another species, *U. mahuidensis*, was also registered in Tandilia mountains (Schwerdt et al. 2014). Ojanguren Affilastro and Cheli (2009) proposed that this species is endemic to the Tandilia and Ventania mountains in southern Buenos Aires province. However, another endemic species of Ventania, *Bothriurus voyati* Maury (1973), was not registered in this study, maybe because it has a short range and requires very specific microhabitats conditions (Maury 1973).

The surface activity of the scorpion species reported here might be underestimated because the capture success of pitfall traps is clearly related to the behavior of each species. For example, wandering species are more easily caught than sit-and-wait ones (Acosta 1995b; Cala-Riquelme & Colombo 2011). Therefore, our results suggest that the absence of some species or the patchy distributions in time of other species might have more to do with the low sampling effort of the traps than with the sampling method *per se*.

The Shannon index could be interpreted as a low value mainly due to the dominance of *B. prospicuus* and *B. bonariensis* in this study. Many factors, such as their low vagility, cannibalism, predation by nocturnal predators, habitat specificity, food size specificity, extreme climate adaptability, and adaptive radiation (Polis 1990; Pande et al. 2004), together with a longer life span than many other invertebrates may act as limiting factors for species diversity (Pande et al. 2004; Nime et al. 2014).

The evenness index suggests differences in the distribution across microhabitats of all species. Many factors could be influencing the spatial distribution of scorpions on mountains, such as physical factors including temperature, precipitation, soil or rock characteristics, stone or litter cover, and environmental physiognomy. Moreover, it is well known that microclimatic conditions (Kristensen & Frangi 1995a, 1995b) and vegetation (Lizzi et al. 2007) of Ventania mountains provide many suitable habitats for cryptozoic species (Ferretti et al. 2012). However, an exhaustive analysis of the microhabitat conditions required by some scorpion species in this mountain system should be carried out in the future for a better approach.

High numbers of *B. prospicuus* and *B. bonariensis* captured during warmer months suggest that higher temperatures promote scorpion activity. *Bothriurus prospicuus* abundance coincided with that reported for this species in Tandilia mountains (Schwerdt et al. 2014). Similarly, *B. bonariensis* activity during warm months was in agreement with that found by Schwerdt et al. (2014). Our results of surface activity also agree with that reported for mountainous systems from southern Uruguay (Costa & Pérez-Miles 1994; Toscano-Gadea 2002, 2013). *Bothriurus flavidus* also was active mostly during summer, as was reported for this species by Peretti (1997) and Ojanguren Affilastro (2005). On the other hand, *U. iheringi* and *U. mahuidensis* were present during months of low temperatures, coinciding with period reported in other studies (Maury 1973; Costa & Pérez-Miles 1994; Toscano-Gadea 2002, 2013; Ojanguren Affilastro 2005; Ojanguren Affilastro & Cheli 2009; Schwerdt et al. 2014). According to Maury (1979), this could be interpreted as a secondary adaptation, which would allow avoiding competition with other scorpions present in the area (e.g. the species of *Bothriurus*).

The effects of temperature on scorpion communities have been previously reported (Bradley 1988; Benton 1992; Ojanguren Affilastro 2005; Araújo et al. 2010; Carvalho et al. 2015). The influence of temperature on surface activity is important for many organisms, as it impacts both hunting ability and predator avoidance through such activities as foraging (Bauwens et al. 1995). Moreover, high temperatures increase plant growth and cause higher numbers of herbivorous insects, which likely improve food availability for scorpions (Wise 1993). Although we found no significant correlation between rainfalls and scorpion abundance, coinciding with findings reported by Toscano-Gadea (2013), in arid and semi-arid environments the beginning of the rainy season is highly correlated with an increase in the surface activity of scorpions, mainly when prey becomes widely available (Polis 1980; Araújo et al. 2010). So, temperature and precipitation are probably the most important determinants of the general geographical range of cryptozoic species (Koch 1977, 1981; Newlands 1978; Prendini 2005; Jiménez & Navarrete 2010).

The knowledge of the scorpion fauna obtained in the present study at a natural reserve in central Argentina could help in preservation of natural grassland habitats. This area is relevant to ensure the conservation of regional diversity, and further studies on natural grassland habitats may help with the necessary management and conservation decisions.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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