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Spatial organisation of the Neotropical lizard *Tropidurus hispidus* (Squamata: Tropiduridae)

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The place where an individual lives and performs its activities (i.e., its home range) is an important attribute of animal ecology (BROWN & ORIANI 1970). Knowledge about how the individuals of a given species use their space can reveal properties of the animal's social systems (KANEKO et al. 2014). For example, one can infer mutual avoidance between individuals, a proxy of territoriality, if home ranges are situated apart from each other (SHELDAHL & MARTINS 2000). On the other hand, non-territorial systems can be expected when there are broad overlaps between the ranges of individuals (STAMPS 1977). In addition, analyses of home ranges can be useful to understand animal mating systems. The number of females associated with a male's home range can be indicative of whether males maintain harems as expected for a polygynous system, or whether they live in mating pairs as expected for a monogamous system (KERR & BULL 2006, ROBLES & HALLOY 2009, HIBBITTS et al. 2012).

Previous evidence suggests that male lizards of the Neotropical lizard genus *Tropidurus* WIED-NEUWIED, 1825 have larger home ranges than females (GIARETTA 1996, VAN SLUYS 1997, RIBEIRO et al. 2009). In addition, it has also been shown in tropidurid lizards that the home ranges of females are often associated with male home ranges and few home range overlaps between males exist (VAN SLUYS 1997, RIBEIRO et al. 2009). Nevertheless, considering the relatively high species diversity of the genus *Tropidurus*, with 30 species being currently recognized (UETZ &

HOŠEK 2016), information on the spatial ecology of many of the species is still needed in order to understand broad patterns (see PASSOS et al. 2015).

Tropidurus hispidus is one of the largest species of its genus and widely distributed in open environments of South America (CARVALHO 2013). These lizards often use rock surfaces and only move over short distances, which is typical of their sit-and-wait foraging strategy (GOMES et al. 2015, VITT et al. 1996). GONZÁLES et al. (2004) found that *T. hispidus* males had larger home ranges than females, but this difference was not significant. Sexual size dimorphism was demonstrated to exist in this species, with males being larger than females (KOLODIUK et al. 2010). As lizard home ranges are generally directly correlated with male body size (CHRISTIAN & WALDSCHMIDT 1984, PERRY & GARLAND 2002), we expected that the home ranges of *T. hispidus* males would be larger than those of females. In the present study, we addressed the use of space by *T. hispidus* lizards in an anthropogenic area. Specifically, we evaluated: i) Intersexual differences in home range sizes, and ii) Intersexual differences in home range overlaps.

The study took place in an anthropogenic area (3°44'21.2" S and 38°34'21.1" W, 20 m a.s.l.), within the urban matrix of the coastal city of Fortaleza, Ceará state, Brazil. In this region, the rainy period extends from January through June, although rains are unpredictable within this period. Temperature is relatively invariable throughout the year, averaging 26.6°C (SOUSA et al. 2009).

We collected spatial data for *T. hispidus* individuals from August through September of 2012. The lizards were sampled within a 0.3-ha grid with reference marks at 5-m intervals. We captured the lizards that we found in the grid with a noose, and identified their sexes based on the presence of dark coloration on the ventral face of the thigh and anal flap, which is present only in adult males (RODRIGUES 1987). In order to mark the lizards, we attached coloured beads to the bases of their tails, following the bead-tagging method of GALDINO et al. (2014). The individuals were then released at the places where they had first been sighted. Spatial data points for these individuals were obtained through lizard re-sightings during intense visual sampling over a period of 20 days. Moreover, to avoid temporal dependencies in the spatial data, we walked through the grid following fixed routes. In addition, each day of sampling included searching for lizards within two periods (one from 07:00 through 12:00 h, and the other from 12:00 through 17:00 h), considering only the first sighting of each lizard per period.

The home range size for each individual was estimated by the minimum convex polygon method, removing the 5% of points that were farthest from the centroid of the cloud of resighting points. We accumulated the home range size values (natural log transformed) against the numbers of sightings to evaluate the minimum threshold of sightings appropriate for reliably estimating the sizes of home ranges (ROSE 1982). Home range overlaps were estimated by generating a matrix with the relative values of pairs of individual range overlaps. The spatial analysis was run in the software environment R (R Core Team 2013) by using the *adehabitatHR* package (CALENGE 2006) for home range estimates and the *rgeos* package (BIVAND & RUNDEL 2012) for overlaps. For these procedures, we used the 'HunteR' script (PASSOS et al. 2015, <https://github.com/NeoLiBE/NeoLiBE/>). As spatial overlap might not necessarily be related to behavioural association (i.e., temporal synchronism in the use of space), we used the Half Weight Index (HWI) (WHITEHEAD 2008) as a measurement of temporal association between pairs of individuals. We performed this analysis using the software SOCPROG (WHITEHEAD 2009). We followed:

$$\text{HWI} = \frac{X}{X + Y_{ab} + 0.5(Y_a + Y_b)}$$

where: X is the number of sampling periods in which both individual 'a' and individual 'b' were observed, Y_a is the number of sampling periods in which only individual 'a' was observed, Y_b is the number of sampling periods in which only individual 'b' was observed, and Y_{ab} is the number of sampling periods in which neither individual 'a' nor individual 'b' were observed. The HWI varies between 0 (no association) and 1 (maximum association). To increase the reliability of our estimates we only considered home range overlaps for those pairs of individuals with a $\text{HWI} > 0.5$. We tested the conformity of the numerical variables with a normal distribution by applying the Shapiro-Wilk test, and homoscedasticity was tested using the F test for comparing two variances. The effect of sex on the sizes of home ranges was evaluated using the Mann-Whitney U test. Descriptive statistics are presented as median and range or mean \pm one standard deviation.

We obtained visual recaptures for 29 individuals, comprising six males, 20 females, and three individuals that could not be sexed and were therefore ignored in the analysis. We obtained 511 spatial points, with a mean of 17.62 ± 8.55 spatial locations per individual (minimum: 1; maximum: 32). The mean number of sightings was 19.00 ± 10.20 for males and 17.35 ± 8.46 for females.

Estimates of home range sizes had less variation for lizards with more than 12 sightings (Fig. 1). Thus, we could estimate home range sizes for 22 individuals (five males and 17 females). Males had larger home ranges than females (males = 136.87, ranging from 9.90 to 340.51 m²; females = 12.20, ranging from 0.73 to 86.03 m²; $W = 13$, $P = 0.02$). We found 20 pairs of individuals with overlapping home ranges: one male–male pair, nine female–female pairs, and ten male–female pairs. However, when the temporal synchrony of individual sightings was considered, the number of spatial overlaps was ten: two female–female pairs and eight male–female pairs. The unique male–male pair with overlapping home ranges was not temporally associated. Of the 17 sampled females, eight females did not have

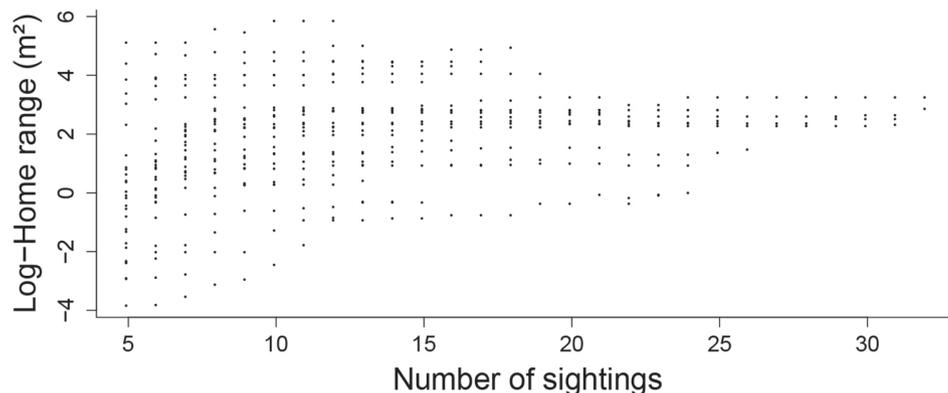
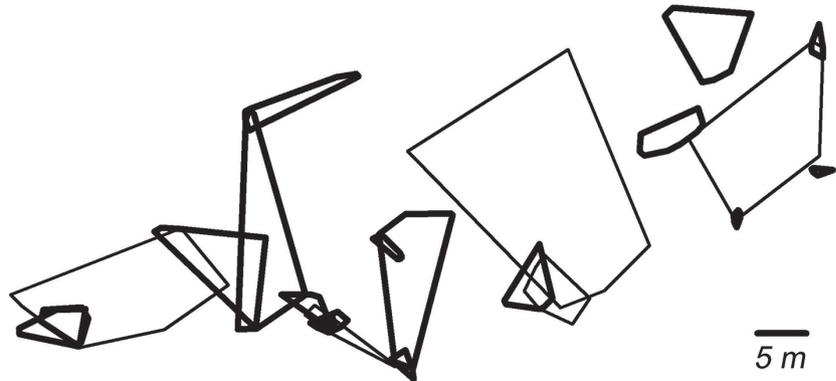


Figure 1. The relationship between cumulative home range size (log-transformed) and the number of sightings of *Tropidurus hispidus* in an anthropogenic area in northeastern Brazil.

Figure 2. Spatial organization of the home ranges of males (fine line) and females (bold line) of *Tropidurus hispidus* in an anthropogenic area in northeastern Brazil. Scale bar = 5 metres.



overlapping home ranges with any males, eight females presented home ranges that were overlapped by one of a single male, and one female had a home range overlapped by those of two males. In addition, the mean number of female home ranges included in, or adjacent to, a male home range was 3.17 ± 1.72 , varying from one to five females per male (Fig. 2).

Male and female *T. hispidus* had different home range sizes with males occupying larger areas than females. This result is similar to those found in other Neotropical iguanian lizards [e.g., *Liolaemus lutzae* – ROCHA (1999); *L. quilmes* – HALLOY & ROBLES (2002); *T. itambere* – VAN SLUYS (1997), and *T. torquatus* – RIBEIRO et al. (2009)]. The larger home ranges of male lizards might be explained by selective pressures to increase the reproductive success of males by maximising their access to females (PERRY & GARLAND 2002, ROBLES & HALLOY 2009). For example, HAENEL et al. (2003a, 2003b) found that males of *Sceloporus undulatus* increased their reproductive success in relation to the number of females associated with their home ranges. Although we did not address fitness issues of *T. hispidus*, we could show that males had up to five females associated with their home ranges. The larger home ranges of males with many females associated with them may reflect the requirements of a polygynous mating system (BULL 2000, KERR & BULL 2006). Thus, our findings regarding the spatial arrangement of male and female *T. hispidus* suggest the formation of harems in accordance with a polygynous mating system.

We found only a few intrasexual home range overlaps in *T. hispidus*. It is important to note that we were able to estimate the home ranges of almost all marked individuals within the grid, thus the low number of overlapping home ranges might suggest mutual avoidance in the use of space, as could be expected for Iguanid lizards (STAMPS 1977). Mutual avoidance in the use of space is one of the expressions of territoriality (MARTINS 1994, SHELDAHL & MARTINS 2000). VAN SLUYS (1997) suggested that the low level of overlap between home ranges in *T. itambere* indicates that these lizards use more exclusive areas in a territorial system. Similarly, RIBEIRO et al. (2009) suggest that the low number of overlapping areas between *T. torquatus* males is indirect evidence of their territorial disposition.

For *T. hispidus*, other characteristics besides their spatial organisation may also indirectly indicate territoriality. For example, in a record of cannibalism in *T. hispidus*, involving the chasing and attacking of a conspecific juvenile by an adult male (SALES et al. 2011), the authors comment that an intrusion into the territory of the adult male by the juvenile may have contributed to the predatory attack. Furthermore, non-lethal injuries, such as tail autotomy, toe amputation, and integument scars observed in *T. hispidus* (PASSOS et al. 2013), may also reflect intraspecific antagonistic encounters. However, additional information on behavioural expressions is needed for confirming territoriality as a characteristic of *T. hispidus* males.

Our study showed that *T. hispidus* males had larger home ranges than females. The spatial organisation found in the studied system suggests intrasexual avoidance in the use of space. In addition, it seems that males are able to gather harems, conforming to a polygynous mating system.

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