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Original investigation

Seasonal variations and population parameters explaining the use of space of neotropical rodents

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ABSTRACT

Space use by animals has been studied for decades; however, gaps still exist in the understanding of how it is affected by biological and environmental factors. The aim of this study was to determine how biological traits, population parameters and seasonal variations affect the use of space by rodents in a tropical savannah environment. This study was performed in two grids in a grassland area at Aguas Emendadas Ecological Station between January 2004 and December 2013. The trapping sessions lasted six consecutive days and were performed monthly. Sherman traps, which were baited and reset daily, were used to capture the animals. The movement area was estimated using the minimum convex polygon method, and the mean movement distance was used to investigate the factors that affect the movement of the rodents. The hypothesis that a significant difference exists in the movement area size among species was corroborated; however, this difference was not related to body weight. As a general pattern for these rodents, males displayed larger movement areas than females. Movement area size showed an inverse relationship to population density. The understanding of the factors that affect the space use by rodents are complex and the interactions of these factors may also modulate space use by rodents. Our results suggest that space use is also affected by climatic variations.

Introduction

Several factors affect the use of space by an animal, including biological factors and environmental parameters (Burt, 1943; Fernandes et al., 2010; Getz et al., 2005; Loretto and Vieira, 2005; Perry and Garland, 2002; Schoener, 1968; Spencer, 2012). Social behaviour, such as mating systems and territories of species may affect morphological, physiological and ecological traits of the animals (Lindstedt et al., 1986; Schoener, 1968), directly influencing their use of space.

Body size is one of the best predictors of life-history features, including home-range size. Many authors reported an allometric relationship between body size and home ranges (Milton and May 1976; Harestad and Bunell, 1979; Swihart et al., 1988), which could be explained by a multitude of factors, including social organization and mating systems (Damuth, 1981). In promiscuous species, the space use of males is expected to be larger than that of females because males tend to increase their effective movement to access females, whereas the smaller amplitude of movement by females may reflect their territorial behaviour for offspring protection (Gaulin and FitzGerald, 1986; Gomez et al., 2011; Wolff, 1993; Wolff et al., 1994). In fact, previous studies showed females using smaller areas, whereas males increase their areas during reproduction (Getz et al., 2005; Magnusson et al., 1995).

Climate effects on the use of space are complex and these effects are often indirectly associated with food resource availability or seasonality and predation risk (Börger et al., 2006; Moorcroft, 2012; Powell and Mitchell, 2012; Spencer, 2012). Seasonal variation in the use of space may be explained by seasonal changes in reproductive activity, population density or food availability.

Studies conducted on rodent populations have shown that the space use size is inversely related to the population density (Ambrose, 1973; Erlinge et al., 1990; Makarieva et al., 2005; Priotto et al., 2002). The presence of a member of the population affects the space used by another member because it imposes limits on its movements (Alho and Souza, 1982). The variables sex, seasonality, population density and body mass may interact in a complex man-

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ner to explain the variation in the movements of mammals (Getz et al., 2005).

In the present study, three species of cricetid rodents were monitored over 10 years, with the aim of detecting how these important biological and environmental factors affect the space use of these animals. We evaluated the following hypotheses: (1) males use larger areas than females, (2) the use of space differs between dry and wet seasons, (3) the distance covered by animals differs between reproductive and non-reproductive periods and may show different responses between sexes, (4) the distance covered by an animal varies between the sampling areas, (5) the distance covered by an animal is directly related to its body weight, and (6) the distance covered by an animal is indirectly related to population density.

Material and methods

Study site

The *cerrado* is a savannah with two well-defined climatic seasons: a cold and dry winter (from April to September) and a hot and wet summer (from October to March) (Oliveira-Filho and Ratter, 2002; Ribeiro and Walter, 2001). According to the classification of Köppen-Geiger, the climate is type Aw, with 1500 mm of mean annual rainfall (Cardoso et al., 2015). The study was performed on the Aguas Emendadas Ecological Station (Estação Ecológica de Águas Emendadas, ESECAE), located in the north-eastern portion of the Federal District, Brazil, in open areas with the presence of *murundus*, which consist of microrelief with trees and shrubs (Oliveira-Filho and Ratter, 2002; Sano and Almeida, 1998). See Ribeiro et al. (2011) for more detailed information on the study site.

Animal capture

Captures occurred between January 2004 and December 2013. Full moon periods were avoided because of the documented decline in rodent activity during these periods (O'Farrell, 1974; Price et al., 1984). Two capture stations were placed in open areas with murundus: Grid 1 (15°32′51″S and 47°36′55″W), with a scarce presence of woody vegetation (n = 18), and Grid 2 (15°32′14″S and 47°36′46″W), with a higher presence of woody species (n = 42) than Grid 1 (Ribeiro and Marinho-Filho, 2005). Each of the grids, separated by 1 km, consisted of 100 points, separated from each other by 15 m, in a total area of 1.82 ha (135 × 135 m). Fifty traps were simultaneously placed in each grid. Capture sessions were performed monthly. In each session, the traps remained in operation for 6 consecutive nights and were checked and baited daily at dawn. Baits consisted of banana, peanut butter, sardine and cornmeal. After 3 nights, the traps were removed from the odd points in each of the grids and transferred to the even points to allow alternate sampling of all 100 points in each grid. All captured individuals were marked with numbered earrings (1005-1, National Band and Tag, Co., Newport, KY) or phalange ablation. Animals were weighed, sexed and classified according to their developmental (juvenile or adult) and reproductive (reproductive or non-reproductive) stages.

The developmental stage was classified according to the relationship between body weight and reproductive stage. The lowest body weight recorded for individuals considered reproductive was used to determine the developmental stage of the rodents. Animals with weight higher than this value were considered adults, whereas animals with weight lower than this value were considered juveniles. Females were considered reproductive when they had vaginal perforation, were pregnant or showed obvious teats. Males were considered reproductive when the testicles were in the scrotum. All capture, handling and marking procedures were approved by the University of Brasilia Animal Care and Use Committee (CEUA-UNBDOC 47208/2009) and followed the Guidelines of animal care and use by the American Society of Mammalogists (Sikes and Gannon, 2011). Captures and collections were performed with authorization from the Brazilian Institute for the Environment (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis—IBAMA No. 15151-1 to 10). More details about the capture method may be obtained in Rocha et al. (2011).

Data analysis

The movement area sizes of individuals of each of the three species captured were estimated with the Minimum Convex Polygon (MCP) method using the Ranges 8 v 2.8 software (Kenward et al., 2008). Although the areas enclosed by the Minimum Convex Polygon are not actual estimates of individual home ranges (sensu Burt, 1943), they allow to compare the movement areas of individuals and determine the effects of season, and trapping grids. The movement areas were calculated only for individuals with four or more captures to ensure a better estimate (Múrua et al., 1986; Pires et al., 2010). To estimate the movement areas with the MCP method, all captures recorded for each individual during a given season (dry or wet) were used, provided they complied with the required number of captures. The animals that had more than 25% of the edge of the perimeter of their movement areas adjacent to the edges of the study grids were excluded from the analysis. The movement areas of individuals who moved between the two study grids were not estimated. This movement occurred with only a few individuals and only once for each and therefore was considered a dispersal event.

To determine whether body weight differs between males and females, a *t*-test was performed for each of the species analysed, with reproductive and non-reproductive animals being evaluated separately. To verify whether the movement areas calculated by MCP differ significantly among species, a covariance analysis (ANCOVA) was performed, using the number of recaptures as a covariable. Subsequently, a Tukey's test was performed using the package HH of the R software to determine which species differed in terms of movement area size (Heiberger, 2015). Movement area estimates were log transformed before the analyses.

To verify whether a significant difference exists in the movement areas calculated by the MCP between sexes and between seasons, an ANCOVA was performed for each species, with the number of recaptures being used as a covariable (Crawley, 2007). For Hairy-tailed Bolo Mouse (*Necromys lasiurus* (Lund 1840)), the study area (grid) was also included in the model. For Delicate Vesper Mouse (*Calomys tener* (Winge 1887)) and Hairy-eared Cerrado Mouse (*Thalpomys lasiotis* (Thomas 1916)), this variable was not used because of the low number of movement area estimates in one of the grids. Subsequently, the normality and homoscedasticity of the residuals of the model were graphically verified (Crawley, 2007).

Several of the factors that may affect the space use by individuals, such as variations in the reproductive stage, body weight and species abundance, change during the period when the movement area is estimated. Therefore, a non-circular distance was calculated as a movement index, which has been used in studies on the space use by small mammals (Jennrich and Turner, 1969; Slade and Russell, 1998). We chose the mean movement distance (MD) as an estimate of movement. This index is based on the mean of the distances covered by the animals among successive captures and was calculated with the data recorded only within each capture session (a maximum of 6 days). Juveniles were excluded from the analyses because of the low number of estimates for this group of animals.