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ORIGINAL INVESTIGATION

Use of space by the marsupial *Marmosops incanus* (Didelphimorphia, Didelphidae) in the Atlantic Forest, Brazil

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Abstract

The biology of small marsupials is poorly known because most species are nocturnal and arboreal. Using the spool-and-line device, we investigated the use of vertical space by male and female *Marmosops incanus* in the Serra dos Órgãos National Park. Diameter and slopes of supports also were compared. The species was sexually dimorphic in body size, males weighing on average 72.6 g and females 48.1 g, but males and females did not differ in the frequency of ground movements (GM) and understory movements (UM), or in diameter and slopes of supports used. Males and females also used the forest strata similarly, moving 67% on the ground and 33% in the understory. Both sexes used 0.9–1.7 cm support diameters, and support slopes near the horizontal (more than 50% of cases), but preferred to access a given height by moving on high slope supports (mostly near 90°). Sexual dimorphism in body size does not seem to constrain movements of *M. incanus*.

Keywords: Marmosops; spool-and-line; movements; body size; vertical strata

Introduction

The study of the natural history of small mammals, specially the marsupials, is not an easy task, because the majority of the species have nocturnal and arboreal habits. Traditionally, small mammals have been studied with live-traps, which allow a limited resolution on the detail of the vertical use of the forest, but alternative techniques have been successful in evaluating trappability, locomotion, diet, life history, reproduction, and vertical use of forest (Charles-Dominique et al. 1981; Miles et al. 1981; Malcolm 1991; Tubelis 2000; Graipel 2003; Graipel et al. 2003; Cunha and Vieira 2002; Moraes Jr. 2004; Moraes Jr. and Chiarello 2005; Vieira and Loretto 2004; Loretto 2006).

Although considered a decisive factor in the study of the biology of the Neotropical marsupials (see Malcolm 1991, 1995 for details), vertical distribution and stratification has only recently become a central query (Atramentowicz 1982; August 1983; Malcolm 1991, 1995; Passamani 1995, 2003; Pires and Fernandez 1999; Cunha and Vieira 2002; Graipel et al. 2003; Grelle 2003; Loretto and Vieira 2005). In this sense, the study of the use of the space (e.g. Atramentowicz 1982; Ryser 1992; Cunha and Vieira 2002; Vieira and Monteiro-Filho 2003; Loretto and Vieira 2005), and reproductive aspects (Ryser 1992; Loretto and Vieira 2005) have received more attention.

Although didelphids are considered generalists in many ways, there are distinctions in use of space and preferred forest strata, such as *Metachirus nudicaudatus*

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and *Caluromys philander*, considered the most terrestrial and the most arboreal species, respectively (Cartmill 1974; Charles-Dominique et al. 1981, 1983; Miles et al. 1981; Emmons and Feer 1990; Antunes 2003; Grelle 2003). Didelphis are considered promiscuous or polygynous, where females tend to have more stable home ranges whereas males tend to be more vagile, resulting in differences in use of space between sexes (Ryser 1992; Loretto and Vieira 2005) However, most information on mating systems of didelphids are restricted to species of *Didelphis* (Fitch and Shirer 1970; O'Connell 1979; Sunquist et al. 1987; Ryser 1992; Ladine and Kissell 1994). Sexual dimorphism in body mass is well-known (review in Nowak 1999), but most information are from species of *Didelphis* (e.g. Cáceres and Monteiro-filho 1999; Cerqueira and Lemos 2000).

Marmosops incanus (Lund, 1840) is an arboreal marsupial of the understory, which does not use upper forest strata such as the canopy (Passamani 1995; Cunha and Vieira 2002). The locomotory behavior of this marsupial is still poorly known, such as the type, size and slope of used supports (usually small and thick branches). In the study area males have, in average, 72.6 g and the females 48.1 g (Macedo et al., 2007), which raises the question if males and females also would differ in their use of the understory.

Here in, we compare the use of vertical space of the forest between females and males of *M. incanus*. The vertical use of forest was studied with a spool-and-line device, used to evaluate the diameter and slope of supports used in movements above the ground. Differences between sexes in vertical use of the forest are expected to result from sexual dimorphism in body size.

Material and methods

Marmosops incanus (Lund, 1840)

It ranges from the east coast of Brazil (Emmons and Feer 1990; Mustrangi and Patton 1997), in the Atlantic forest (Streilein 1982), up to the semi-deciduous Atlantic forest, and areas covered with the cerrado and caatinga vegetation in the State of Minas Gerais, Brazil (Câmara et al. 2003). It is a small nocturnal marsupial, with low mobility, and basically insectivorous food habits (Fonseca and Kierulff 1989; Astúa de Moraes et al. 2003). It inhabits the humid forests since the sea level up to 800 m of altitude in the continent and in great islands.

Study area and field methods

The study was conducted in an area of Atlantic Forest, in the Parque Nacional da Serra dos Órgãos (Serra dos Órgãos National Park), municipality of Guapimirim, 90 km from the Rio de Janeiro city, Brazil, in a place locally known as Garrafão (22°28′28″ S, 42°59′86″ W). The weather is mild-humid-mesothermic (Nimer 1989). During the study, mean minimum and maximum monthly temperatures were 10.7 and 30.5 °C, respectively, and total monthly rainfall varied between 0.2 and 508 mm.

Animals were tracked from April 1998 to February 2003 in bimonthly trapping sessions of five consecutive nights as part of the capture–recapture program of the Laboratório de Vertebrados, Universidade Federal do Rio de Janeiro (Federal University of Rio de Janeiro). Traps were distributed in three 0.64-ha grids located along the watershed of the Iconha River, at 748, 652, and 522 m altitude. Each grid had 25 trap stations 20 m apart in a 5 × 5 design. Each trap station had 2 live traps on the ground, a Tomahawk model 201 (40.64 cm × 12.70 cm × 12.70 cm, Tomahawk Live Trap Co., Tomahawk, Wisconsin) and a Sherman model XLK (7.64 cm × 9.53 cm × 30.48 cm, H. B. Sherman Trap Co., Tallahassee, Florida). This trapping design was based on the objectives of the capture–recapture program, particularly of evaluating altitudinal differences in species composition and population parameters of small mammals.

Trapped animals were handled quickly with manual restraint. After identification, marking with ear tags (National Band and Tag Co., Newport, Kentucky), and measurement, individuals were equipped with a spool-and-line device that consisted of bobbinless cocoons #5 of nylon thread (approximately 1.7 g and 175 m of thread, Culver Textiles Corp., New York) wrapped in a polyvinyl chloride film with a two rounds of masking tape securing the film (Boonstra and Craine 1986; Miles et al. 1981).

A device was attached to the fur between the shoulders of each individual by using an ester-cyanoacrylate-based glue (Henkel Loctite Adesivos Ltd., Manaus, Brazil). The thread released by the devices allowed mapping of the animal's path. Animals recaptured in the next trapping session had already lost the polyvinyl chloride film and the fur was partially or completely regrown, indicating that the procedure was harmless to the animals. Cocoons were dyed with different colors to facilitate identification of the path of different individuals. Trapping and handling conformed to guidelines sanctioned by the American Society of Mammalogists (Animal Care and Use Committee 1998). The use of spool-and-line devices does not affect survival of small mammals (Steinwald et al., 2006).

Movement measures

Thread released by each animal was tracked and collected the day after capture, except for the first day of the trapping session. On the first day, tracking began at least 4 h after the release of the animal because there were no threads from previous days to track. First-day paths allowed us to determine nest location with certainty, and to evaluate possible differences in movement patterns immediately after release. Nests were marked when found so we could continue tracking the next day.

Animal paths were mapped by polar coordinates (azimuth and distance) taken with a compass and tapeline between points where the animal clearly changed movement direction, or support diameter and slope (when moving in the understory). Change in direction was defined as any alteration

of more than 5° in the animal's path. A clinometer was used to determine the path slope when the animal was moving above the ground. Changes in slope were defined as any alteration of more than 10°. To calculate total movement of an individual, we multiplied total weight of the collected thread by the ratio between total cocoon length and weight. Movements were separated in ground movements (GM) and understory movements (UM). UM were further separated in upward (U) when the individual was ascending, and downward (D) when descending, and horizontal (H) when moving near a horizontal plane.

Statistical analyses

Variables were tested for the Gaussian distribution with the Kolmogorov–Smirnov test. Sexual dimorphism in the relative frequency of GM vs. UM along each path was compared by a two-way factorial ANOVA. The use of relative frequency allowed us to consider all paths tracked, including those paths where the thread broke before reaching the end. Half of the paths were tracked for more than 96.6 m, the median path length tracked. However, the distribution of path lengths tracked was bimodal, with one mode at the interval 70–85 m (15% of the paths) and another at 160–175 m (20% of paths).

Sexual dimorphism in body mass was tested with the unpaired Student's *t*-test with Welch correction for different Standard Deviations using Instat 3.0 (GraphPad Software, Inc.). Kolmogorov–Smirnov test was used to test if the samples followed the Gaussian distribution in the same software.

The number of cases for the diameter and slope of the supports used by individuals varied because of variable length of thread tracked. Female and male cases were organized in frequency histograms, with class intervals defined with the algorithm of Sturges (Vieira 1998). Descending movements were transformed into negative values to contrast the frequency of ascending and descending movements. Frequency histograms were compared between sexes by the Kolmogorov–Smirnov test for data on frequency distributions.

Each use of a support by an individual was treated as an independent statistical event. Availability of supports of different diameters and slopes was highly variable from one point of support use to another, and it was impossible to predict the availability of support diameters and slopes based on the previous point. Thus, points of support use were considered independent in space, and each choice made by an individual also was unpredictable and considered an independent event. Besides, individuals with more events of support measured counted more for the inference of species mean values than individuals that had only a few supports measured.

Results

Of the 157 individuals captured, 45 (28.66%) were equipped with the spool-and-line device 74 times (24 female and 50 male paths). Eighteen (24.32%) of the 74 paths were tracked and mapped in the same day of release. We obtained 1456 measurements of support diameter for males and 684 for females, and 1452 slope measurements for males and 687 for females. Females and males did not differ either in GM or UM (Table 1). Therefore, we pooled movement distances of the two sexes, resulting in 67.38% of GM against 32.52% UM. Body mass of males and females tracked differed significantly ($p = 1.3 \times 10^{-5}$, $t = 4.674$, d.f. = 52). Males weighed on average 76.75 g, whereas females weighed 51.94 g, a 1.48 ratio.

Table 1. Two-way ANOVA comparing frequency of movements of *Marmosops incanus* between forest strata (ground vs. understory) and sex

	SS	d.f.	MS	*F*	*p*
Intercept	30.556	1.000	30.556	899.924	**<0.001**
Sex	0.000	1.000	0.000	0.000	1.000
Strata	3.156	1.000	3.156	92.951	**<0.001**
Interaction sex × strata	0.047	1.000	0.047	1.382	0.242
Error	4.753	140.000	0.034		

Significant values in bold face.

The frequency distribution of support diameters did not differ between females and males with 95% confidence (Komolgorov–Smirnov $\chi^2 = 4.557$) (Fig. 1). However, about 90% of movements were in first class (94.3% in females and 89.4% in males). We redivided the data of the first class in 10 new classes, for both sexes, but again there was no significant difference between sexes (Komolgorov–Smirnov $\chi^2 = 5.3898$).

The frequency distribution of support slopes also did not differ between sexes with 95% confidence (Komolgorov–Smirnov $\chi^2 = 1.3029$) (Fig. 2). Low slopes (0 to 10°) and high slopes (70–90°) were used more frequently in both sexes, corresponding to 51.57% and 54.19% of the slopes of males and females, respectively. Slopes of 10–30° were the least frequently used in both sexes (Fig. 2).

Discussion

Because males and females have clear differences of body size, one could also expect significant differences in the ratio between GM and UM in both sexes. A large size could constrain support diameter and inclination by males, which were on average 1.48 times larger than females in the study area. Movement areas of males also are larger than females, more precisely 1.51 times (unpublished data), similar to the body size ratio. However, this sexual dimorphism did not result in differences in the use of space and supports of the forest. Therefore, within its body size range there is no significant constraint to move above the ground.

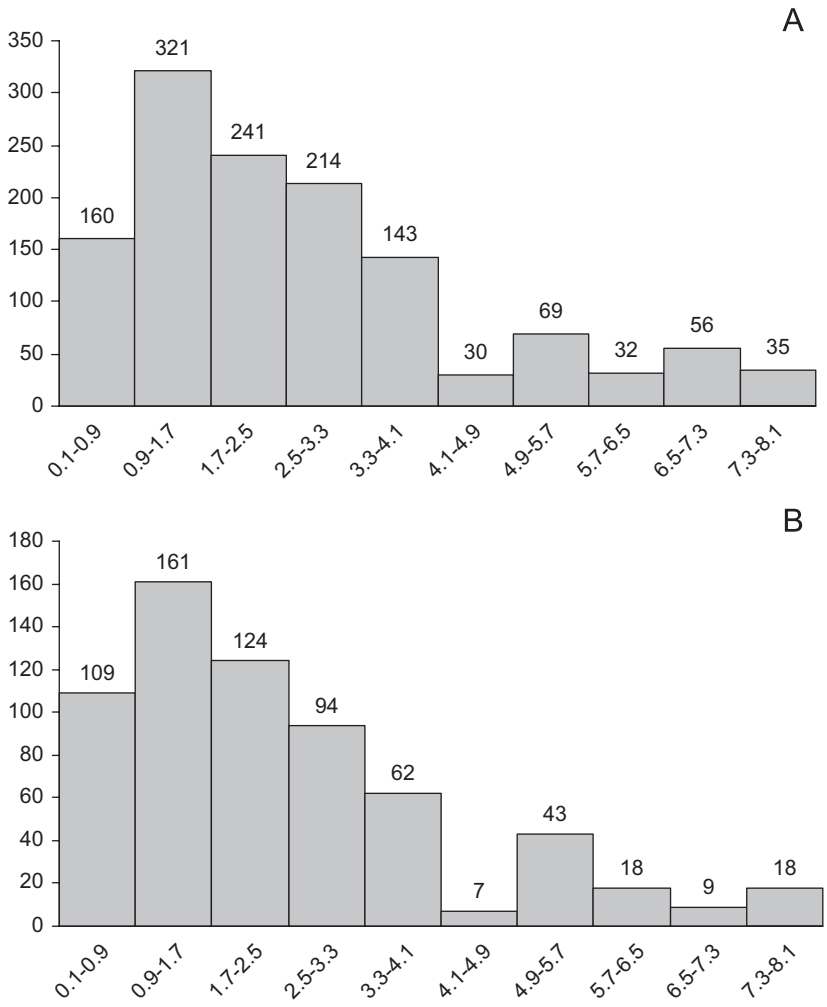

Fig. 1. Diameter of supports used in understory movements of males (A) and females (B) of *Marmosops incanus*. *X*-axis is in centimeters (cm). Numbers above bars are the number of cases for each diameter class.

The body mass of *M. incanus* must be below the boundary of the weight sustained by the branches used, even the thinnest ones (from 0.9 to 1.7 cm).

In interspecific comparisons, however, the effect of body size was significant (Cunha and Vieira 2002). Body size also affected vertical use of forest within *Didelphis aurita* (Cunha and Vieira 2005), a species with a large intraspecific variation in body size (mean body mass ± sd is 1.639,9 ± 372,94 g for males, and 1.304,6 ± 359,08 g for females, Macedo et al., 2007). Therefore, the scale of body size variation within *M. incanus* seems to be below the threshold where body size becomes a significant factor in interspecific comparisons (e.g. Kelt and Van Vuren 2001). The scale of body size variation of *D. aurita* may be right above this threshold.

Individuals of both sexes behaved similarly in the type of supports used regarding slopes and diameters. Males and females used more frequently supports with diameters between 0.9 and 1.7 cm, and seem to prefer to climb up quickly using high slopes until the desired height. Once the height is achieved they perform most of the movements above the ground on horizontal supports. When returning to the ground they use slopes and diameters of support similar to those used previously to climb up.

Other remarkable characteristic was that *M. incanus* is semi-arboreal marsupial, moving on average 67.38% on the ground. This result further support previous observations that *M. incanus* do not use the upper forest strata (Charles-Dominique et al. 1981; Passamani 1995; Cunha and Vieira 2002; Macedo et al., 2007), and more recent field observations of a preference for the lower forest strata to build nests and temporary refuges, usually beneath 2.5 m high (pers. obs.).

When releasing individuals, researchers frequently report *M. incanus* using high slope supports, which lead rapidly to a vantage point above the ground. Without the spool-and-line device this behavior could be easily interpreted as an escape strategy, but the tracking method revealed that it is actually a locomotory

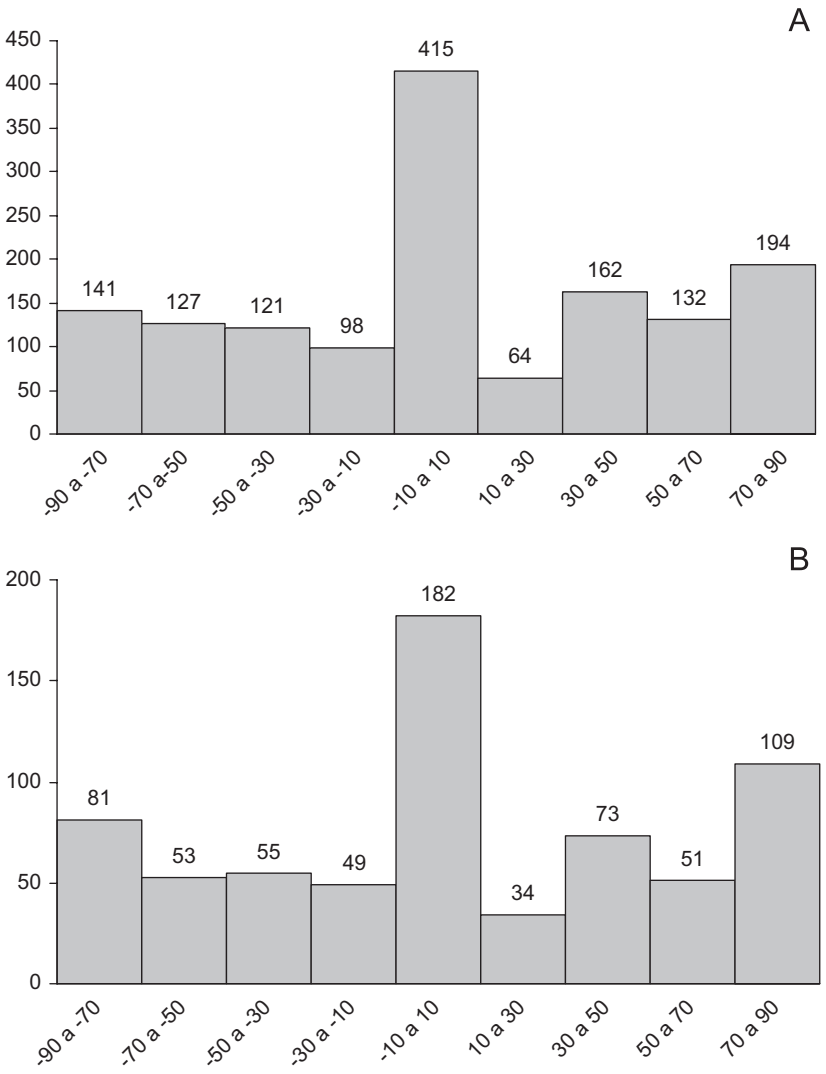

Fig. 2. Slopes of supports used by males (A) and females (B) of *Marmosops incanus* in understory movements. The positive classes represent upward movements (U), and negative classes downward movements (D). *X*-axis is in degrees (from 0 to 180). Numbers above bars are the number of cases for each class.

behavior of *M. incanus* in its daily activities. Going up and down high slope supports could be a tactic to avoid predators or aggressive conspecifics. When moving within the dense crown of understory trees, *M. incanus* can find more protected paths than in upper strata.

Once more, the spool-and-line device has shown to be useful into describing behaviors previously unknown, which could be wrongly interpreted by non-rigorous observations. It has happened with *D. aurita* and *M. nudicaudatus*, also studied in the same study area. Despite leading to unknown features, the method allows more complete understanding of the biology and ecology of a given species, possibly revealing recurrent patterns for related taxonomic groups.

Sexual dimorphism in body size seems to be a general pattern in didelphid marsupials, but it may not affect the vertical use of the forest in small species such as *M. incanus*. The effect of body size on the vertical use of the forest is detectable only on a larger scale of body size variation. It remains to be determined the scale at which body size becomes an important effect on vertical use of the forest. The study of species larger than *M. incanus*, such as species of *Philander* and *Micoureus*, could provide the answer.

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Zusammenfassung

Raumnutzung von *Marmosops incanus* (Didelphimorphia, Didelphidae) im Atlantischen Regenwald Brasiliens

Die Biologie kleiner Beuteltiere ist wenig bekannt, da die meisten Arten nachtaktiv und arboreal sind. Mittels der Spool-and-Line-Methode wurde die vertikale Raumnutzung von männlichen und weiblichen Tieren der Art *Marmosops incanus* im Serra-dos-Órgãos-Nationalpark untersucht. Durchmesser und Neigung der genutzten tragenden Strukturen wurden verglichen. Die Art zeigte geschlechtsspezifische Gewichtsunterschiede: Männchen wogen durchschnittlich 72.6 g, Weibchen im Durchschnitt 48.1 g. Die Geschlechter unterschieden sich jedoch nicht hinsichtlich der Aufenthaltsfrequenz am Boden oder im Unterholz und auch nicht bezüglich Durchmesser und Neigung sie tragender Strukturen. Sowohl Männchen als auch Weibchen verbrachten ca. zwei Drittel der Zeit am Boden und ein Drittel im Unterholz. Der Geschlechtsdimorphismus in der Körpergröße bei *M. incanus* scheint demnach keine Auswirkungen auf die Bewegungen oder Beweglichkeit zu haben.

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