

A radio tracking study of home range and movements of the marsupial *Micoureus demerarae* (Thomas) (Mammalia, Didelphidae) in the Atlantic forest of south-eastern Brazil

Edsel Amorim Moraes Junior^{1,2} & Adriano Garcia Chiarello¹

¹ Conservation, Ecology and Animal Behaviour Group, Programa de Pós-graduação em Zoologia de Vertebrados, Pontifícia Universidade Católica de Minas Gerais. Avenida Dom José Gaspar 500, Prédio 41, Coração Eucarístico, 30535-610 Belo Horizonte, Minas Gerais, Brasil. E-mail: edsel.bhz@terra.com.br; bradypus@pucminas.br

² Corresponding author.

ABSTRACT. From August 2001 to July 2002 the home range and movements of seven *Micoureus demerarae* (Thomas, 1905) (three males and four females) were investigated using radio tracking in the União Biological Reserve, state of Rio de Janeiro, south-eastern Brazil. A total of 436 locations was obtained and home range estimated with fixed Kernel (95% of data points), and minimum convex polygon (MCP) methods, with 100 and 95% of data points. Male home ranges estimated by MCP (100%) ranged from 5.4-24.2 ha and females from 0.3-10.7 ha. Corresponding figures calculated with Kernel (95%) were 4-10.9 ha for males and 1.3-5.9 ha for females. Animals travelled on average 423 m/night, with males travelling significantly further (582.8 m/night) than females (335.1 m/night) (t test, $t = 3.609$, $p = 0.001$). We concluded that radio tracking produced much larger home ranges than those estimated with traditional live-trapping techniques, suggesting that the latter might underestimate ranging when the area covered with traps is relatively small (ca. 1 ha or less). Radio tracking also indicated that *M. demerarae*, although predominantly arboreal and weighting only ca. 130 g., has movements similar in magnitude to larger-sized terrestrial didelphimorph marsupials, such as *Didelphis* Linnaeus, 1758, *Philander* Linnaeus, 1758 and *Metachirus* (Desmarest, 1817).

KEY WORDS. Kernel, minimum convex polygon, radio-telemetry, small mammals, travelling.

RESUMO. A radio tracking study of home range and movements of the marsupial *Micoureus demerarae* (Thomas) (Mammalia, Didelphidae) in the Atlantic forest of south-eastern Brazil. No período de agosto de 2001 a julho de 2002 a área de uso e o movimento de sete *Micoureus demerarae* (Thomas, 1905) (três machos e quatro fêmeas) foram acompanhados, através de rádio-telemetria, na Reserva Biológica União, Rio de Janeiro, sudeste do Brasil. Foi obtido um total de 436 localizações e estimou-se a área de uso através dos métodos Kernel fixo (95% das localizações) e polígono mínimo convexo (PMC), com 100 e 95% das localizações. A área de uso dos machos estimada pelo PMC (100%) variou de 5,4-24,2 ha e fêmeas de 0,3-10,7 ha. Áreas calculadas com Kernel (95%) foram 4-10,9 ha para machos e 1,3-5,9 ha para fêmeas. Os animais locomoveram em média 423 m/noite, com machos se deslocando mais (582,8 m/noite) que as fêmeas (335,1 m/noite) (Teste t; $t = 3,609$; $p = 0,001$). Concluímos que o rádio rastreamento proporcionou áreas de uso superiores ao de estudos tradicionais realizados com capturas em armadilhas, sugerindo que pode haver uma subestimativa quando a área coberta com armadilhas é relativamente pequena (1 ha ou menos). O rádio-rastreamento também indicou que *M. demerarae*, embora seja predominantemente arborícola e pesa cerca de 130 g, possui movimentos semelhantes em magnitude a marsupiais terrestres de maior porte, como *Didelphis* Linnaeus, 1758, *Philander* Linnaeus, 1758 and *Metachirus* (Desmarest, 1817).
PALAVRAS CHAVE. Kernel, pequenos mamíferos, polígono mínimo convexo, rádio-telemetria.

The Didelphidae is one of the most diverse families among extant marsupials, but relatively little is known about the natural history of most species (NOWAK & PARADISO 1991). *Micoureus demerarae* (Thomas, 1905) is nocturnal with adults weighting about 130 g. It is a highly mobile (CHARLES-DOMINIQUE *et al.* 1981) insectivore-omnivore marsupial (LEITE *et al.* 1994); CARVALHO *et al.* 1999) with a predominantly arboreal habit, as demonstrated

by previous studies (CHARLES-DOMINIQUE *et al.* 1981, MILES *et al.* 1981, STALLINGS 1988, FONSECA & KIERULFF 1989, PASSAMANI 1995, PIRES & FERNANDEZ 1999). This specie is widely distributed, being encountered in South America, from Colombia south to Argentina (EMMONS & FEER 1997). Recent taxonomic revisions

suggest that *M. demerarae* is, in fact, a group of seven distinct species, one of which endemic to the centre-south portion of the Atlantic forest (L.P. Costa personal communication). However, since true taxonomic status and nomenclature are still uncertain, we have used here the traditional name *M. demerarae* for this taxon, following GARDNER (1993).

Several studies have been conducted to quantify home range and movement patterns of small mammals, but the majority of these have relied upon the traditional technique of capture-mark-recapture using live traps placed in grids (PIRES & FERNANDEZ 1999) or alternatively, using spool-and-line techniques (MILES *et al.* 1981). Radio tracking, however, is not constrained by limitations in trap numbers, the area covered by traps, or line length and weight. Therefore, it may provide a less biased estimate for important ecological parameters such as home range and movement patterns. With the exception of the study carried out by STALLINGS *et al.* (1994), there are no published results of home range and movement studies of Atlantic forest small mammals based on radio tracking, the main objective of this paper. These data are not only important for a better understanding of the natural history of this species but are also needed to guide conservation strategies of mammals increasingly confined to isolated forest remnants of the Atlantic forest (CONSERVATION INTERNATIONAL DO BRASIL *et al.* 2000). As a second objective, this study compares results based on radio tracking with those obtained using more traditional techniques for small mammals, such as live-trapping.

MATERIAL AND METHODS

Study area

The study was carried out in União Biological Reserve (UBR), a 2,400 ha federal reserve administered by the Brazilian Environmental Agency (IBAMA) and located on the borders of Casimiro de Abreu and Rio das Ostras municipalities, in north Rio de Janeiro state, south-eastern Brazil (22°27'36"S and 42°02'15"W). The main vegetation type is dense ombrophilous forest (IBGE 1993). During the study period the annual rainfall was 1,138 mm, with temperatures averaging 24.5°C. The dry season occurs from April to September, and the wet season from October to March (LAPENTA *et al.* 2003).

Data collection and analysis

Data were collected from August 2001 to July 2002. Wild (and resident) individuals of *Micoureus demerarae* were captured using wire live-traps baited with banana and commercial cod liver oil ("Scott Emulsion"), placed 1-2 m above the ground or in tree platforms, following the methods of STALLINGS (1988) and MALCOLM (1991). Thirty traps were left baited and opened four nights/month during one year, totalling 120 trap-nights per month and 1,440 trap-nights for the whole study. All traps were closed during radio-tracking to avoid influencing movement patterns of individuals being monitored (see below). Captured individuals were anaesthetised (ketamin 10 mg/kg)

and fitted with Wildlife Materials Inc. (model SOM-2190) radio collars. These collars weighted on average 3.5 g, which represents less than 5% of the adult weight of *M. demerarae* and were, therefore, within the weight limits recommended not to disturb the natural behaviour of mammals (COCHRAN 1969). Every marked individual was radio-tracked during four full nights (1800-0600 h) per month, until the death of the animal (natural or predation) or battery exhaustion/equipment failure. A Telonics receiver (model TR-2; frequency: 164-165 MHz), a three-element Yagi antenna and headphones were used for radio tracking. Positions of marked individuals were calculated through triangulation, recording a minimum of three azimuths of each animal every 60 minutes during observation nights. Azimuths were recorded at < 5 min intervals at distances < 150 m from monitored (radio-collared) individuals. These positions were used to calculate the individual's position using the software Locate II (version 1.6, Pacer, Canada). When possible, sleeping places of marked individuals were located and their position mapped. Locations in UTM (Universal Transverse Mercator) coordinates of each marked animal were plotted on scaled (1: 10,000) maps of the area. These data were then analysed using Animal Movement Analyst Extension (AMAE) version 2.0 (HOOGE *et al.* 1999) for Arcview 3.2 (Environmental Systems Research Institute, ESRI, Redlands, California, USA).

For comparative purposes, home ranges were calculated using two methods: the minimum convex polygon ("MCP") (MOHR 1947), and fixed Kernel ("KER") (WORTON 1989). Home ranges calculated with the MCP used either 100% of locations (to allow comparisons with other studies) or 95% of locations, in which the most peripheral points (outliers) were excluded. As pointed out by WHITE & GARROT (1990) using outliers can greatly overestimate home range size, including parts never visited by the individuals. For the same reason 95% of locations were used to calculate accurate home ranges with Kernel. A fixed Kernel was used with bandwidth ("h") chosen as 30 m, as indicated by AMAE software and in accordance with what is believed to be the perception radius of this species (POWELL 2000). Location error was calculated measuring the area of an ellipse formed by the intersection of the three azimuths. Only those location points with an error (ellipse) area < 0.09 ha were considered valid, and included in the analyses. For each marked individual a cumulative curve of home range in relation to monitoring time was constructed, using for these home range estimates based on MCP (100%), following HARRIS *et al.* (1990). We understand that locations collected every 60 minutes might not be considered by some as truly independent observations. We however, agree with other authorities in that sample size is more important than autocorrelation of data points, especially when Kernel is used to estimate a home range (REYNOLDS & LAUNDRE 1990, MINTA 1992, McNAY *et al.* 1994, OTIS & WHITE 1999). We decide, therefore, do not discard important and hard to get biological information in order to accurately map home range details of the study animal.

RESULTS

A total of 436 valid locations of seven adult individuals (four females and three males), monitored during periods lasting from one to five months, were recorded (Tab. I). Interruptions to specific monitoring periods were due to the following circumstances: two individuals were preyed upon (MD-0M and MD-2F); the radio-collar of three others stopped working (MD-3M and MD-5M); one did not function properly (MD-1F); and one individual removed its radio-collar (MD-4F). Thus, only one individual (MD-6F) had to be recaptured at the end of the field study to retrieve its collar and release it back into the forest. The home range of female MD-1F showed stabilization around 100 locations (Fig. 1); for the other females the number of locations was too small to allow strong inference about home range stabilization. Of the three monitored males, two

(MD-0M and MD-5M) reached an asymptote after 40 locations (Fig. 1). In general, home ranges were larger for males than for females (Tab. II) but small sample size hampered statistical comparison between sexes. Using all valid locations (MCP 100%) the home range of males varied from 5.4 to 24.2 ha and females' from 0.3-10.7 ha. Kernel and MCP (both with 95% of valid locations) produced comparable estimates for Males MD-0M and MD-5M and for the female MD-1F, the better sampled individuals. For the remaining, differences between these two methods were higher (Tab. II). Kernel (95%) allowed visualization of the intensity with which each animal used its home range (Figs 2 and 3). Intensively used areas were close to or coincided with nests or resting sites. It was also noticed that home ranges of males had, in general, more than one intensively used area (Fig. 2), while home range of females were more concentrated around a single area (Fig. 3).

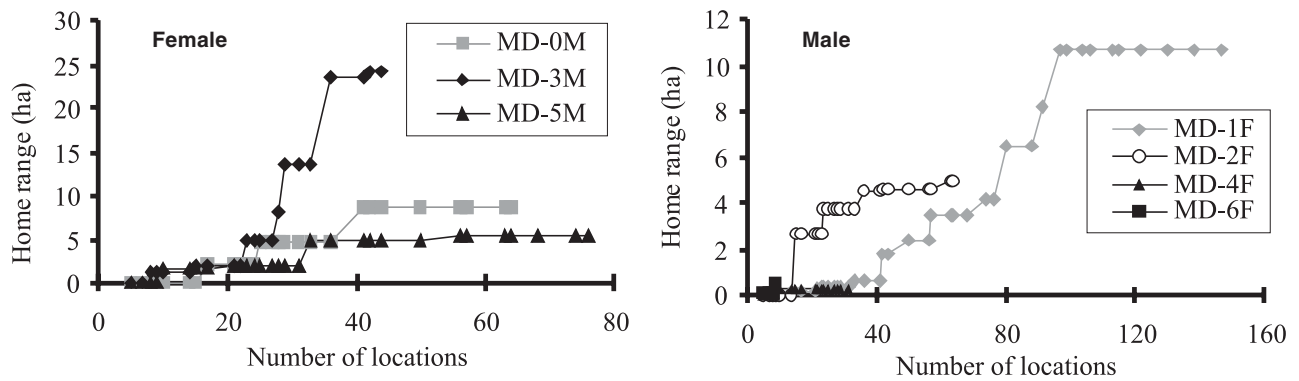
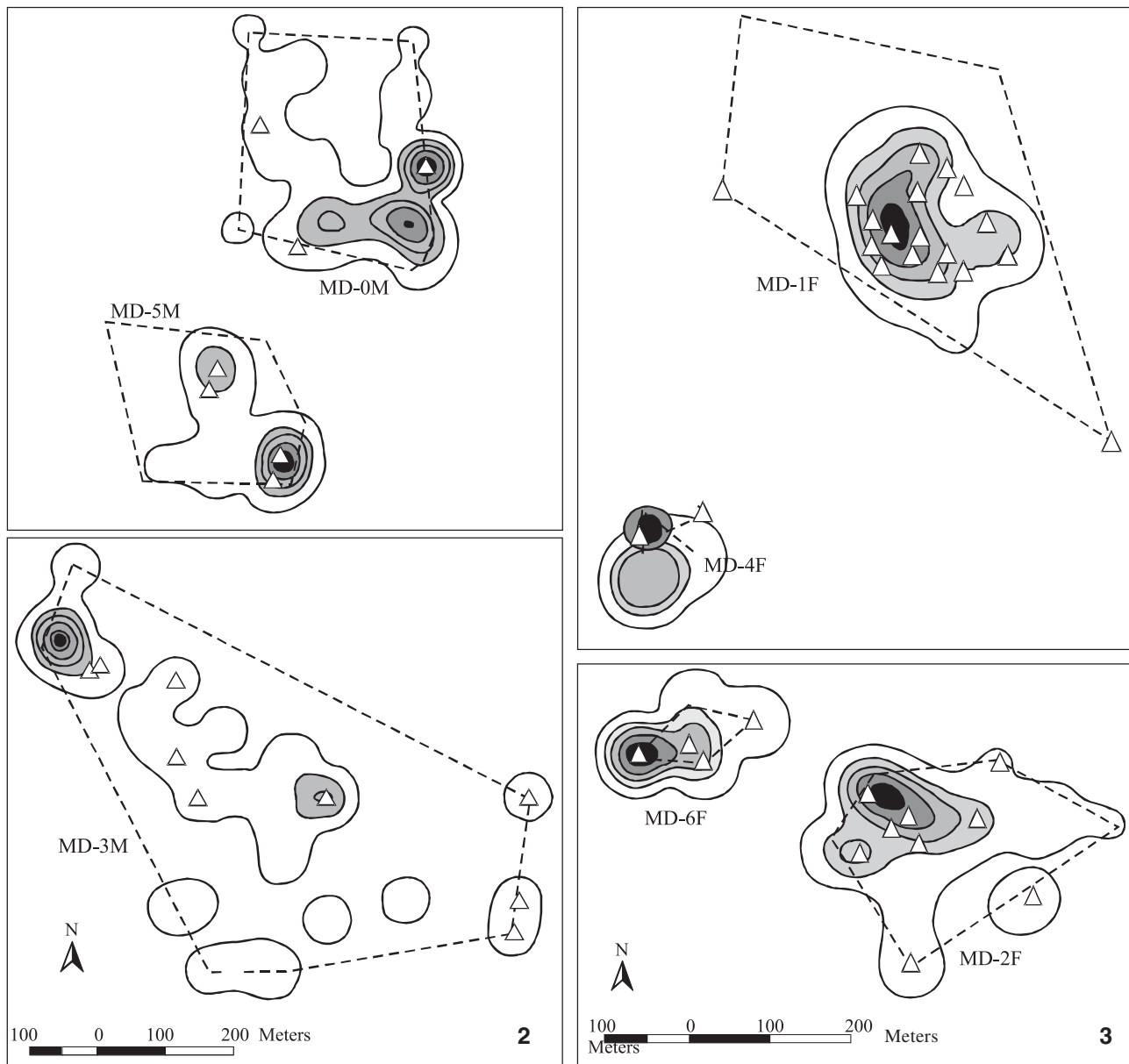


Figure 1. Cumulative curves of home range areas plotted against number of locations for females (A) and males (B). Areas were calculated using Minimum Convex Polygon Method (100%).

Table I. Number of sampled nights, locations recorded and monitoring period for seven radio-tracked *Micoureus demerarae* in União Biological Reserve, south-eastern Brazil.

	Number of nights	Number of locations	2001					2002							
			A	S	O	N	D	J	F	M	A	M	J	J	
Males															
MD-0M ^a	4	64	■												
MD-3M ^b	6	43					■	■	■						
MD-5M ^b	7	76									■	■	■		
Females															
MD-1F ^b	18	147		■	■	■	■	■	■	■					
MD-2F ^a	6	66		■	■	■									
MD-4F ^c	3	31										■	■		
MD-6F ^d	4	9												■	■
Total	48	436													

Circumstances/fate of individuals that caused end of monitoring time: (a) individual preyed upon (carcass and collar found on the ground); (b) radio-collar failure; (c) individual apparently managed to remove the collar (collar found on the ground); (d) individual recaptured to retrieve collar after end of field study.



Figures 2-3. Home ranges of: (2) males MD-0M and MD-5M (above) and MD-3M (below) and (3) females MD-1F and MD-4F (above) and MD-2F and MD-6F (below), calculated by Minimum Convex Polygon method (100%) (straight lines), and fixed Kernel method (contour lines). Concentric contours indicate intensity of use, ranging from 95% (most external contours) to 5% (most internal contour line). Location of nests or daily resting places are indicated by triangles.

As shown in figure 4, there was no home range overlap among males, however, home range of females overlapped between and were contained within home ranges of males. It is important to note that animals were monitored in different time periods and, therefore, not all observed overlaps were, in fact, recorded contemporaneously. For example, home range of the female MD-1F only included the home range of MD-2F

after the latter was found dead (its carcass showed signs indicating predation). Similarly, the female MD-6F was only captured within the area of the other female MD-1F four months after the last contact (radio signal) with MD-1F. Nevertheless, overlapping between the male MD-3M and the female MD-1F was recorded contemporaneously.

Marked individuals moved, on average, 423 m/night

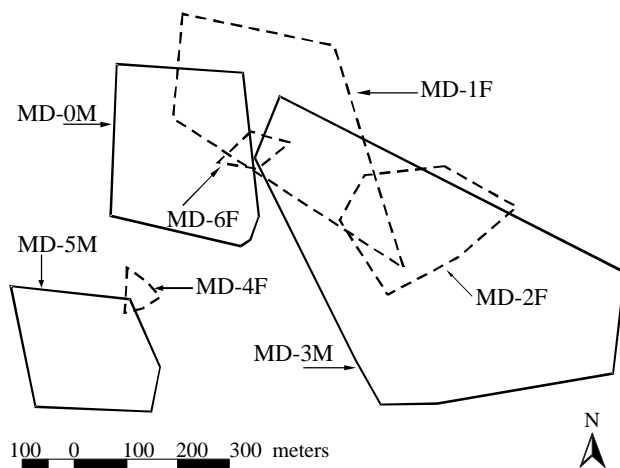


Figure 4. Home ranges of seven *Micoureus demerarae* in União Biological Reserve, south-eastern Brazil, calculated using the Minimum Convex Polygon method (100%). Males are indicated by continuous lines and females by dashed lines.

Table II. Number of locations and home ranges of seven *M. demerarae* calculated using minimum convex polygon (MCP) and Kernel estimators.

Individuals	Gender	Number of locations	MCP		Kernel (95%)
			100%	95%	
MD-0M	male	64	8.5	7.1	7.3
MD-3M	male	43	24.2	21.1	10.9
MD-5M	male	76	5.4	3.2	4.0
MD-1F	female	145	10.7	3.6	4.6
MD-2F	female	66	5.0	4.3	5.9
MD-4F	female	31	0.3	0.1	1.3
MD-6F	female	9	0.5	0.5	2.4

(range = 34-1,140 m/night) (Tab. III) but significant differences were detected between individuals (ANOVA; $F_{[5,41]} = 7.750$, $p < 0.001$). Males and females also differed significantly (t Test; $t = 3.609$, $p = 0.001$), with males ranging, on average, 583 m/night (S.E. = 53 m; range = 317-1,097 m/night) and females 335 m/night (S.E. = 47 m; range = 34-1,104 m/night).

DISCUSSION

The relative stabilization of cumulative home ranges for males MD-0M and MD-5M and for females MD-1F and MD-2F indicate that these estimates can be considered good approximations of true home ranges (HARRIS *et al.* 1990). However, even for the individuals with high number of locations, home ranges here reported should be considered as underestimates of the true areas since they were calculated after monitoring periods lasting less than one full year. It is likely, therefore, that longer

Table III. Sample size (N) and average distance travelled/night of seven radio-tracked *M. demerarae* in União Biological Reserve, south-eastern Brazil. Standard error (S.E.) and range of distances are also shown.

Individual	Gender	N	Distance travelled/night (m)		
			Mean	S.E.	Range
MD-0M	male	4	850	146	491 - 1,097
MD-3M	male	6	472	56	323 - 641
MD-5M	male	7	525	60	317 - 679
MD-1F	female	18	335	56	34 - 1,140
MD-2F	female	6	575	120	265 - 1,068
MD-4F	female	3	198	60	85 - 288
MD-6F	female	4	78	6	61 - 92
Total		48	423	40	34 - 1,140

periods of monitoring would produce even larger home ranges.

The Kernel method was considered to produce the best estimates for home ranges. Besides giving excessive emphasis on external points, ignoring any location information recorded within the perimeter of the polygon, the MCP method might include several localities never actually used or passed by the individual, thus overestimating its home range (KENWARD 2001, KERNOHAM *et al.* 2001). On the other hand, the Kernel method did show areas more intensively used by the animal, illustrating its internal structure. According to KERNOHAM *et al.* (2001), this method offers several advantages: it produces accurate estimates even with location numbers as small as 30; it is less sensitive to lack of independence between locations; it allows for more than one center of activity and is less influenced by external points (KERNOHAM *et al.* 2001). Additionally, the use of programs such as GIS (Geographic Information System) like AMAE for ArcView, greatly improves results due to the high precision with which these programs work (SELKIRK & BISHOP 2002).

It is known that, everything else being equal, larger individuals have larger ranges than smaller individuals because the former need higher absolute amounts of energy and, consequently, have to move greater distances in order to find enough food to satisfy their needs (MCNAB 1963). This may explain why males had larger home ranges than females in this study, since males were heavier (130 g) than females (103 g). An alternative explanation is that in *Micoures demerarae* only females seem to be territorial (PIRES *et al.* 1999, PIRES & FERNANDEZ 1999). If that is really the case, the territory of a female might represent a barrier to the movement of other females, thus restricting their home ranges. The females MD-1F and MD-2F, for example, were monitored simultaneously during September, a period with no overlap between their ranges; the individual MD-1F only "invaded" the home range of MD-2F after the later was preyed upon. However, the contemporaneous overlapping between ranges of MD-3M and MD-1F suggest that males have larger ranges because they might monitor/mate with more than one female.

In another study of *M. demerarae* in south-eastern Brazil (Poço das Antas Biological Reserve, state of Rio de Janeiro), PIRES & FERNANDEZ (1999) estimated home ranges of 0.10-2.45 (males) and 0.10-1.10 ha (females), considering all captures and recaptures of each individual. That study was carried out in a fragmented region where forest remnants are small (1.2 to 13.3 ha in size). It is difficult to believe that differences in ecological parameters, such as forest structure and food resources, might account for the huge discrepancies observed in home range among study sites, which were located in similar floristic and climatic areas of Atlantic forest regions. It seems more reasonable to conclude, therefore, that these differences are rather due to the different methods used and that live trapping might underestimate home range of some species when trap grids cover relatively small areas.

Studies about the movements of small mammals have been conducted using several techniques (MILES *et al.* 1981), however, for the Atlantic forest *Micoureus demerarae* this is the first study using radio tracking. MILES *et al.* (1981) calculated an average distance of 603 m/night for three captured individuals of *Marmosa cinerea* (= *Micoureus demerarae*), a figure similar to the average distances traversed by males in the present study. PIRES *et al.* (2002) observed movements of up to 860 m/day for this species in the Atlantic forest fragments of Poço das Antas Biological Reserve. The larger movement detected in the present study was 1,140 m, similar in magnitude to *Didelphis marsupialis* Linnaeus, 1758 movements recorded by SUNQUIST *et al.* (1987). Using spool-and-line, MILES *et al.* (1981) recorded nocturnal averages of 801 m, 506 m and 438 m/night for *D. marsupialis*, *Metachirus nudicaudatus* (Desmarest, 1817) and *Philander opossum* Linnaeus, 1758 respectively. These figures indicate that *Micoureus demerarae* move equivalent distances to larger-bodied species of marsupials. The high moving capacity of this species is even more impressive when one considers that the other three marsupial species mentioned move mostly on the ground, whereas *M. demerarae* is predominantly arboreal. Arboreal species of marsupials have high rates of metabolism (EISENBERG & WILSON 1981); as a consequence, it is likely that the observed high level of activity and long distances travelled are results of the species need to find enough food to satisfy its relatively high demand for energy.

PIRES *et al.* (2002) recorded four movements of males of this species between isolated fragments. Due to the low frequency of observed movements (recorded via capture-mark-recapture), these authors remarked that subpopulations of each forest fragment are not completely isolated from each other, rather, they function like a true metapopulation (i.e., subpopulations linked by dispersing individuals). In the present study both male (MD-3M) and female (MD-2F) were observed to use a grassland area. These results, together with the large home ranges here reported for the species, indicate that *Micoureus demerarae* is much wider ranging than previously thought. As a consequence, some movements attributed to dispersion might

simply be due to foraging. Therefore, it is recommended that future studies back live-trapping results with telemetry data, as this approach would allow not only a better understanding of home range dynamics but also a more precise analysis of forest fragmentation effects. This approach would facilitate, for example, knowledge on how truly isolated subpopulations of this marsupial are, when inhabiting forest remnants surrounded by grassland or agriculture. On what frequency males and females venture themselves outside forest fragments? What distances are they able to cross in areas dominated by pastures and other open vegetation types? Do they perform this routinely or are these movements really due to dispersion? These and other questions were still not adequately answered, but nevertheless they are essential to the conservation of *Micoureus demerarae* as well as other species of small mammals of the Atlantic forest.

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