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HOMING BEHAVIOR OF *Philander frenatus* (DIDELPHIMORPHIA, DIDELPHIDAE) ACROSS A FRAGMENTED LANDSCAPE IN THE ATLANTIC FOREST OF BRAZIL

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ABSTRACT: We report the first record of homing behavior of a Neotropical marsupial, the opossum *Philander frenatus*. The individual studied returned to the home forest fragment where it was captured (1050 m away) crossing a hostile matrix, instead moving to a much closer fragment (50 m distant). Movements did not follow wind or the direction of the closest fragment, but they were significantly oriented towards the home fragment. The individual probably had previous experience with the release site. This unique observation suggests that the ability of *P. frenatus* to overcome the effects of habitat fragmentation may be higher than considered previously.

RESUMO: Comportamento de "homing" de *Philander frenatus* (Didelphimorphia, Didelphidae) em uma paisagem fragmentada da Mata Atlântica do Brasil. Relatamos o primeiro registro de comportamento de "homing" de um marsupial neotropical, *Philander frenatus*. O indivíduo estudado retornou para o fragmento onde foi capturado (distante 1050 m) atravessando uma matriz hostil, ao invés de se deslocar para um fragmento muito mais próximo (distante 50 m). Os movimentos não seguiram a direção do vento ou do fragmento mais próximo, sendo significativamente orientados para o fragmento de captura. O indivíduo provavelmente tinha experiência prévia com o local de soltura. Este registro sugere que a habilidade de *P. frenatus* de tolerar os efeitos da fragmentação de habitat pode ser maior do que considerada previamente.

Key words. Landscape connectivity. Marsupials. Matrix use. Movements. Perceptual range.

Palavras chave. Capacidade perceptual. Conectividade da paisagem. Marsupiais. Movimentos. Uso da matriz.

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Homing behavior is frequently studied as the ability of an animal to return to its home range after being moved outside of its area of normal activity (Bovet, 1990). Such behavior is relatively well documented for many invertebrates (e.g. Edelstam and Palmer, 1950) and vertebrates (e.g. Marnane, 2000; Avens et al., 2003). In mammals, homing behavior was recorded for several groups (e.g. Henshaw and Stephenson, 1974; Oliver et al., 1998), including small mammals such as voles (Ostfeld and Manson, 1996), squirrels (Bovet, 1995), and mice (Robinson and Falls, 1965). For Neotropical small mammals, however, information is available for two rodent species only, *Proechimys roberti* (Alho, 1980) and *Akodon azarae* (Hodara and Busch, 2006), with no information on homing by didelphid marsupials.

Several potential mechanisms used by homing mammals were suggested, but their actual occurrence remains largely unknown. One conceivable means for returning home would be through random wandering, which was suggested for small rodents (Griffo, 1961; DeBusk and Kennerly, 1975). Potential mechanisms for oriented homing include the direct perception of the home site using vision (Hodara and Busch, 2006), the use of the geomagnetic field for compass orientation (Kimchi et al., 2004), and the use of visual landmarks (Collett et al., 1986).

In fragmented landscapes, information on homing ability may help to evaluate how frequently organisms perform interfragment movements and use the matrix, attributes directly related to population persistence (Laurance, 1991; Viveiros de Castro and Fernandez, 2004). Movements between fragments are important in connecting populations and minimizing the deleterious effects of isolation (Fahrig and Merriam, 1985; Burkey, 1989), whereas matrix use may compensate the effects of habitat loss (Ewers and Didham, 2006; Lira et al., 2007). In the Atlantic Forest of Brazil, interfragment movements and foraging in the matrix were both reported for didelphid marsupials (Pires et al., 2002; Lira et al., 2007). Such movements were frequently longer than species' perceptual range (Forero-Medina and Vieira, 2009), suggesting the existence of indirect navigation mechanisms. Information regarding homing behavior provides insights to understand such mechanisms, and may help to predict species responses to increasing fragmentation.

We report the first record of homing behavior of a Neotropical marsupial, the opossum *Philander frenatus* (Olfers, 1818), in a fragmented landscape in the Atlantic Forest of southern Brazil. *Philander frenatus* is a solitary, nocturnal and medium-sized didelphid marsupial (adult weight ca. 400-600 g). It has semi-terrestrial habits (Cunha and Vieira, 2002) and omnivorous-carnivorous diet (Astúa de Moraes et al., 2003). It is common in forest fragments, and apparently tolerant to the fragmentation of Atlantic Forest (Fernandez and Pires, 2006).

Since 2005 a study on the perceptual range (sensu Zollner and Lima, 1997) of didelphid marsupials is carried out in the Macacu river basin, in the municipalities of Guapimirim (22°2'S, 42°59'W) and Cachoeiras de Macacu (22°28'S, 42°39'W), Rio de Janeiro State, Brazil. The climate is mild-humid-mesotermic (Nimer, 1989), and vegetation is classified as dense evergreen forest ("Ombrófila Densa"; IBGE, 1991). The landscape is characterized by small forest remnants (< 100 ha) structurally isolated by a matrix of urban areas, pastures, plantations, and paved roads (Cabral and Fiszon, 2004).

For the study of perceptual range, adult marsupials are captured in forest fragments, removed, transported to remote locations more than 1 km away, and released in the vicinities of a forest fragment in a matrix composed of either manioc plantations (*Manihot esculenta*) or pasture. The animals receive a spool-and-line device before release to record their movement (Boonstra and Craine, 1986), and are released at various distances from the edge of the fragment. The ability of the marsupials to orient towards the fragment is used as a measure of their perceptual range (Zollner and Lima, 1997). Up to 85 m of the individual paths are recorded in detail with a compass and tapeline, to obtain the orientation and

tortuosity of movements. At the moment of release the directions to the nearest fragment (target), home fragment (where the animal was captured), and wind are recorded.

The *V* test of circular statistics (Zar, 1999) is used to test orientation of the path, which requires independence of azimuths. Spearman's correlations between successive azimuths with various lags are used to determine how many direction changes were necessary for azimuths to become independent. The observed distribution of individual azimuths is then compared to the directions of target fragment, home fragment, and wind using the software Oriana 2.0 (Kovach Computing Services, 2004). Tortuosity of the path is measured with the fractal mean index (Nams, 2005) in the software "Fractal" (Nams, 1996). Fractal mean index varies from 1 (a complete straight path) up to 2 (a path that is so tortuous as to cover a plane).

The homing behavior was detected during the field session of May 9 to 12, 2008. The adult *P. frenatus* was captured on May 9, 2008 in a forest fragment (42º 50' 45.3" S, 22º 33' 26.1" W). It was removed and transported by car over 6875 m to a field base station, without visual contact with the surroundings. The base station was located at 280° from the capture point, 5100 m away (linear distance), where the animal was weighted, measured, and ear-tagged. It was translocated on the same day to the release site, inside an opaque cage to avoid contact with the surroundings. The release site (42° 50' 09.3" S, 22° 33' 43.6" W) was at 160° from the home fragment, 1050 m away. The animal was released in the twilight at 17h40, in an infrequently used pasture with 0.30-0.70 m grasses and shrubs, 50 m away from the nearest point on the border of the target fragment. Three days after, on May 12, 2008, the animal was recaptured in its home fragment, at the same point of the first capture.

To return to its home fragment the animal had to cross a series of landscape elements in the matrix (**Fig. 1**): a 1 m wide flooded ditch, 360 m of infrequently used pasture, possibly

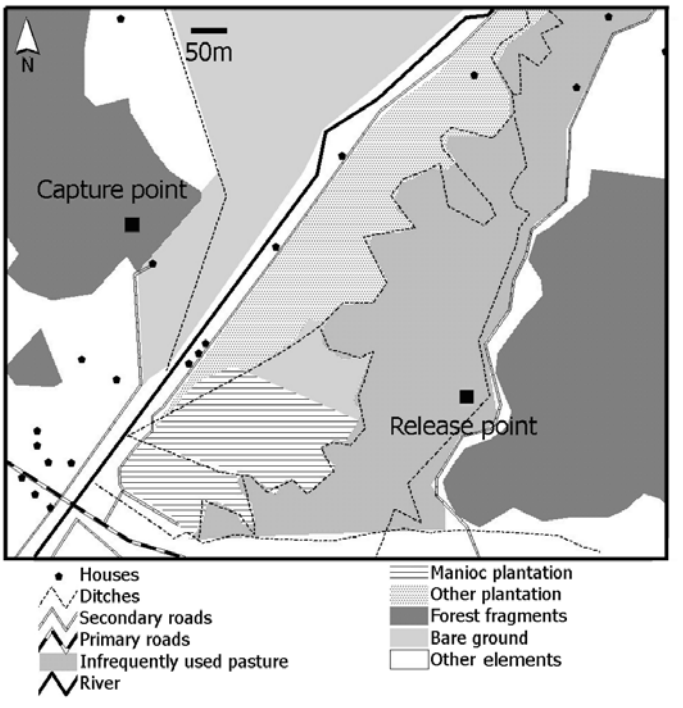

Fig. 1. Landscape elements in the matrix separating the release point and the capture point (home fragment).

200 m of bare ground or 350 m of manioc plantation, another 1 m wide flooded ditch, 90 m of either orange, guava, or bean plantation, a 5 m wide secondary road, a 10 m wide river (Guapiaçu river) on a stretch without any natural or man-made bridges, 50 m of mowed ground, another 1 m wide flooded ditch, and 120 m of mowed soil. These measurements were based on aerial photographs and field observations.

The first 63 m of the individual movement path were recorded in detail with the thread release by the spool-and-line device (**Fig. 2**). The individual moved 17 m on the approximate direction of the target fragment, but then turned backwards, following an oriented path. Azimuths became independent after eight points of direction change. The selected independent azimuths were not biased towards the target fragment (N=9, u=-2.192, P=0.99), or following wind direction (N=9, u=-0.762, P=0.77). However, the animal was significantly oriented towards the direction of its home fragment (N=9, u=1.705, P=0.04). The fractal mean index was 1.11.

Movements among fragments are generally infrequent in didelphid marsupials in the Atlantic Forest (Pires et al., 2002; Lira et al., 2007). The open matrix is probably hostile, offering increased predation risk and little food, shelter and mating opportunities. Therefore, it was surprising that the individual chose to return to the home fragment instead moving to a closer fragment, only 50 m distant. The landscape elements crossed were all open, offering little or no cover, and considerable obstacles to cross. Potential predators were also observed in the matrix, such as humans, domestic dogs, and birds of prey (e.g. *Tyto alba*, *Buteogallus meridionalis*, *Parabuteo unicinctus*).

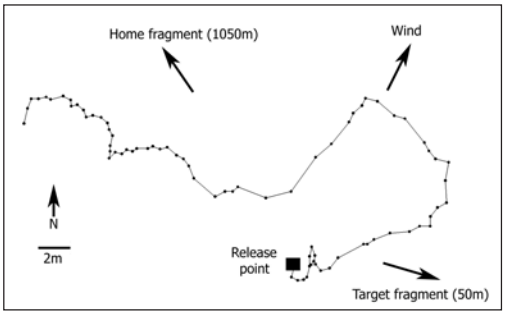

Fig. 2. First 63 m of movement of *P. frenatus* after release during the homing behavior. The points along the path represent changes in movement direction. The directions of home fragment (capture site), target fragment and prevailing winds are showed.

Three general mechanisms may allow an animal to return to its home site (Rogers, 1988): random movements, some form of navigation, or familiarity with the terrain. Our results suggest that the individual studied did not return home by random movements. First, the return time (up to 3 days) may be considered short, given the nocturnal habits of this species and the need to cross a series of obstacles, including 360 m of infrequently used pasture, a dense vegetation that must increase path tortuosity and time to cross a certain distance. Second, other individuals released in the vicinities either oriented to the target fragment or not oriented at all, with no clear directional bias in their movement. Third, the path tortuosity was more similar to oriented than non-oriented individuals released in the same area (unpublished data).

It is unlikely that orientation to the home fragment was based on direct perceptual mechanisms such as visual, olfactory and auditive cues, given the long distance to the home fragment (1050 m). This distance ensured that the home fragment was located outside the perceptual range (100 m) reported for *P. frenatus* in the same region (Forero-Medina and Vieira, 2009). The movement did not follow wind direction either, which could be used to maintain a nearly straight path while looking for habitat, a mechanism reported for the marsupial *Didelphis aurita* in the same landscape (Forero-Medina and Vieira, 2009).

The most likely hypothesis for the observed homing behavior is that the individual had previous experience with the release site. Griffo (1961) suggested that an individual may know during its life an area (called "life range") larger than its home range, by per-

forming occasional exploratory movements outside the home range, and by shifting its position in time. Both alternatives are conceivable for *P. frenatus*. In a fragmented landscape of the Atlantic Forest, the home range of *P. frenatus* ranged from 0.6-7.4 ha, and some individuals had home ranges that encompassed more than one fragment (Lira et al., 2007). Interfragment movement and foraging in the matrix were both reported for *P. frenatus* (Pires et al., 2002; Lira et al., 2007). Therefore, it is possible that an individual of *P. frenatus* may cross distances of 1050 m during its lifetime. The need to cross the Guapiaçu river might not be a problem because species of *Philander* are good swimmers (Hershkovitz, 1997), and are capable of crossing distances of at least 260 m between islands (Boyett et al., 2000).

Regardless the exact mechanism involved, this is the first record of a Neotropical marsupial performing an oriented homing behavior crossing an open matrix. The ability of *P. frenatus* to overcome the effects of habitat fragmentation may be higher than considered previously, and possibly is the main reason in explaining its commonness in the fragmented landscape of Macacu river basin.

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LITERATURE CITED

ALHO CJR. 1980. Homing ability in the wild rodent *Proechnemys roberti* determined by radiotelemetry. Revista Brasileira de Biologia 40:91-94.

ASTÚA DE MORAES D, RT SANTORI, R FINOTTI, and R CERQUEIRA. 2003. Nutricional and fibres contents of laboratory-established diets of Neotropical opossums (Didelphimorphia, Didelphidae). Pp. 229-237, *in*: Predators with pouches: the biology of carnivorous marsupials (M Jones, C Dickman, and M Archer, eds.). CSIRO Publishing.

AVENS L, J BRAUN-MCNEILL, S EPPERLY, and KJ LOHMANN. 2003. Site fidelity and homing behavior in juvenile loggerhead sea turtles (*Caretta caretta*). Marine Biology 143:211–220.

BOONSTRA RE and ITM CRAINE. 1986. Natal nest location and small mammals tracking with a spool and line technique. Canadian Journal of Zoology 64:1034-1036.

BOVET J. 1990. Orientation strategies for long distance travel in terrestrial mammals, including humans. Ethology Ecology & Evolution 2:117-126.

BOVET J. 1995. Homing in red squirrels (*Tamiasciurus hudsonicus*): the importance of going straight. Ethology 101:1-9.

BOYETT WD, MJ ENDRIES, and GH ADLER. 2000. Colonization-extinction dynamics of opossums on small islands in Panama. Canadian Journal of Zoology 78:1972-1979.

BURKEY TV. 1989. Extinction in Nature Reserves: The Effect of Fragmentation and the Importance of Migration between Reserve Fragments. Oikos 55:75-81.

CABRAL DC and JT FISZON. 2004. Padrões sócio-culturais de desflorestamento e suas implicações para a fragmentação florestal: estudo de caso na bacia do Rio Macacu, RJ. Scientia Forestalis 66:13-24.

COLLETT TS, BA CARTWRIGHT, and BA SMITH. 1986. Landmark learning and visuo-spatial memories in gerbils. Journal of Comparative Physiology. A, Neuroethology, Sensory, Neural, and Behavioral Physiology 158:835-851.

CUNHA AA and MV VIEIRA. 2002. Support diameter, incline, and vertical movements of four didelphid marsupials in the Atlantic forest of Brazil. Journal of Zoology 258:419-426.

DEBUSK J and TE KENNERLY J. R. 1975. Homing in the Cotton Rat, *Sigmodon hispidus* Say and Ord. American Midland Naturalist 93:149-157.

EDELSTAM C and C PALMER. 1950. Homing behaviour in gastropods. Oikos 2:259-270.

EWERS RM and RK DIDHAM. 2006. Confounding factors in the detection of species responses to habitat fragmentation. Biological Reviews 81:117-142.

FAHRIG L and G MERRIAM. 1985. Habitat patch connectivity and population survival. Ecology 66:1762-1768.

FERNANDEZ FAZ and AS PIRES. 2006. Perspectiva para a sobrevivência dos marsupiais brasileiros em fragmentos florestais: o que sabemos, e o que ainda precisamos aprender? Pp. 191-201, *in*: Marsupiais Brasileiros: Biologia, Ecologia e Evolução (NC Cáceres and ELA Monteiro-Filho, eds.). Editora da Universidade Federal de Mato Grosso do Sul, Campo Grande.

FORERO-MEDINA G and VIEIRA MV. 2009. Perception of a fragmented landscape by Neotropical marsupials: effects of body mass and environmental variables. Journal of Tropical Ecology 25:53-63.

GRIFFO JV Jr. 1961. A study of homing in the cotton mouse, *Peromyscus gossypinus*. American Midland Naturalist 65:257-289.

HENSHAW RE and RO STEPHENSON. 1974. Homing in the gray wolf (*Canis lupus*). Journal of Mammalogy 55:234-237.

HERSHKOVITZ P. 1997. Composition of the family Didelphidae Gray, 1821 (Didelphoidea: Marsupialia),

with a review of the morphology and behavior of the included four-eyed pouched opossum of the genus *Philander* Tiedemann, 1808. Fieldiana: Zoology, New Series 86:1-103.

HODARA K and M BUSCH. 2006. Return to preferred habitats (edges) as a function of distance in *Akodon azarae* (Rodentia, Muridae) in cropfield-edge systems of central Argentina. Journal of Ethology 24:141-145.

IBGE. 1991. Manual técnico da vegetação brasileira. Rio de Janeiro.

KIMCHI T, AS ETIENNE, and J TERKEL. 2004. A subterranean mammal uses the magnetic compass for path integration. Proceedings of the National Academy of Sciences 101:1105-1109.

LAURANCE WF. 1991. Ecological correlates of extinction proneness in Australian tropical rainforest mammals. Conservation Biology 5:79-89.

LIRA PK, FAS FERNANDEZ, HAS CARLOS, and PL CURZIO. 2007. Use of a fragmented landscape by three species of opossum in southeastern Brazil. Journal of Tropical Ecology 23:427-435.

MARMANE MJ. 2000. Site fidelity and homing behaviour in coral reef cardinalfishes. Journal of Fish Biology 57:1590–1600.

NAMS VO. 1996. The VFractal: a new estimator for fractal dimension of animal movement paths. Journal of Landscape Ecology 11:289-297.

NAMS VO. 2005. Using animal movement paths to measure response to spatial scale. Oecologia 143:179-188.

NIMER E. 1989. Climatology of Brazil. IBGE, Rio de Janeiro.

OLIVER GW, PA MORRIS, PH THORSON, and BJ LE BOEUF. 1998. Homing behavior of juvenile northern elephant seals. Marine Mammal Science 14:245-256.

OSTFELD RS and RH MANSON. 1996. Long-Distance Homing in Meadow Voles, *Microtus pennsylvanicus*. Journal of Mammalogy 77:870-873.

PIRES AS, PK LIRA, FAZ FERNANDEZ, GM SCHITTINI, and LC OLIVEIRA. 2002. Frequency of movements of small mammals among Atlantic Coastal Forest fragments in Brazil. Biological Conservation 108:229-237.

ROBINSON W and JB FALLS. 1965. A study of homing of meadow mice. American Midland Naturalist 73:188-224.

ROGERS LL. 1988. Homing tendencies of large mammals: a review. Pp. 76-92, *in*: Translocation of wild animals (L Nielsen and R Brown, eds.). Wisconsin Humane Society, Milwaukee.

VIVEIROS DE CASTRO EB and FAS FERNANDEZ. 2004. Determinants of differential extinction vulnerabilities of small mammals in Atlantic forest fragments in Brazil. Biological Conservation 119:73-80.

ZAR JH. 1999. Biostatistical Analysis. Prentice Hall, New Jersey.

ZOLLNER PA and SL LIMA. 1997. Landscape-level perceptual abilities in white-footed mice: perceptual range and the detection of forested habitat. Oikos 80:51–60.