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## COMMUNICATION

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## HOME RANGE AND SPATIAL ORGANIZATION BY THE HOARY FOX *LYCALOPEX VETULUS* (MAMMALIA: CARNIVORA: CANIDAE): RESPONSE TO SOCIAL DISRUPTION OF TWO NEIGHBORING PAIRS

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**Abstract:** The Hoary Fox *Lycalopex vetulus*, is a small omnivore-insectivore canid inhabiting open environments/areas of the Brazilian savannah, whose spatial organization and territoriality is still unknown. Space use and social organization of two breeding pairs with adjacent home ranges were determined through radio tracking from October 2002 to April 2003 in a mosaic of cultivated pastures and Cerrado vegetation in eastern Mato Grosso, Brazil. Home ranges were 140–299 ha in size, with individual areas of the male and female in each breeding pair overlapping extensively. After the death of both individuals of one pair, the neighboring pair progressively occupied the vacant space, expanding markedly its range into about half the area originally occupied by the previous pair. Factors driving a pair of Hoary Foxes to expand their territory into a vacant area after death of the neighboring pair were not clearly determined. Absence of territorial defence, however, could have contributed to the range shift observed. This is the first time that the response of neighboring foxes to social disruption of an adjacent pair has been documented for Hoary Foxes.

**Keywords:** Cattle pastures, movement patterns, South American Canidae, territoriality.

**Portuguese Abstract:** Resumo: A raposa-do-campo *Lycalopex vetulus*, é um pequeno canídeo insetívoro-omnívoro que habita ambientes abertos da savana brasileira, cuja organização espacial e territorialidade ainda é desconhecida. Uso do espaço e organização social de dois casais reprodutivos com áreas domiciliares adjacentes foram determinadas através de rastreamento por rádio telemetria de outubro de 2002 a abril de 2003 em um mosaico de pastagens e vegetação de Cerrado no leste de Mato Grosso, Brasil. As áreas de vida tinham 140–299 ha, com áreas individuais de machos e fêmeas de cada par reprodutivo sobrepondo-se extensivamente. Após a morte de ambos os indivíduos de um dos pares, o par vizinho ocupou progressivamente o espaço vago, expandindo marcadamente sua área em cerca de 50% da área originalmente ocupada pelo par anterior. Fatores que levaram um par de raposas para expandir seu território em uma área vaga após a morte do par vizinho não foram claramente determinadas. Ausência de defesa territorial, no entanto, pode ter contribuído para a mudança de área observada. Esta é a primeira vez que a resposta de raposas vizinhas à ruptura social de um par adjacente foi documentada para a raposa-do-campo.

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For Author Details & Author Contribution see end of this article.

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## INTRODUCTION

The Hoary Fox *Lycalopex vetulus*, is a non-cooperative, solitary, small canid (3–4 kg body weight) with a distribution restricted to Brazil (Dalponte 2009). It is classified as a species of Least Concern (Dalponte & Courtenay 2004) for conservation purposes. In a more recent assessment, however, it has been classified as Vulnerable to extinction in Brazil (Lemos et al. 2013).

The Hoary Fox inhabits open areas of Brazil, particularly the herbaceous and sub-shrubland of the Cerrado (Brazilian savannah), transitional areas, and cattle pastures (Dalponte & Courtenay 2004; Rocha et al. 2008). It is an omnivore-insectivore consumer (Dalponte 1997). Although with no morphological adaptations that enable them to gain access to the concealed termite galleries of hard exposed above-ground nests, such as those found in true myrmecophagous mammals, it is an active predator of leaf-feeding termites (Dalponte 1995; Dalponte 1997; Juarez & Marinho Filho 2002; Dalponte 2003; Dalponte & Courtenay 2004; Jácomo et al. 2004; Courtenay et al. 2006; Lemos & Facure 2011). Rich termite patches occur in cattle pastures (mainly above-ground concentrations of *Syntermes* and *Cornitermes* species) along with dung beetles, and these resources are exploited on a seasonal and opportunistic basis (Ferreira-Silva & Lima 2006).

In central Brazil, the Hoary Fox can subsist foraging and breeding in cattle pastures year-round (Juarez & Marinho-Filho 2002; Dalponte 2003; Courtenay et al. 2006). Hoary Fox can reach densities of 1.5 foxes/km<sup>2</sup> (radio tracking; Courtenay et al. 2006).

The Hoary Fox has a monogamous mating system consisting of a reproductive pair with extensively overlapping home ranges (Dalponte 2003; Dalponte & Courtenay 2004; Courtenay et al. 2006). Data on home ranges, spatial organization and territoriality of the Hoary Fox is scarce, and restricted to four studies in central Brazil (Juarez & Marinho Filho 2002; Dalponte 2003; Courtenay et al. 2006; Lemos 2016). Field data on the social behavior of the Hoary Fox, related to temporo-spatial aspects, social interactions and habitat use are limited by few studies (Dalponte 2003; Courtenay et al. 2006; Lemos 2016). The spatial relationship between neighboring pairs of Hoary Fox, however, is still unknown, as well as the factors related to changes in home range size.

Home ranges are relatively confined areas where most animals carry out their daily activities and should be defined relative to a specific time interval (Powell 2000). Home ranges of mammalian carnivores may

vary in size depending on body size (Gittleman & Harvey 1982), and tend to be larger as animal size increases (Ewer 1973). Ranges can also vary according to sex, habitat type distribution and availability (Ross et al. 2012), and productivity of the habitats, as well as food dispersion and availability (Macdonald 1983; Sandell 1989). Considering food availability, for example, ranges may be larger where prey density is lower (Zoellick & Smith 1992), and smaller where food resources are clumped (Eide et al. 2004).

A territory is an area within an animal's home range over which the animal has exclusive or priority use, and it may comprise the animal's entire home range (Powell 2000). Territoriality is an important mechanism by which social carnivores limit or exclude potential competitors of the same species from access to mates, food, space, and cover (Mech 1970; Gese 1998).

Owners of territories usually win territorial disputes against intruders of the same species. Winners in the competition for territories achieve considerable direct and indirect reproductive benefits (Alcock 2005). A territory should provide all the key resources for an individual or group, allowing self-sufficiency within the smallest possible area (Vaughan 1978). Neighbors of the same species represent potential competitors for space, food and partners (Mech 1970; Gese 1998). Territoriality limits the number of animals competing for food resources, mating opportunities and formation of new social groups. Territorial behavior in carnivores includes vocalizations, postures and odoriferous marking at territory boundaries (Brown & Orians 1970; Kruuk 1972; Peters & Mech 1975; Harrington & Mech 1978).

Olfactory communication plays an important role in the social life of carnivores, especially strongly territorial species (Ewer 1973; Macdonald 1983; Gorman & Trowbridge 1989). Urine and feces constitute scent marks used by carnivores and have an advantage over other ways of communicating due to their persistence in the environment, and because they do not require the territory owner to be physically present (Ewer 1973). Scent marking as a form of territorial definition is well established in larger canids such as the Gray Wolf *Canis lupus* and Coyote *Canis latrans* (Allen et al. 1999), but is less well studied in smaller canids.

Among canids, defense of territories is usually conducted by the dominant pair (Mech 1970; Macdonald 1979; Ralls et al. 2007; Darden et al. 2008; Arnold et al. 2011). In the event of social disruption, the absence of these dominant individuals can enable the neighboring pair to attempt to expand into the non-defended area (Gese 1998).

Studies on territoriality in canids indicate that changes on spatial distribution between social units may occur due to shifts in territorial boundaries in response to loss of one or both individuals of the alpha pair (Gese 1998). Data on usurping a vacant territory due to death or abandonment by the original occupants are rarely recorded among canid species due to the difficulty of observing elusive and nocturnal carnivores (Mech 1974; Kleiman & Brady 1978; Gese 1998).

The aims of this study were to describe the home ranges and document patterns of home range overlap of two neighboring Hoary Fox mated pairs, and to document for the first time the responses of neighboring Hoary Fox dyads to removal of an adjacent pair.

## MATERIAL AND METHODS

The social organization of Hoary Fox (Images 1,2) was studied in an area of 6.5km<sup>2</sup> located at Laranjal Ranch, 10km north of Nova Xavantina (14°33'S & 52°23'W; Fig. 1), eastern Mato Grosso State, Brazil. The local landscape consists of patches of Cerrado vegetation in a matrix of cultivated pasture and field crops. Pastures are permanent and composed of introduced, exotic African grasses (*Brachiaria* and *Andropogon*) that

range from 10–80 cm high. The pastures support high densities of leaf-feeding termites consisting of above ground mounds of *Cornitermes* and below ground nests of *Syntermes* (Ferreira-Silva & Lima 2006; Image 3). Every year from November to April, a monoculture crop of soybean dominates part of the landscape, and from May to October the ground remains almost totally exposed, with some grasses and shrubs composing the vegetation. Climate has two distinct seasons: wet (October–March) and dry (April–September), type Aw in the Köppen classification (Alvares et al. 2013). Average yearly rainfall is around 1,600mm (Nimer 1981).

Foxes were captured with leghold traps (coil spring soft-catch foothold traps Victor 1.1 / 2 x 2; Woodstream Corporation, Lititz, Pennsylvania, USA) and immobilized with Zoletil 50® (dosage 0.1ml / kg body weight), measured, weighed, sexed and fitted with very high frequency (VHF) radio transmitters (Telonics, Inc.) weighing about 3% of the animal body weight.

Captures followed the procedures recommended by the American Society of Mammalogy (Sikes & Gannon 2011), and the Brazilian Law Nº 11.794, of 08 October, 2008 which regulates procedures for the scientific use of animals, and were approved by the Brazilian Government (Chico Mendes Institute Biodiversity Conservation - ICMBio / SISBIO's Permanent Collection



**Figure 1.** Study area (black star), 10km N from the municipality of Nova Xavantina, eastern Mato Grosso State, Brazil.





**Image 1.** Uncollared adult male Hoary Fox, *Lycalopex vetulus*, from Nova Xavantina, Mato Grosso, Brazil.



**Image 2.** Radio collared adult female Hoary Fox, *Lycalopex vetulus*, photographed in Nova Xavantina, Mato Grosso, Brazil, on 2003.



**Image 3.** Picture of the study site in Nova Xavantina, Mato Grosso, Brazil, comprising pastures filled with termites' mounds.

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Radio locations were obtained by triangulation from three fixed towers located on internal roads in the study area, using a two-element Yagi antenna. Foxes were monitored an average of three sessions per week,

totaling 66 sessions at dawn and dusk (between 17:00hr and 07:00hr). Triangulations to calculate the location of each individual were made through Trackmaker 12 program, and size of home ranges were compared with 100% and 95% of the locations by the minimum convex polygon (MCP; Mohr 1947). Home range and overlapping areas between pairs were estimated using ArcGIS 9.3 software (ESRI 2010). Additionally, 10 sessions between 08:00hr and 15:00hr were previously conducted to check daytime activity.

All foxes were located during each monitoring bout, yielding up to three triangulations per individual, with an interval of 1.5–2 h between each triangulation.

Two mated Hoary Fox pairs (male M1 and female F1 of pair P1 and male M2 and female F2 of pair P2) with adjacent ranges were followed from October 2002 to April 2003. To better understand changes in size and shape of home ranges of the breeding pairs, we divided the study period into three distinct phases. The first phase comprised the first three months of the study (Phase I: 1 October to 31 December 2002), during which the two breeding pairs (P1 and P2) associated with their offspring and occupied stable areas. The second phase (Phase II: 5 January to 7 February 2003), started with the death of F2, during which M2 alone took care of the puppies. The third phase (Phase III: 9 February to 9 April 2003), began after the death of M2. Urine marking behavior was opportunistically recorded during radio tracking.

## RESULTS

A total of 174 radio locations were obtained for male M1, and 169 for female F1 from 1 October 2002 to 9 April 2003. We obtained 127 radio locations for male M2 from 1 October 2002 to 7 February 2003, and 76 locations for female F2 from 1 October to 31 December 2002.

Pair P2 was monitored for a shorter period because the female F2 was killed by domestic dogs *Canis familiaris* on 5 January 2003 and male M2 died with symptoms of pesticide poisoning on 9 February 2003. Estimated home ranges (MCP 100%) of M1 and F1 were 421ha and 458ha, respectively, and those of M2 and F2 were 401ha and 205ha (Table 1). Estimated ranges of M1 and F1 (95% MCP) were 283ha and 299ha, respectively, and to M2 and F2 (95% MCP) were 204ha and 140ha, respectively (Table 1). Home range size did not differ greatly between individuals, but did differ between different phases of the study (Table 2). The smallest area

**Table 1.** Arithmetic mean home ranges sizes (Minimum convex polygon - MCP 100% 95% and) of four Hoary Foxes *Lycalopex vetulus* (two breeding pairs) from 01 October 2002 to 09 April 2003, at Nova Xavantina, Mato Grosso State, Brazil.

Fox	Monitoring period (days)	Number of locations	Home range MCP (ha) 100% 95%
M1	191	174	421 223
F1	191	169	458 240
M2	130	127	401 200
F2	92	76	205 140

M1 - Male Pair 1; F1 - Female Pair 1; M2 - Male Pair 2; F2 - Female Pair 2

**Table 2.** Home ranges (Minimum convex polygon 95%) of four Hoary Fox *Lycalopex vetulus* (two breeding pairs) analyzed in three distinct phases in Nova Xavantina, Mato Grosso State, Brazil.

Phase	Fox	Monitoring period (days)	Number of locations	Home range (ha)
1	M1	92	83	170.6
1	F1	92	77	190.2
1	M2	92	82	196.7
1	F2	92	76	140
2	M1	130	148	214.6
2	F1	130	125	230.7
2	M2	130	127	204.2
3	M1	191	174	283.7
3	F1	191	169	299.3

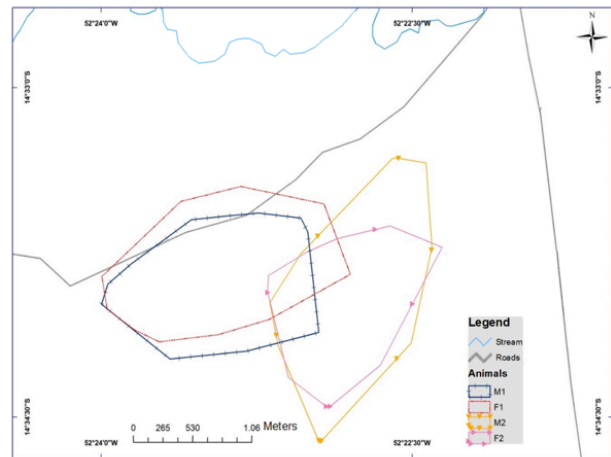
was that of F2 (140ha) in the first phase, and the largest was that of F1 (299ha) in the third phase.

In Phase I, the overlapping area between pairs P1 and P2 was small, ranging from 22ha to 24ha with an estimated average overlap of 13% (Fig. 2 and Table 3). In Phase II, there was an advance of pair P1 over the area of pair P2, ranging from 30ha to 41ha, and an estimated average overlap of 22% (Fig. 3 and Table 4). In Phase III the expansion was substantial, ranging from 68ha to 104ha, and an average overlap estimate of 53% (Fig. 4 and Table 4).

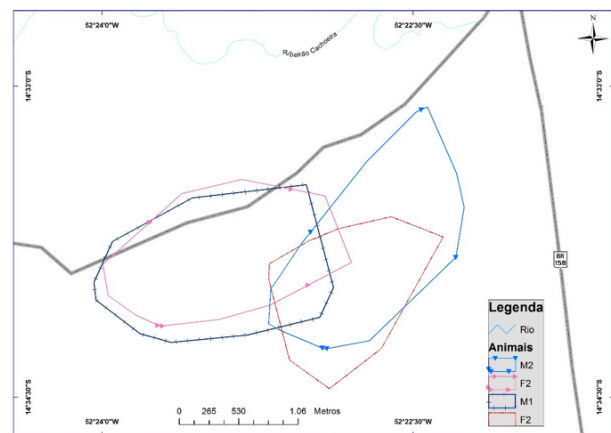
No activity was detected during diurnal monitoring bouts. Foxes exhibited activity after dark, but by the first light of day they were already in their resting sites.

## DISCUSSION

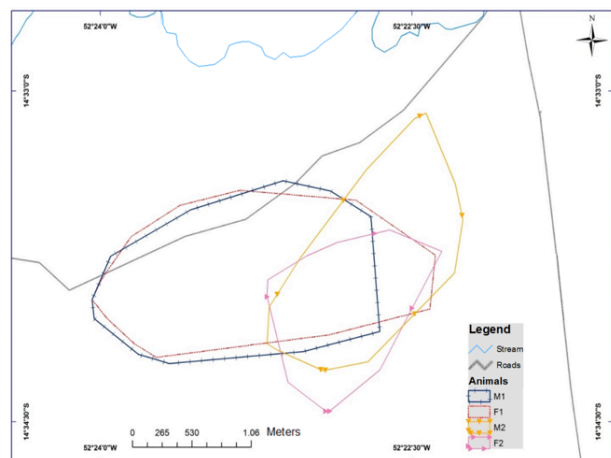
The largest Hoary Fox home ranges described in the present study (140–299ha using MCP 95% were smaller than those reported in previous studies conducted in



**Figure 2.** Home ranges of two Hoary Fox *Lycalopex vetulus* breeding pairs during the first phase of the study (from 01 October to 31 December 2002), with all foxes alive.



**Figure 3.** Home ranges of two Hoary Fox *Lycalopex vetulus* breeding pairs during the second phase of the study (5 January to 7 February 2003), after the death of female F2 of pair P2.



**Figure 4.** Home ranges of two breeding pairs of Hoary Fox *Lycalopex vetulus* during the third phase of the study (09 February to 09 April 2003), after the death of the male M2 of pair P2.

**Table 3. Home range overlap between two Hoary Fox *Lycalopex vetulus* breeding pairs in the first phase of the study (01 October to 31 December 2002).**

Overlap percentages				
Foxes	M1	F1	F2	M2
M1		141ha - 74%	23ha - 16%	23ha - 11%
F1	141ha - 82%		22ha - 15%	24ha - 12%
F2	23ha - 13%	22ha - 11%		135ha - 68%
M2	23ha - 13%	24ha - 12%	135ha - 96%	

central Brazil (Juarez & Marinho-Filho 2002; Courtenay et al. 2006; Lemos 2016). Juarez & Marinho-Filho (2002), using the MPC, but without information on the percentage of the locations used in the calculations, estimated home ranges of 208 and 385ha for a young and a lactating female Hoary Fox, respectively. Lemos (2016), working in Southern Goiás State with a larger sample of individuals (n = 38), estimated an average adult Hoary Fox home range area of 268ha, using 95% kernel density autocorrelation estimator (AKDE) over 392 days.

Courtenay et al. (2006) reported overlapping among a family group of between 420ha and 456ha respectively, using the restricted polygon 95% and grid cell 95% in 12 months from August 1991 to July 1993. Different methods in estimating home range sizes, more extensive tracking periods and more individuals monitored in previous studies, may contribute to the relatively smaller size of the home range areas we reported.

An additional factor influencing the range size of Hoary Fox in our study may be the movement restriction during the reproductive stage, including the period dedicated to raise offspring, when mobility of breeding pairs and family groups may be limited to their natal range (Courtenay et al. 2006).

The Hoary Fox may be able to subsist in cattle pastures by adopting a primarily insectivorous diet throughout the year, consuming large proportions of leaf-feeding termites in the dry season and dung beetles in the rainy season (Ferreira-Silva & Lima 2006). Although arthropods, particularly soldiers and workers of leaf-feeding termites, have low nutritional values for mammals (Redford & Dorea 1984), pastures provide relatively abundant and concentrated resources for Hoary Fox. We hypothesized that these resource concentrations can meet food demands for Hoary Fox all year round and also permit the foxes to use relatively small home ranges.

Factors driving a pair of Hoary Foxes to expand their

**Table 4. Home range overlap between individuals of two Hoary Fox *Lycalopex vetulus* breeding pairs in the second phase of the study (05 January to 7 February 2003).**

Overlap percentages				
Foxes	M1	F1	F2	M2
M1		197ha - 85%	31ha - 22%	30ha - 15%
F1	197ha - 92%		38ha - 27%	41ha - 20%
F2	31ha - 14%	38ha - 17%		
M2	30ha - 15%	41ha - 18%		

**Table 5. Home range overlap between individuals of two breeding pairs of Hoary Foxes *Lycalopex vetulus* in the third phase of the study (9 February to 9 April 2003).**

Overlap percentages				
Foxes	M1	F1	F2	M2
M1		259ha - 87%	68ha - 49%	81ha - 40%
F1	259ha - 92%		92ha - 65%	104ha - 50%
F2	68ha - 24%	92ha - 30%		
M2	81ha - 29%	104ha - 35%		

territory into a vacant area after death of the neighboring pair were not clearly determined. The Hoary Fox exhibit several potential forms of territorial defence (e.g., urine marking, scat deposition, body rubbing, scraping and roar barking; Dalponte 2003). The absence of any of these could have contributed to the changes in the spatial organization.

Although the number of monitored foxes was small, this is the first time that the responses of neighboring foxes to social disruption of an adjacent pair have been documented for Hoary Foxes.

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### Communications

#### Home range and spatial organization by the Hoary Fox *Lycalopex vetulus* (Mammalia: Carnivora: Canidae): response to social disruption of two neighboring pairs

-- Julio C. Dalponte, Herson S. Lima, Stuart Klorfine & Nelton C. da Luz, Pp. 11703–11709

#### People's attitude towards wild elephants, forest conservation and Human-Elephant conflict in Nilambur, southern Western Ghats of Kerala, India

-- C.K. Rohini, T. Aravindan, K.S. Anoop Das & P.A. Vinayan, Pp. 11710–11716

#### Analysis of regurgitated pellets of Spotted Owlet *Athene brama* (Temminck, 1821) (Aves: Strigiformes: Strigidae) from Punjab, India

-- Renuka Malhotra & Neena Singla, Pp. 11717–11724

#### Species diversity and abundance of birds on Bharathiar University Campus, Tamil Nadu, India

-- L. Arul Pragasam & M. Madesh, Pp. 11725–11731

#### On the taxonomy of the first record of rare deep-water rough shark species of Oxynotidae (Chondrichthyes: Squaliformes) in the western Indian Ocean

-- Sarah Viana & Mark W. Lisher, Pp. 11732–11742

#### Forest evergreenness and tree endemism in the central Western Ghats, southern India

-- Divakar K. Mesta & Ganesh R. Hegde, Pp. 11743–11752

#### Distribution of *Rhododendron falconeri* Hook. F. (Ericales: Ericaceae) in Yuksam-Dzongri trekking corridor of Khangchendzonga National Park, Sikkim, India

-- Aseesh Pandey & Hemant K. Badola, Pp. 11753–11759

### Peer Commentary

#### The characteristics, representativeness, function and conservation importance of tropical dry evergreen forest on India's Coromandel Coast

-- Mark Everard, Pp. 11760–11769

### Short Communications

#### Mugger Crocodile *Crocodylus palustris* Lesson, 1831 (Reptilia: Crocodylia: Crocodylidae) in river Saberi of Godavari system in southern Odisha, India: conservation implications

-- Subrat Debata, Swetashree Purohit, Anirban Mahata, Sudheer Kumar Jena & Sharat Kumar Palita, Pp. 11770–11774

#### A new record of the lesser-known butterfly Small Woodbrown *Lethe nicetella* de Nicéville, 1887 (Lepidoptera: Nymphalidae: Satyrinae) from Khangchendzonga National Park, Sikkim, India

-- Sailendra Dewan, Bhoj Kumar Acharya & Sudeep Ghatani, Pp. 11775–11779

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