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ORIGINAL PAPER

Camera-trap studies of maned wolf density in the Cerrado and the Pantanal of Brazil

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Abstract The maned wolf (*Chrysocyon brachyurus*) is threatened by large-scale habitat loss, in particular due to conversion to agricultural land. This is the first published study on maned wolf density and the first test of individual identification from camera-trap photographs. We present results from two Brazilian regions: the Cerrado and the Pantanal. Using capture–recapture analysis of camera-trap data, we estimated densities per 100 square kilometers of 3.64 ± 0.77 individuals at the Cerrado site and 1.56 ± 0.77 individuals at the Pantanal site. Parallel radio-telemetry studies at the Pantanal site showed that maned wolves occupied home ranges of 39–58 km^2 (mean = 50.3 ± 7.67 km^2). Our study in the Cerrado took place in a private farm with a mixture of agricultural land and native habitats, representative of the majority of the present-day Cerrado. Whereas many other mammalian species have suffered in the region, our results show that the maned wolf may cope better with this highly fragmented landscape than one might have feared. Finally, the paper briefly compares maned wolf density with density of puma (*Puma concolor*) in the Pantanal site.

Keywords Brazil · Camera trapping · Cerrado · *Chrysocyon* · Density · Maned wolf · Pantanal · Puma

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Introduction

The savannah-adapted maned wolf (*Chrysocyon brachyurus*) is one of the keystone conservation species of the Brazilian savannahs. The species is threatened by large-scale habitat loss, in particular due to conversion to agricultural land (Fonseca et al. 1994). Around 80% of the original Cerrado vegetation have been lost (Myers et al. 2000), and only about 1.5% of the region are protected (Ratter et al. 1997). The IUCN Canid Specialist Group concludes that population surveys are needed, and that investigations of the suitability of agricultural land as maned wolf habitat are essential (Rodden et al. 2004). This paper addresses both of these aspects.

To the best of our knowledge, no study of maned wolf density has been published before. In order to estimate density of this nocturnal and rarely observed canid we used camera-trapping data combined with capture–recapture analysis. This relatively new method has already proven efficient for a number of elusive tropical mammal species (Karanth 1995; Karanth and Nichols 1998; Noss et al. 2003, 2004; Trolle and Kéry 2003, 2005; Maffei et al. 2004; Silver et al. 2004; Sanderson and Trolle 2005).

This paper presents results from two Brazilian study sites: one in the Cerrado and one in the Pantanal. Our Cerrado study area was a private farm consisting of a mosaic of agricultural land and native habitats, allowing us to assess how the maned wolf is able to cope with the highly fragmented landscape, representative of the majority of the present-day Cerrado region. For the Pantanal site, we were able to compare the camera-trapping results with radio-telemetry data for maned wolf. In addition, we briefly present activity patterns of the maned wolf. Finally, we compare density of maned wolf in the Pantanal site with that of another dominant large carnivore, the puma (*Puma concolor*).

Study areas

The Cerrado study area was the Fazenda Cauaia ranch (headquarters at 19° 28.98′, 44° 01.01′W), Minas Gerais state, approximately 50 km north of Belo Horizonte. The ranch covers 1,760 ha, with 50% cattle pasture and corn plantations and 50% native (although not unaltered) habitats. The main natural habitats were cerrado woodland ('cerradão') (characterized by gnarled, thick-barked trees), dry forest related to limestone outcrops (Brina 1998), and marshes. The original cerradão vegetation has been almost entirely eradicated in the study area; only one island of this habitat remained, however, small woodland patches occurred in many places. All natural habitats were used extensively by the 1,300 head of cattle, which undoubtedly had a substantial impact on the vegetation.

The Pantanal study area (field stations at 16° 42.66′, 56° 01.65′W and 16° 41.20′, 56° 10.49′W) was the 106,000 ha private reserve Estância Ecológica SESC Pantanal, between the Rio Cuiabá river and the tributary Rio São Lourenço, north-eastern Pantanal wetlands, Mato Grosso. It consists of gallery forest, semi-deciduous forest with the understorey dominated by acurí palms (*Scheelea phalerata*), Cerrado woodland, scrubland, and seasonally inundated grassland. Typical of the Pantanal (Trolle 2003), the study area was affected considerably by ranching-related activities such as dry-season fires to promote introduced pasture up until the cattle were removed when the reserve was established in 1998.

Materials and methods

Field methodology

Passive TrailMaster camera-trap equipment was used for the surveys (Goodson and Associates, Inc., Lenexa, Kansas) (Trolle 2003). At both sites, traps covered all major habitats and were set up along either car tracks or animal trails.

In the SESC Pantanal reserve, a camera-trapping area of approximately 54 km^2 was chosen in the north-eastern corner of the reserve. In each of four sub-areas, 14 trapping stations were camera trapped for nine consecutive nights. Trap density was 1 trap/km^2. Two cameras per trap were used (for more details see Trolle and Kéry 2005). At the Cerrado study area, data were obtained during a general survey of large and medium-sized mammals. We used 15 camera traps with single cameras. The methodology outlined in Trolle and Kéry (2003) was followed. Trappers' lure (Pro's Choice, Carman's Superior Animal Lures) was applied to attract carnivores. During the study period, 45 points were camera trapped, covering a minimum convex polygon area of 16 km^2.

In the SESC Pantanal area five adult maned wolves (3 females and 2 males) were captured in wood traps, made according to the specifications supplied by Dietz (1984), fitted with radio collars (Wildlife Materials, Inc.) and monitored for 5–12 months in 2002.

Data analysis

The maned wolf photos were examined to determine characteristics that could serve to distinguish individuals: black markings on legs and face, white tip of tail, tail shape, hair patterns on the flanks, and body structure. We took care to account for the differences in the observed features resulting from differences in camera angle, body position, and lighting conditions. Based on the number of ''captures'' and ''recaptures'' during the survey, it is possible to estimate population abundance using the closed population models of the program CAPTURE (White et al. 1978; Rexstad and Burnham 1991). We assumed that the maned wolf population was closed during the 25–36-day survey periods. CAPTURE provides estimators for seven models that make different assumptions about sources of variation of detection probability, and recommends the model that best fits the data.

To estimate population density, we divided the abundance estimate from the recommended model by the effective sample area that includes a circular buffer around each camera-trap site. We applied two alternative buffers: (1) half the mean maximum distance moved (HMMDM) among multiple captures of individual maned wolves during the survey period (Wilson and Anderson 1985), and (2) the full MMDM (Parmenter et al. 2003). For the Pantanal site, we conducted the same density analysis for puma as described above for the maned wolf (and in Kelly et al. 2004). We used the time information recorded on all camera-trap photographs to evaluate activity patterns for maned wolves. To determine home ranges from radio-telemetry data we used the Minimum Convex Polygon method (Mohr 1947).

Results

At the Cerrado site we obtained 93 maned wolf photographs (31 separate observations), and at the Pantanal site 15 photographs (10 separate observations). Maned

wolves were very interested in the lure used in the Cerrado study, often remaining at the traps for extended periods (2–9 min), photographing both flanks with the single camera. At each site we identified four individuals (Table 1).

In the Cerrado case we considered each night to be an independent sampling occasion and grouped multiple observations of a single individual on the same night. This resulted in a matrix of 18 captures (individual × trap-night) over the 25-day survey period. In the Pantanal case, we pooled the data across the four sub-areas, grouping the first day of trapping in each sub-area to constitute day 1, the second day of trapping in each sub-area to constitute day 2, etc., for a total of 9 sampling occasions. CAPTURE recommended the M(th) model as the one that best fits the Cerrado data, combining heterogeneous capture probability with a differential response over time among individuals. In the case of the Pantanal data, Capture recommended the M(o) model, assuming a constant capture probability for all individuals.

The mean maximum distance moved (MMDM) for the maned wolf individuals was 3.7 km at the Cerrado site and 4.5 km at the Pantanal site. We estimate conservatively that population density is 1.56 ± 0.83/100 km^2 at the Pantanal site (Table 2). Population density is likely to be higher at the Cerrado site, 3.64 ± 0.77/100 km^2, but this estimate is only tentative until a systematic survey covering a wider area can be conducted at this site. Maned wolf activity recorded was strictly crepuscular and nocturnal, with a peak between 18.00 and 03.00. Home ranges for the five maned wolves radio collared in the SESC Pantanal area based on 31–201 locations covered 39–58 km^2 (mean = 50.3 ± 7.67 km^2).

In the Pantanal site we identified three individual pumas from 10 photographs obtained. In one adult male the tail has no black tuft at the end, while faint spotting is also visible on the flanks. A second adult male has a full black tail tuft, as well as a radio-collar. The third individual is a juvenile animal with heavy spotting on its

Table 1 Features used for distinguishing individual maned wolves (a—Cerrado site; b—Pantanal site)

Ind.	ID
(a)	
1	Thin tail with a markedly white tip, and a diagonal marking in the hair pattern on the right flank
2	Grey spots on the face/muzzle, grey/black extending far up on front and hind legs, and a relatively bushy tail
3	Dark lines or parts in the hair where the head joins the neck and where the neck joins the body, a diagonal marking in the hair pattern on the left flank, a tail that is in between the shapes of the tails for individuals 1 and 2, and distinct patterns of black on the legs in comparison with the other individuals
4	Relatively little black on its legs, and a wider/fuller body
(b)	
1	Thin tail with no white, diagonal marking in the hair pattern on the left flank
2	Tail slightly fuller, white tip, kinked
3	Tail fuller, white extends 1/3 of its length from the tip, black on hindlimbs extends above heel
4	Tail fuller, white extends 1/2 of its length from the tip, diagonal marking in the hair pattern on left flank distinct from individual 1

Table 2 Estimation of maned wolf population size and density (a—Cerrado site; b—Pantanal site)

Method	Buffer (km)	Area (km^2)	*N* (SE)	*D* (SE)
Panel a[a]				
HMMDM	1.85	51	4 (0.61)	7.84 (1.47)
MMDM	3.70	110	4 (0.61)	3.64 (0.77)
Panel b[b]				
HMMDM	2.26	134	4 (1.13)	2.99 (2.04)
MMDM	4.53	257	4 (1.13)	1.56 (0.83)

[a] *N* is the number of independent maned wolves in the study area according to the M(th) model

[b] *D* is the estimated number of independent maned wolves per 100 km^2 . N is the number of independent maned wolves in the study area according to the M(o) model

flanks. For the two adult males we recorded MMDMs of 6.5 and 2.5 km, respectively. Density estimates are given in Table 3. Photographic records were concentrated between 17.30–21.15 and 02.30–06.45, overlapping with maned wolf activity patterns.

Discussion

Biological considerations

Camera trapping is a promising new method for conducting density studies of the maned wolf, with no studies of maned wolf density published before. However, various radio-telemetry studies of home ranges have been conducted. For the Cerrado region, the following home-range sizes have been published: 21.7–30.0 km^2 (average 25.2 ± 4.4 km^2; $n = 3$ pairs) in Serra da Canastra National Park (Dietz 1984); 15.6–104.9 km^2 (average 57.0 ± 34.3 km^2; $n = 5$) in Águas Emendadas Ecological Station (Rodrigues 2002); 4.7–79.5 km^2 (average 49.0 ± 31.8 km^2; $n = 5$) in Emas National Park (Silveira 1999), and 75 ± 34.6 km^2 ($n = 3$) in São Paulo (Carvalho and Vasconcelos 1995). In the SESC Pantanal area, home range sizes were 39–58 km^2 (mean = 50.3 ± 7.67 km^2; $n = 5$).

Maned wolves appear to be facultatively monogamous and territories are defended against adjacent pairs, although they may overlap at the boundaries (Rodrigues 2002; Rodden et al. 2004). In the SESC Pantanal area, radio-tracked individuals that were assumed to be mated pairs shared 50–90% of their observed ranges, whereas females with adjacent territories shared only 10–20% and males of adjacent territories only 1% of their ranges.

Table 3 Estimation of puma population size and density at the Pantanal site

Method	Buffer (km)	Area (km^2)	*N* (SE)	*D* (SE)
HMMDM	2.24	133	4 (1.35)	3.01 (1.38)
MMDM	4.48	254	4 (1.35)	1.57 (0.64)

D is the estimated number of independent pumas per 100 km^2 . *N* is the number of independent pumas in the study area according to the M(h) model, the model which best fits the data according to the Capture program

The four individuals identified at each of our study sites may thus represent two pairs whose territories overlap at the edges, or may include subadults and/or floater individuals moving along the boundaries of occupied territories (Dietz 1984). These variables considered, it is difficult to directly compare the home range sizes given above with the densities found in our study areas. Nevertheless, it seems that our results (3.64 ± 0.77 and 1.56 ± 0.77/100 km^2, respectively) reflect a higher abundance of maned wolf than expected, given the altered state of the study areas. However, our density estimates also reinforce the conclusions that large suitable areas are required to maintain viable populations of maned wolves.

The general mammal survey we conducted in the Fazenda Cauaia of the Cerrado region revealed that many of the larger mammal species have either disappeared altogether or become rare (M. Trolle, personal observation). However, the maned wolf seems to be one of the positive exceptions. The maned wolf is an omnivore whose diet consists primarily of fruit and small mammals such as rodents (Rodden et al. 2004). Although the human-induced fragmentation and disappearance of natural habitats has undoubtedly had a negative effect on the small mammal biodiversity, the overall *biomass* of small mammalian prey may still be high, dominated by a few species that are able to exploit the agricultural land. This could be one major factor contributing to the continued well being of the maned wolf. In addition to food, the maned wolves require shelter for their dens, such as shrubs and tall grass (Rodden et al. 2004), and plenty of suitable hideouts are still found in the study area.

In conclusion, it appears that the maned wolf may in fact be able to adapt well to a mixture of agricultural land and natural habitats. Further studies in unprotected areas of the Cerrado, both of maned wolf density and the food availability for the species, are needed to investigate whether the very interesting indications of this study are representative for the Cerrado region as a whole. If this was indeed the case, then the conservation status of maned wolves may be better than previously thought.

Pumas and maned wolves were the two large carnivores recorded in the Pantanal study site (jaguars are known to occur in the SESC area, but seem to prefer the wetter western parts of the reserve). The preliminary data presented here show both spatial and temporal overlap between the two species, and further research is needed to explain how these two sympatric carnivores co-habit. Pumas in turn present population densities significantly lower than those recorded for Chaco and Chiquitano dry forest sites (3–7/100 km^2) in neighboring Bolivia where jaguars are present at densities of 1.5–5/100 km^2 (Kelly et al. 2004).

Methodological considerations

The camera-trapping study at the Cerrado site was designed as a species inventory, not a systematic density study of maned wolves. As a result, the area covered by the camera traps, 16 km^2, was less than the average home range of the species. Noss and Maffei (2005) recommend that the area covered by camera traps be at least 4 times the size of the average home range of the species in question. Even the Pantanal survey covered only 54 km^2, insufficient since home ranges for maned wolves inhabiting this area average 50 km^2. To ensure that our density estimate is conservative, therefore, we have used the largest recommended buffer and the minimum abundance estimate (equivalent in both cases to the number of individuals identified).

The MMDM is used in the camera-trapping surveys as a proxy for home range diameter, and is used to estimate effective survey area in two ways: Wilson and Anderson (1985) recommend applying a buffer of HMMDM around trap sites, whereas Parmenter et al. (2003) recommend applying a buffer equal to MMDM. The smaller the buffer, the smaller the survey area and the higher the estimated population density. The full MMDM of 3.7 km for the Cerrado site coincides with the mean home-range radius (as opposed to the diameter) from the radio-telemetry studies at other Cerrado sites reported above: 3.68 km ± 0.75. In turn, assuming the home ranges described by the telemetry study at SESC Pantanal are circular, then average radius of 3.99 km (± 0.31) coincides roughly with the full MMDM described above of 4.53 km (± 1.03). We therefore recommend using the full MMDM as a buffer, which in these cases corresponds to home range radius. A camera trap survey covering a wider area at each of the sites would serve to confirm the density estimates presented here.

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