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Home range and activity patterns of *Conepatus semistriatus* (Carnivora, Mephitidae) in Emas National Park, Brazil

Gitana Nunes Cavalcanti[1,*], **Luis Diego Alfaro-Alvarado**[1,2] **and Flávio Henrique Guimarães Rodrigues**[1]

[1] Universidade Federal de Minas Gerais, PPG-ECMVS, ICB/UFMG, Av. Presidente Antônio Carlos 6627, Pampulha, CEP 31270-910, Belo Horizonte, MG, Brasil
[2] Instituto Internacional en Conservación y Manejo de Vida Silvestre, Universidad Nacional, Apartado 1350-3000, Heredia, Costa Rica

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Abstract

Skunks (Mephitidae) have not been well studied throughout the Neotropics. In Brazil there is a general lack of data on the ecology, behavior, distribution, systematics, morphology and biogeographic patterns of the two species occurring in the country (*Conepatus semistriatus* and *C. chinga*). The focus of this study was on understanding the home range and activity patterns of *C. semistriatus*. Field research was conducted in the Emas National Park, where three skunks with radio-collars were located on 157 separate occasions. The observed patterns of activity indicate that the species is predominantly nocturnal, with a great expenditure of time on foraging. Temperature had a direct influence on the animal's behavior, but there was no apparent influence of light on activity patterns. Average home range areas were $1.39 \pm 0.87\ km^2$ (Minimum Convex Polygon method) and $0.69 \pm 0.25\ km^2$ (Local Convex Hull method). There was high home range overlap between individuals, $0.27\ km^2$ based on the Minimum Convex Polygon method, at sites with easy access to resources.

Keywords

Carnivora; Cerrado; *Conepatus semistriatus*; ecology; telemetry

Introduction

In South America, according to Dragoo et al. (2003), three species of the Genus *Conepatus* are recognized: *C. humboldti* (Gray, 1837), *C. semistriatus* (Boddarert, 1785) and *C. chinga* (Molina, 1782). The latter two have been recorded in Brazil. Very little information is available in the literature regarding the basic ecology of

*) Corresponding author; e-mail: gitanacavalcanti@yahoo.com.br

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skunk species in the Neotropics (Sunquist et al., 1989). Indeed, there is a general paucity of data on the ecology, behavior, distribution, systematics, morphology and biogeographic patterns of these species (Eizirik et al., 2006; Oliveira, 2006). Even the taxonomic validity of the two species occurring in Brazil was being questioned until recently, when genetic data supported the split (Kasper et al., 2009).

The geographic distributions of *C. semistriatus* and *C. chinga* remain unknown, and according to Oliveira (2009), should be considered a top research priority in Brazil. In North America, other species of the skunk Family Mephitidae have received greater attention because some of them may be vectors for rabies (Wade-Smith & Verts, 1982), and in some rare instances cause crop damage (Olson & Lewis, 1999), while other species have shown dramatic population declines (Gompper & Hackett, 2005). For species occurring in South America, data on activity patterns, home range and habitat use (Donadio et al., 2001; Kasper et al., 2009; Reppucci et al., 2009; Kasper et al., 2012b), diet (Travaini et al., 1998; Donadio et al., 2004; Montalvo et al., 2008), and abundance (Kasper et al., 2012a) have been collected for *C. chinga*. Also, Johnson et al. (1988) discussed the influence of seasonal changes on the activity patterns of *C. humboldti* and assessed the home range area of this species in Chile. However, the information available for *C. semistriatus* is even more limited, as only two studies have reported any ecological data, including an estimate of the species' home range in the llanos of Venezuela (Sunquist et al., 1989) and a more recent analysis of its activity patterns in Costa Rica (Gonzalez-Maya et al., 2009) based on camera trapping data.

This general lack of information about Mephitids in Brazil requires the realization of basic studies on behavior and ecology on these species, particularly to clarify the differences between them. Although there is no specific information regarding population sizes, *C. chinga*, which occurs in southern Brazil, appears to be abundant. Based on track logging data, it also seems that *C. semistriatus* is not rare, although it has not been readily observed at most localities where it is known to occur. Emas National Park, located in central Brazil, is an area where the species is considered easily observable. The aim of the current study was to acquire new information to help create a more realistic profile of the basic ecology of *Conepatus semistriatus*. Specifically, the study focused on determining the typical home range and activity pattern of this understudied species.

Methods

Study area

The current study was conducted at Emas National Park (PNE; 18°19′S-52°45′E, fig. 1), an area of 132 000 hectares that crosses the boundary of two states in Brazil and includes the municipalities of Mineiros-GO, Chapadão do Céu-GO and Costa Rica-MS. The local climate, according to the Köppen system of classification, is best described as type AW, characteristic of typical tropical moist climates, with two distinct seasons: a dry winter and a humid summer. The dry season is quite

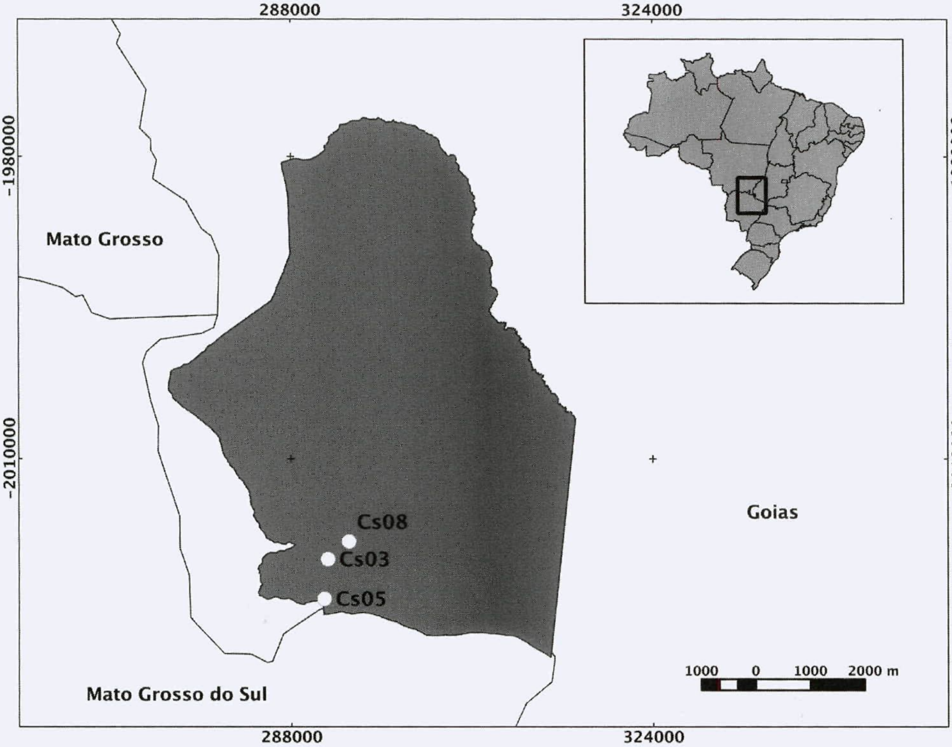

Figure 1. Location of Emas National Park in central Brazil, and the sites where individual *Conepatus semistriatus* were captured (Cs03, Cs05 and Cs08).

pronounced, with very low levels of rainfall (less than 60 mm) between April and September, while annual rainfall in the study area ranges from 1500 to 2000 mm (IBAMA, 2004).

PNE is composed of ten distinct vegetation types: Riparian Forest, *Campo Úmido*, *Campo de Murunduns*, *Vereda*, Mesophytic Interfluvial Forest, *Campo Limpo*, *Campo Sujo*, *Campo Cerrado* and *Cerrado "sensu stricto"* (IBDF/FBCN, 1981). The dominant vegetation type in the region is *campo sujo*, which characterizes nearly 95% of the total area of PNE (Silveira, 2004).

Capture and marking

The current study was conducted between the months of May and November of 2009. We located *C. semistriatus* individuals by driving the main roads running through Emas National Park at night and scanning the vicinity with a sealed beam spotlight. We also captured individuals in administrative headquarters of the park and the visitor's entrance area (Portão Bandeira). When an animal was spotted, it was pursued and captured using a dip net. Captured animals were then sedated with an injection of Zoletil® 50 mg (Virbac; tiletamine hydrochloride and zolazepam hydrochloride), total dosage of 8.89 mg/kg for each individual, and standard biometric measures were taken from the body, head, tail, ears, front and back legs. We also recorded the gender, reproductive status and weight of each individual. The captured animals were also classified to their appropriate age category as a cub, juvenile, sub-adult and adult, according to a combined assessment of tooth wear and body size. This entire protocol was pre-approved by the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA, license number 15500-1, certified on 28/11/2008).

A total of eight individuals were captured and processed. Three of these animals were fitted with radio-collars (model #1820, 27 g, ATS – Advanced Telemetry Systems, Isanti, USA) equipped with activity and mortality sensors operating in the 164 MHz frequency range. The other 5 captured individuals were considered too young and/or the ratio of their neck circumference to skull length was too small ($\leqslant$0.5 cm) to allow them to be safely fitted with radio collars without the potential risk of losing the device and/or physically harming the animal in some way. After the animals were processed and allowed sufficient time to recover from the sedative, gauged by the return of normal reflexes within 1 h 10 min to 1 h 40 min, they were released in the same area where they had been captured.

Radio-telemetry and monitoring

The three individuals outfitted with radio-collars were monitored daily during seven months. The individuals were located once a day, for home range calculation, with a minimum period of 12 hours between locations. Additional locations, in distinct times along the day, were made to determine activity schedule. We detected the telemetry signals, emitted by the radio transmitter in the form of pulses, by using a receiver with an antenna. Upon detecting a signal, the precise location of each individual was determined by using the "homing-in" technique (White & Garrott, 1990). Monitoring and signal detection efforts were conducted during both daytime and nighttime, attempting to achieve an acceptable proportionality between these periods. A handheld GPS device (Garmin 12XL) was used to register the exact geographic coordinates each time an animal was successfully located.

Home range and overlapping

We used the RStudio program (Copyright © 2007 Free Software Foundation, Inc. http://fsf.org/) and the software package "adehabitatHR" to calculate home range, accumulation of location events, home range area overlap and distance between locations on consecutive days, assuming the independence of individual location events with only one registered location every 24 hours. Analyzes of home ranges and areas of overlap were performed according to the Minimum Convex Polygon method (MCP; Mohr, 1947), with 95% of locations, and using the Local Convex Hull method (a-LoCoH; Getz & Wilmers, 2004; Getz et al., 2007; Campos & Fedigan, 2009). In Adaptive LoCoH, hulls are created from the maximum number of nearest neighbors such that the sum of their distances from the root point is less than or equal to the spatial scale and sample size of the data set. The accumulation curve of locations was calculated from 100% of the events by employing the MCP method.

Activity patterns

The activity pattern for each individual with a radio-collar was inferred from its overall activity log at different times of the day. Activity was determined by small variations in movement of the radio signal. That is, when a radio signal was detected in an irregular spatial manner, the animal was considered active, while a regularly detected signal suggested that the animal was in repose. These data were then grouped into four distinct time periods (8:00 to 13:59; 14:00 to 19:59; 20:00 to 01:59; 02:00 to 07:59). The frequency of activity was estimated by dividing the number of records for when the three individuals being monitored were active, by the total number of records per hour. Values for the ambient temperature during monitoring periods were obtained from data collected by a meteorological station located within the park, so that the average temperature for each hour could be calculated. A Chi-square test was used to detect any correlations between periods of activity and temperature, and between the onset of activity with nightfall. These statistical analyses were performed using the program R version 2.10.0.

Results

We successfully captured and fitted 2 adult male (referred to as Cs03 and Cs05) and one sub-adult male (Cs08) *C. semistriatus* individuals with radio-collars. We subsequently re-located these animals 533 times during radio telemetry monitoring efforts and analyzed 251, 197 and 85 activity records for the individuals Cs03, Cs05 and Cs08, respectively.

Home range

The mean home range of the three radio-collared individuals, obtained by 95% MPC, was 1.39 ± 0.87 km^2, while the mean home range, obtained from a-LoCoH, was 0.69 ± 0.25 km^2 (table 1). The average distance between successful localizations of each individual on consecutive days was 425 ± 482 m, 597 ± 380 m and 1024 ± 888 m for Cs05, Cs03 and Cs08, respectively.

Bi-nucleated home range areas were detected for individuals Cs03 and Cs08, and three core areas for Cs05. There was overlap in home range area between Cs03 and Cs05, with 0.27 km^2 (MCP 95%). Besides those monitored, four other skunks, one female and three males, were also captured and other individuals were observed in the same areas. Cs07 was captured within the boundaries of the home range of Cs08, an area that corresponds to the southern extent of the park.

Table 1.
Estimates of *Conepatus semistriatus* home range in Emas National Park, according to Minimum Convex Polygon (MCP 95%) and a-LoCoH.

Individual	Age group	*N*	Estimated home range area (km^2)	
			MPC 95%	a-LoCoH
Cs03	Adult	65	1.18	0.78
Cs05	Adult	61	0.63	0.41
Cs08	Sub-adult	31	2.34	0.89
Average ± SD			1.39 ± 0.87	0.69 ± 0.25

N indicated number of successful re-locations; SD indicates standard deviation.

Activity patterns

The skunks monitored here were predominantly nocturnal, with the onset of their peak activity period at twilight. These individuals were active 100% of the time when sampled at 21:00, 23:00, 01:00 and 06:00 (fig. 2).

There was no significant relationship detected between the onset of nocturnal activity with the time of sunset (Cs003: $z = -0.165$, $df = 47$, $P = 0.869$; Cs005: $z = -0.883$, $df = 50$, $P = 0.377$; Cs008: $z = -0.901$, $df = 10$, $P = 0.368$). Rather, animals became active up to 1 hour before sunset. We observed greater vari-

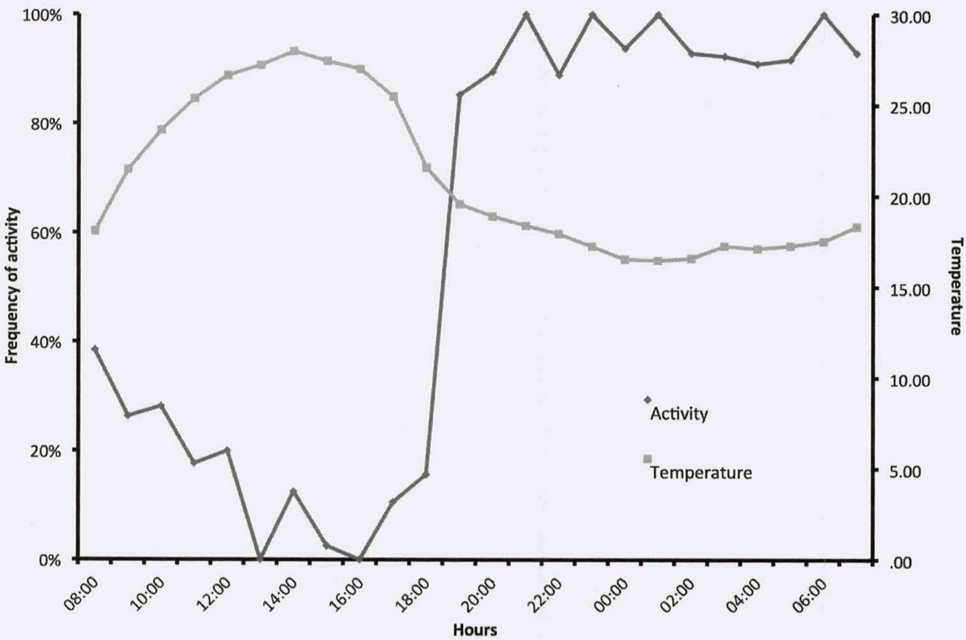

Figure 2. Daily activity pattern (black line) and average temperature (gray line) per hour of *Conepatus semistriatus* in Emas National Park in central Brazil.

ation in the timing at which the animals entered into resting periods, which in some cases extended for up to three hours of continuous activity after sunrise. In general, however, these animals were active for up to 14 hours with very few periods of rest during the night and diurnal activity was only occasionally observed.

The activity periods of these individuals was directly related to ambient temperature (Cs03: $z = -7828$, $df = 248$, $P < 0.0001$; Cs05: $z = -7157$, $df = 195$, $P < 0.0001$; Cs08: $z = -4546$, $df = 82$, $P < 0.0001$), such that as temperature decreased, their frequency of activity was greater.

Discussion

Home range

Information about the home range of *Conepatus semistriatus* is scarce. In the present study, we found the average home ranges of three radio-collared individuals to be 1.39 ± 0.87 km^2 (MCP 95%) and 0.69 ± 0.25 km^2 (a-LoCoH). Our estimates are more than double the largest previously estimated home range for the species, also using MCP, whereby Sunquist et al. (1989) determined the home range area of their subjects in the Venezuelan llanos to be 0.18 km^2 in the wet season and 0.54 km^2 in the dry season. There is little information available regarding the home ranges of other Mephitid species in South American, aside from a few area estimates ranging from 1.95 to 0.55 km^2 for *C. chinga* (Donadio et al., 2001; Reppucci et al., 2009; Kasper et al., 2012a) and 0.09 to 0.16 km^2 for *C. humboldt* (Fuller et al., 1987; Johnson et al., 1988), which are summarized in table 2. Different methods, different ecological requirements of each species, the relative abundance of

Table 2.
Home range areas for three *Conepatus* species in South America, according to the Minimum Convex Polygon method (MCP).

Species	Country	Gender	MCP (km^2)	Reference
Conepatus semistriatus	Venezuela	F	0.18 and 0.54	Sunquist et al., 1989
	Brazil	M	1.18 ± 0.66	This study
Conepatus chinga	Brazil	M	1.65 ± 0.59	Kasper et al., 2012b
	Brazil	F	0.55 ± 0.36	Kasper et al., 2012b
	Argentina	–	1.09	Reppucci et al., 2009
	Argentina	M	1.95	Donadio et al., 2001
Conepatus humboldt	Chile	F	0.164	Fuller et al., 1987
	Chile	M[1]	0.116	Fuller et al., 1987
	Chile	F[1]	0.09	Fuller et al., 1987
	Chile	M[1]	0.138	Johnson et al., 1988
	Chile	F[1]	0.146	Johnson et al., 1988
	Chile	F	0.11	Johnson et al., 1988

[1] Juvenile.

resources and the degree of environmental disturbance where each population is located, may all have an influence on this variation.

We observed a great deal of overlap among the home ranges of individual skunks captured in Emas National Park during the current study. The administrative headquarters of the park and the visitor's entrance area (Portão Bandeira) were continuously frequented by the individual skunks monitored. Besides, the presence of other not-monitored individuals has been observed in the same sites. These locations may be characterized as significant food source areas, regularly used by animals that are tempted by the presence of trash dumpsters and electric lights that attract insects. Individual *C. semistriatus* were regularly seen consuming avocado (*Persea americana*) and mulberry (*Morus* sp.), both of which are exotic species commonly found in the more intensively used areas, such as near the park headquarters and entrance. Skunks are well known opportunistic foragers (Rosatte, 1987; Travaini et al., 1998; Cantú-Salazar et al., 2005), and behavior of the *C. semistriatus* individuals that we observed in Emas National Park was consistent with this generalization.

The largest individual home range area recorded in Emas National Park was estimated for a sub-adult male. Additionally, this same animal displayed the greatest distance between consecutive location events, demonstrating that this individual was active throughout a major portion of the park. Unlike the monitored adults that were observed frequenting the administrative headquarters in search of easy access food resources, the sub-adult male individual did not focus any of its activity on the entrance area of the park, which also presented readily available food resources. Thus, the greater degree of movement by this particular individual may be a direct reflection of the higher energy requirements of younger individuals, as was also observed in *C. humboldti* (Johnson et al., 1988). Furthermore, variations in home range area may also be attributable to other limiting factors, such as habitat availability, searching for a suitable mate during the breeding season and dietary preferences (McNab & Morrison, 1963; Erlinge & Sandell, 1986; Sandell & Liberg, 1992; Gehring & Swihart, 2004; King & Powell, 2007). The home range area of this particular sub-adult male, although apparently stable during our monitoring period, could potentially be even greater than what was registered here. As suggested by Rabinowitz (1997), there is need for caution in interpreting the cumulative curve of re-location events, which may vary according to seasonality, the time of day an animal is located and the duration of monitoring. Besides the relatively short time periods spent monitoring this individual during the current study, there were some days when the subject was not located at all, and large distances between events were observed when it was successfully located on consecutive days. These considerations suggest that the true home range area of this particular animal may have been underestimated.

We would not expect a great expansion in the home range area estimates for the other individuals that were monitored during the current study, despite observing a small increase in their location accumulation curves. These particular animals are older and possibly more likely to remain stable or show a decrease in their home ranges over time, since the energy requirements to protect a smaller territory is lower, not to mention the physical limitations of efficiently searching for food resources over a larger area (Lindstedt et al., 1986).

Activity

Conepatus semistriatus is a predominantly nocturnal carnivore and initiates its peak activity period at dusk, corroborating the observations of other researchers (Sunquist et al., 1989; Emmons & Feer, 1997; Silveira, 1999; Gonzalez-Maya et al., 2009; Cheida et al., 2011). Principally nocturnal behavior has also been observed in other Mephitid species, which are distributed throughout the Americas (Johnson et al., 1988; Lucherini et al., 2004). The preference for nocturnal activity shown by *C. semistriatus* in Emas National Park may be directly influenced by thermoregulatory constraints, a situation that has been observed in other carnivore species (see Brady, 1979; Dalponte, 2003). Indeed, the current study found a significant relationship between ambient temperature and the activity levels of individual *C. semistriatus*. The study area is characterized by extreme variations in temperature, being very hot during the day (>30°C) and declining by as much as 10°C to reach much cooler temperatures at night. During evening hours the temperature is much milder, such that the risk of dehydration is decreased and it is less physiologically demanding for these animals to be most active at this time. During the day, when the temperature rises considerably, these animals tend to remain at rest, finding shelter in cool burrows where it is more efficient to maintain normal body temperature and minimize water loss.

Despite the clear preference for nocturnal behavior, the skunks monitored here began their activities during twilight and our observations indicate that there was no significant relationship between activity levels and brightness. Johnson et al. (1988) reported changes in the period of peak activity for *C. humboldti* in the Parque Nacional Torres Del Paine (PNTDP) in Chile, which was strongly correlated to seasonality. Thus, in the winter, these skunks tended to show a shift to increasing frequency of their activity during daytime periods, since the nighttime temperature got very low and snowfall was common during these months. In our study, active animals were observed only occasionally during the day and, most of the time, the skunks remained in their burrows for the duration of this period.

The beginning of active periods in Neotropical *Conepatus* spp. have been documented to occur at different hours, while the total time period in which the animals remain active has been estimated to be much less than that observed for the animals monitored in the current study (Johnson et al., 1988; Donadio et al., 2001; Kasper et al., 2009). In other words, our findings here suggest that individual *C. semistriatus* remain continuously active for longer time periods compared to other *Conepatus*, with an earlier onset of activity and later cessation of activity with respect to dusk and dawn. Furthermore, the home ranges of many individuals overlapped in areas where trash bins were located, reinforcing our perception of the species as being highly adaptability.

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