High consumption of primates by pumas and ocelots in a remnant of the Brazilian Atlantic Forest

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Received: January 21, 2013 – Accepted: April 15, 2013 – Distributed: August 31, 2014
(With 1 figure)

Abstract

We studied the diet of the ocelot and puma during the years 2007 and 2008 at the Feliciano Miguel Abdala Reserve, in Minas Gerais, south-eastern Brazil. We collected 49 faecal samples (scats) from cats, and identified the species of cat from 23 of them by the analysis of the microstructure patterns of hairs found in their faeces: 17 scats of the puma (*Puma concolor*) and six of the ocelot (*Leopardus pardalis*). In the puma scats, we identified three species of primates (*Brachyteles hypoxanthus*, *Alouatta guariba* and *Sapajus nigritus*), the remains of which were found in eight of 17 collected (47.1%), representing 26.7% of items consumed. For the ocelot, we detected capuchin monkey (*S. nigritus*) remains in three of the six scats (50%), accounting for 18.7% of items consumed by ocelot. We were unable to identify the cat species in the remaining 26 faecal samples, but we were able to analyse the food items present. Primates were found in five of these 26 faeces (19.2%) and represented 10.2% of the items found. Although the sample size is limited, our results indicate a relatively high consumption of primates by felines. We believe that this high predation may be the result of the high local density of primates as well as the greater exposure to the risks of predation in fragmented landscapes, which tends to increase the incidence of the primates using the ground.

Keywords: Alouatta guariba, Brachyteles hypoxanthus, Caratinga Biological Station, *Sapajus nigritus,* predation.

Alto consumo de primatas por onças-pardas e jaguatiricas em um fragmento na Mata Atlântica no Brasil

Resumo

Nós estudamos a dieta de jaguatiricas e onças-pardas entre os anos de 2007 e 2008 na Reserva Feliciano Miguel Abdala, em Minas Gerais, sudeste do Brasil. Nós coletamos 49 amostras fecais de felinos, em 23 das quais foi possível a identificação do predador através da análise do padrão microestrutural dos seus pelos encontrados nas fezes, sendo 17 fezes de onça-parda (*Puma concolor*) e seis de jaguatirica (*Leopardus pardalis*). Nas amostras de onça-parda nós identificamos três espécies de primatas (*Brachyteles hypoxanthus*, *Alouatta guariba* e *Sapajus nigritus*), cujas partes não digeridas foram encontradas em oito das 17 fezes coletadas, representando 26,7% dos itens consumidos por onças-pardas. Para jaguatirica, nós detectamos macacos-prego (*S. nigritus*) em três de seis fezes, o que correspondeu a 18,7% dos itens consumidos. Para as 26 amostras fecais restantes, cuja identificação do predador não foi possível, nós analisamos os itens alimentares presentes. Restos de primatas foram identificados em cinco dessas fezes (19,3%), representando 10,2% dos itens encontrados. Apesar do tamanho da amostra ser limitado, nossos resultados indicam uma taxa relativamente alta de consumo de primatas por felinos. Nós acreditamos que essa alta taxa de predação pode ser resultado da grande densidade local de primatas, bem como do aumento do risco de predação em paisagens fragmentadas, o que tende a aumentar a incidência do uso do chão por parte dos primatas.

Palavras-chave: Alouatta guariba, Brachyteles hypoxanthus, Estação Biológica de Caratinga, *Sapajus nigritus,* predação.

1. Introduction

Predation of primates is difficult to observe directly (Isbell, 1990). In most cases it is confirmed only by indirect means, primarily through faecal analysis (Irwin et al., 2009). However, such indirect evidence is still important for understanding the role of predation in the ecology, behaviour and conservation of primates (Isbell, 1994; Arnold et al., 2008). The development of alarm vocalisations, defence mechanisms, use of refuges and even interspecific associations are, for example, considered evolutionary characteristics influenced by predation (Isbell, 1994; Bshary and Noë 1997; Cowlishaw, 1997; Day and Elwood, 1999; Treves, 1999; Zuberbühler and Jenny, 2002; Pruetz et al., 2008).

While terrestrial primates seem to be more heavily preyed upon by carnivorous mammals (*e.g.*Cowlishaw, 1997; Zuberbühler and Jenny, 2002; Pruetz et al., 2008), the main predators of arboreal primates appear to be birds of prey (Heymann, 1990; Sherman, 1991; Oversluijs Vasquez and Heymann, 2001;De Souza Martins et al., 2005; Miranda et al., 2006) and constrictor snakes (Tello et al., 2002). However, there are records of cats preying on Neotropical primates (*e.g.*Peetz et al., 1992; Olmos, 1994; Miranda et al., 2005; Ludwig et al., 2007; Matsuda and Izawa, 2008), of which all are mostly arboreal. This suggests that Neotropical felines can also play an important role in the predation of primates.

Available studies of cat diet so far indicate that the smaller cats, *Leopardus* spp. and *Puma yagouaroundi* É. Geoffroy, 1803, preferentially prey on small vertebrates such as marsupials, rodents, birds, reptiles and amphibians (e.g. Facure and Giaretta, 1996; Wang, 2002; Chinchilla, 1997; Tófoli et al., 2009; Silva-Pereira et al., 2011; Bianchi et al., 2011). On the other hand, the diets of the two largest species of Neotropical cats, the puma, *Puma concolor* (Linnaeus, 1771) and the jaguar, *Panthera onca* (Linnaeus, 1758), consist largely of artiodactyls, large rodents and armadillos (Iriarte et al., 1990; Chinchilla, 1997; Garla et al., 2001; De Azevedo, 2008; Martins et al., 2008). These studies seem to indicate that primates are not the principal prey for either of the two groups of cats (smaller and large).

Here we report evidence of the relatively high consumption of primates by the puma and ocelot, *Leopardus pardalis* (Linnaeus, 1758), in a fragment of Atlantic Forest in south-eastern Brazil, indicating the potential implications of such predation for primate populations in fragmented habitats.

2. Material and Methods

We collected faecal samples from cats in the Feliciano Miguel Abdala Reserve (FMAR) (19° 50'S and 41° 50'W), which belongs to Caratinga Biological Station, Minas Gerais, south-eastern Brazil, from March 2007 to May 2008. The FMAR has 957 hectares of forest, the vegetation being characterised as lower montane semi-deciduous forest (IBGE, 1995; Oliveira-Filho and Fontes, 2000). According to the Köppen classification of climate, FMAR is AW (hot and humid subtropical), with a dry season (April-September) and a rainy season (October-March). The average annual rainfall is 1091 mm and the average minimum and maximum annual temperatures are 16.7 °C and 25.4 °C, respectively (Veado, 2002).

During the fieldwork we hiked, mainly on trails and roads, throughout the study area in search of faecal samples from wild carnivores. In the field, we differentiated the faecal samples of felines through the observation of some diagnostic features such as cylindrical shape with sub-divisions, relatively sharp, rounded or tapered ends and substantial presence of hair and bones. Some faeces had a whitish colour, due to the concentration of calcium from the bones of ingested prey (Chame, 2003). These features all agree with the descriptions in the literature (Chame, 2003; Borges and Thomás, 2004) and were used to differentiate feline faecal samples from other carnivores. We also confirmed the presence of ocelot, puma and jaguarundi (*P. yagouaroundi*) in the area with the use of camera traps installed at the same time as the collection of faecal samples (Paschoal et al., 2012).

In the laboratory, we processed the faeces and identified the predator species by analysing the microstructural pattern of the cuticle and medullar characteristic of their hairs found in faecal samples (from self-grooming) (Quadros, 2002). We also analysed the microstructural patterns of prey hair and other undigested remains such as teeth, claws, nails and bones, which we compared directly with material deposited in the zoological museum collections of the Pontifícia Universidade Católica de Minas Gerais and Universidade Federal de Minas Gerais. From the number of prey items found, we calculated the frequency of occurrence (percentage of total faeces in which an item was found) and percentage occurrence (number of times a specific item was found as percentage of all items found) (Ackerman et al., 1984). Although the analysis of carnivore diets by frequency of occurrence is limited (Klare et al., 2011), this procedure was preferred because it is the most widely used in dietary studies of cats facilitating, therefore, the comparison of other results to the results presented here.

We considered each primate item found in a scat as representing one individual, provided that the number of teeth and/or claws (when present) did not indicate otherwise (i.e., one item/scat one prey individual). For *Puma concolor* we estimated the number of preyed primates also on the basis of corrected biomass. For this, the consumed biomass and number of preyed individuals were corrected according to Ackerman et al. (1984) equation ($Y= 1.98 + 0.035 X$, where Y= consumed biomass/scat and X= prey weight, both in kilograms). We used Paglia et al.(2012) as source for primate body weights. This correction factor produces more conservative values as it corrects for the fact that the remains of a single individual prey can be eliminated through more than one scat (Ackerman et al., 1984). For ocelot faeces and for faeces of unidentified felids, correction factors are not available and therefore were not used.

3. Results

We collected 49 faecal samples from cats. Through microstructural analysis of the pattern of hair, the identification of the originating predator was possible for only 23 faecal samples (17 of puma and 6 of ocelot). The faecal samples that could not be identified were grouped in a category of "unidentified cat" (Table 1).

Considering all faecal samples, identified and unidentified, Primates was the mammalian order with the second largest number of occurrences of remains in faeces, representing 16.8% of the total items found, second only to Rodentia (26.3% of items) (Table 1). The capuchin monkey, *Sapajus nigritus* (Goldfuss, 1809), was the primate with the highest number of occurrences (6.3% of the items), being detected in six of the faecal samples. The remains of muriqui, *Brachyteles hypoxanthus* (Kuhl, 1820), (Figure 1) and brown howler monkey, *Alouatta guariba* (Humboldt, 1812) were each found in five faecal samples.

The order Rodentia was the order most consumed by ocelots, followed by Didelphimorphia and Primates. The capuchin monkey was the only primate found in faecal samples identified as belonging to the ocelot (Table 1). Primates, on the other hand, was the order of mammals most consumed by pumas, and among these the muriqui was the most common species found: 16.6% of the items and in five of the 17 faecal samples of this cat.

Based on number of items, we estimate that 16 individuals of primates (six capuchins, five howlers and five muriquis) were consumed by cats (Table 1). Considering the corrected biomass as a basis for the estimation, we estimate that a minimum one individual of each primate species (capuchin, howler monkey and muriqui) was consumed by puma (Table 2).

4. Discussion

Predation on muriqui (*B. hypoxanthus*), brown howler monkey (*A. guariba*) and capuchin monkey (*S. nigritus*) by ocelots has been reported in FMAR by Bianchi and Mendes (2007). However, in the present study, we recorded the first instance of predation of *B. hypoxanthus* by puma. Although pumas and ocelots are known to prey on howler and capuchin monkeys in other areas (Brito, 2000; Ludwig et al., 2007; Miranda et al., 2005), this is the first record of puma predation on *Brachyteles*. Until now muriqui has only been reported as prey of jaguar (Olmos, 1994) and ocelot (Bianchi and Mendes, 2007).

The most recent publication with data on the demography of Caratinga muriquis (surveys in 2003 and 2004; Strier et al., 2006), detected an increase in the mortality of newborns and infants in comparison with previous periods (Strier, 1999). Larger infants and juvenile muriquis may be more susceptible to predation than adults, because at this stage they spend a significant amount of time foraging independently (Printes et al., 1996). Lynch and Rímoli (2000) also found higher mortality rates for infant capuchin monkeys in FMAR than in other areas. Both sources (Strier et al., 2006; Lynch and Rímoli, 2000) mention predation among the potential causes of these deaths. In most cases the analysis of the faecal content does not allow accurate inferences about the age classes of the individuals (infants or adults) since relatively intact parts that could provide clues are normally not found in faeces. However, a higher proportion of underhairs in relation to guardhairs found in faeces suggest the presence of young prey (Quadros, 2002). On the basis of this, we infer that at least three infants or newborns (one each of the three primate species found in faeces) were predated in FMAR during the period of the study. Corroborating this, one of the scats had parts of a finger whose dimensions were of a young muriqui (Figure 1).

Figure 1. Parts of fingers (phalanges with nails) of a young muriqui (*Brachyteles hypoxanthus*) found in a faecal sample from puma (*Puma concolor*) collected in FMAR, Caratinga, south-eastern Brazil. Scale: cm.

Assuming that the muriqui population in FMAR is around 300 individuals (Strier, 2010), and considering that our study spanned approximately one year, our conservative estimate of 1-5 muriquis killed/year would indicate an annual predation rate, by felids alone, of 0.3-1.7% of the local muriqui population. A similar rate would apply to capuchin monkeys if the current abundance of this primate is in fact similar to that of muriquis, as is indicated by a previous study (Almeida-Silva et al., 2005a). For brown howlers this rate might be halved, as howlers seem to be roughly twice as abundant as muriquis in FMAR (Almeida-Silva et al., 2005a). We stress, however, that these predation rates are likely underestimates not only because of the conservative nature of our estimates but also due to the fact that our sampling is far from exhaustive, both spatially and temporally. Further, other predator species, both native and domestic species, were not examined.

A study by Paschoal et al. (2012) using camera traps between 2007 and 2008 did not indicate that ocelots and pumas are present in the study area at particularly high densities. It is likely therefore that high consumption of primates in FMAR is a result of factors other than predator abundance. The abundance of primates may be one, since the local densities of muriquis and brown howler monkeys are among the highest ever recorded for the Atlantic Forest (Hirsch, 1995; Strier and Fonseca, 1996). Furthermore, the

Table 1. Prey found in scats of ocelots (*Leopardus pardalis*), pumas (*Puma concolor*), and unidentified felids in FMAR, south-eastern Brazil. n = number of items.

	Leopardus pardalis			**Puma concolor**			**Unidentified felids**			**Total**		
	n	**%items**	**%scats**	**n**	**%items**	**%scats**	**n**	**%items**	**%scats**	**n**	**%items**	**%scats**
Mammalia	12	75.0	100.0	27	90.0	100.0	42	85.7	100.0	81	92.3	100.0
Didelphimorphia	3	18.8	50.0				12	24.5	42.3	15	15.8	30.6
Monodelphis sp.							1	2.0	3.8	1	1.1	2.0
Didelphis aurita (Wied-Neuwied, 1826)							2	4.1	7.7	2	2.1	4.1
Marmosops incanus (Lund, 1840)							1	2.0	3.8	1	1.1	2.0
Metachirus nudicaudatus (Desmarest, 1817)							2	4.1	7.7	2	2.1	4.1
Didelphidae unidentified	3	18.8	50.0				6	12.2	23.1	9	9.5	18.4
Cingulata				2	6.7	11.8	1	2.0	3.8	3	3.2	6.1
Dasypus sp. (Linnaeus, 1758)				2	6.7	11.8	1	2.0	3.8	3	3.2	6.1
Primates	3	18.8	50.0	8	26.7	47.1	5	10.2	19.2	16	16.8	32.7
Alouatta guariba (Humboldt, 1812)				2	6.7	11.8	3	6.1	11.5	5	5.3	10.2
Brachyteles hypoxanthus (Kuhl, 1820)				5	16.7	29.4				5	5.3	10.2
Sapajus nigritus (Goldfuss, 1809)	3	18.8	50.0	1	3.3	5.9	2	4.1	7.7	6	6.3	12.2
Lagomorpha				2	6.7	11.8	4	8.2	15.4	6	6.3	12.2
Sylvilagus brasiliensis (Linnaeus, 1758)				2	6.7	11.8	4	8.2	15.4	6	6.3	12.2
Carnivora				7	23.3	35.3	8	16.3	30.8	15	15.8	30.6
Nasua nasua (Linnaeus, 1766)				4	13.3	23.5	5	10.2	19.2	9	9.5	18.4
Galictis cuja (Molina, 1782)				1	3.3	5.9	2	4.1	7.7	3	3.2	6.1
Eira Barbara (Linnaeus, 1758)				1	3.3	5.9	1	2.0	3.8	2	2.1	4.1
Procyon cancrivorus (G. Cuvier, 1798)				1	3.3	5.9				1	1.1	2.0
Artiodactyla				1	3.3	5.9				1	1.1	2.0
Artiodactyla unidentified				1	3.3	5.9				1	1.1	2.0
Rodentia	6	37.5	66.6	7	23.3	35.3	12	24.5	38.5	25	26.3	51.0
Akodon cursor (Winge, 1887)	1	6.3	16.7							1	1.1	2.0
Akodon sp.	1	6.3	16.7							1	1.1	2.0
Calomys sp.	1	6.3	16.7							1	1.1	2.0
Oxymycterus sp.	1	6.3	16.7							1	1.1	2.0
Cuniculus paca (Linnaeus, 1766)				3	10.0	17.6	5	10.2	19.2	8	8.4	16.3
Dasyprocta leporina (Linnaeus, 1758)				2	6.7	11.8	1	2.0	3.8	3	3.2	6.1
Coendou sp.							2	4.1	7.7	2	2.1	4.1
Echimyidae unidentified				2	6.7	11.8	2	4.1	7.7	4	4.2	8.2
Muridae unidentified	1	6.3	16.7							1	1.1	2.0

Table 1. Continued...

	Leopardus pardalis			Puma concolor			Unidentified felids			Total		
	n	**%items**	**%scats**	**n**	**%items**	**%scats**	**n**	**%items**	**%scats**	**n**	**%items**	**%scats**
Rodentia unidentified	1	6.3	16.7				2	4.1	7.7	3	3.2	6.1
Reptilia	2	12.5	33.3	2	6.7	11.8	1	2.0	3.8	5	5.3	10.2
Squamata	2	12.5	33.3	2	6.7	11.8	1	2.0	3.8	5	5.3	10.2
Lacertilia unidentified	1	6.3	16.7							1	1.1	2.0
Teiidae unidentified				1	3.3	5.9				1	1.1	2.0
Viperidae unidentified	1	6.3	16.7	1	3.3	5.9	1	2.0	3.8	3	3.2	6.1
Amphibia										1	1.1	2.0
Hylidae unidentified							1	2.0	3.8	1	1.1	2.0
Aves	2	12.5	33.3	1	3.3	5.9	4	8.2	15.4	7	7.4	14.3
Aves unidentified	2	12.5	33.3	1	3.3	5.9	4	8.2	15.4	4	4.2	8.2
Invertebrates							1	2.0	3.8	1	1.1	2.0
Gastropoda							1	2.0	3.8	1	1.1	2.0
Total	16	100	-	30	100		49	100	-	95	100	-
Number of scats		6			17		26			49		

Table 2. Corrected biomass and number of individuals of primates preyed upon by puma. The values were corrected using the Ackermanet al.(1984) equation (See methods for details).

Prey species	Parameter	Results
Alouatta guariba	Number of scats	2
	Body weight (kg)	5.625
	Correction factor (kg/scat)	2.176
	Corrected biomass (kg)	4.352
	Number of individuals consumed	0.77
Brachyteles hypoxanthus	Number of scats	5
	Body weight (kg)	13
	Correction factor (kg/scat)	2.435
	Corrected biomass (kg)	12.175
	Number of individuals consumed	0.93
Sapajus nigritus	Number of scats	1
	Body weight (kg)	3.5
	Correction factor (kg/scat)	2.102
	Corrected biomass (kg)	2.102
	Number of individuals consumed	0.6

Table 3. Importance of primates in the diets of ocelots (*Leopardus pardalis) and* pumas (*Puma concolor)* in Neotropical Forests

Study site			% primates in diet		
Name	**Area (ha)**	**Species**	**Items**	**Faeces**	**Source**
FMAR	**957**	**Puma**	**26.7**	**47.1**	**This study**
Sirena Biological Station/Corcovado National Park	47757	Puma	12.0	36.4	Chinchilla (1997)
Juréia-Itatins Ecological Station	80000	Puma	12.0	24.9	Martins et al. (2008)
Vale Nature Reserve/Sooretama Biological Reserve	28800	Puma	5.8	9.2	Brito (2000)
Maya Biosphere Reserve	288500	Puma		4.0-9.8	Novack et al. (2005)
Barro Colorado Island	1500	Puma	5.0	6.8	Moreno et al.(2006)
Iguaçu National Park	185200	Puma	1.6	1.8	De Azevedo (2008)
Salto Morato Natural Reserve	2340	Puma	-	3.3	Vidolin (2004)
Cockscomb Basin	42500	Puma	0	0	Foster et al (2010)
Vila Rica do Espírito Santo State Park/ Cagibi Farm/ Guajuvira Farm	703	Puma	0	0	Rocha-Mendes et al. (2010)
Cocha Cashu Biological Station	7501	Puma	0	0	Emmons (1987)
FMAR	**957**	**Ocelot**	**18.8**	**50.0**	**This study**
Caratinga Reserve	957	Ocelot	13.0	26.7	Bianchi and Mendes (2007)
Balsa Nova	700	Ocelot	7.0	17.0	Abreu et al. (2008)
Barro Colorado Island	1500	Ocelot	5.0	6.8	Moreno et al. (2006)
Barro Colorado Island	1500	Ocelot	4.0	4.34	Moreno and Giacalone (2006)
Salto Morato Natural Reserve	2340	Ocelot	-	3.3	Vidolin (2004)
Cocha Cashu Biological Station	750*	Ocelot	1.7	-	Emmons (1987)
Cockscomb Basin Forest Reserve	25000	Ocelot	0	0	Konency (1989)
Vale Nature Reserve	22000	Ocelot	0	0	Facure and Giaretta (1996)
Sirena Biological Station/Corcovado national Park	47757	Ocelot	0	0	Chinchilla (1997)
Juréia-Itatins Ecological Station	80000	Ocelot	0	0	Martins et al. (2008)
Vila Rica do Espírito Santo State Park/ Cagibi Farm/ Guajuvira Farm	703	Ocelot	0	0	Rocha-Mendes et al. (2010)
Soberanía National Park	22000	Ocelot	0	0	Moreno et al. (2006)
Parque Estadual Serra do Mar	5000	Ocelot	0	0	Wang (2002)
Bugre District, São Luis do Purunã District, Santa Rita Ranch	-	Ocelot	0	0	Silva-Pereira et al. (2011)
Vale Nature Reserve/Sooretama Biological Reserve	28800	Ocelot	0	0	Bianchi et al. (2010)

[1] Area of coverage of the study in the Cocha Cashu Biological Station.

high rates of predation of primates may also be a result of their atypical behaviour of often descending to the forest floor, which has been observed both in muriquis and brown howler monkeys at FMAR (Almeida-Silva et al., 2005b; Mourthé et al., 2007). Muriquis have been observed performing activities, such as resting, feeding, socialisation and locomotion, which are normally restricted to the arboreal stratum, on the forest floor of FMAR (Printes et al., 1996; Mourthé et al., 2007).

Our findings corroborate the study of Bianchi and Mendes (2007) and suggest a high proportion of primates in the diet of cats in FMAR in relation to other Atlantic Forest areas. Both ocelots and pumas are opportunistic predators (Emmons, 1987; Delibes et al., 2011) being able to feed on abundant or vulnerable species, even if they are not the most common prey. This might be further increased in fragmented landscapes, since primates living in forest remnants need to descend to ground level frequently to get around, hence exposing themselves to attacks from terrestrial predators. As shown in Table 3, the occurrence of primates in the diet of ocelots has been recorded mainly in smaller fragments (700 to 2500 ha), including FMAR, with 957 ha (Vidolin, 2004; Moreno et al., 2006; Moreno and Giacalone, 2006; Bianchi and Mendes, 2007; Abreu et al., 2008).

Although the ocelot feeds mainly on small vertebrates (e.g. Emmons, 1987; Ludlow and Sunquist, 1987; Konency, 1989; Wang, 2002), there may be an increase in the importance of larger prey in the diet of this cat in fragmented locations or on islands where larger cats are absent or are at low densities (Moreno et al., 2006). This feature, coupled with the ocelot's tolerance to fragmented and isolated environments, which appears to be greater than that of the larger cats, suggests that ocelots may be playing a significant role in population control of medium and large mammals, including arboreal primates, at sites such as this. The diet of pumas consists mainly of mammals of medium and large size (Ackerman et al., 1984; Iriarte et al., 1990; De Azevedo, 2008), but larger prey such as the tapir, *Tapirus terrestris* (Linnaeus, 1758) and peccaries, *Pecari tajacu* (Linnaeus, 1758) and *Tayassu pecari* (Link, 1795) are extinct in FMAR (Veado, 2002).

It would be worthwhile to investigate whether the rate of predation on primates in FMAR indicates a likely scenario for populations of endangered primates in other isolated Atlantic Forest fragments (Hatton et al., 1984; Mittermeier et al., 2006). More than 80% of the remaining fragments of this biome are less than 50 ha in size and almost 50% of their area is within 100 m of an edge as well as being isolated from each other (Ribeiro et al., 2009). Future studies should also verify whether predation is a leading cause in the decline in the population of primates in Atlantic Forest remnants or whether other factors inherent in isolated populations with high densities (inbreeding depression, increased susceptibility to disease, intra and interspecific competition) offer even greater risks to these populations.

Acknowledgements

We thank the Fundo de Incentivo à Pesquisa da Pontifícia Universidade Católica de Minas Gerais (FIP, PUC Minas # 1523 – S1) for funding this study, FAPEMIG (Fundação de Amparo à Pesquisa de Minas Gerais) for contributing funds during the analysis (CRA-APQ-01145-10), and IBAMA for granting permission to collect data (# 13153 – 1). We are also grateful to the employees of FMAR and local researchers (Karen Strier, Daniel Ferraz, Robson Hack, Samantha Rocha, Luisa Arnedo, Carla Possamai and Fernanda Tabacow) for their support and assistance during the project's execution, the researchers André Hirsch and Leandro Scoss for their contributions and suggestions and the researcher Sônia Talamoni, Universidade Federal de Minas Gerais and PUC Minas Museum of Natural Sciences for making their material available during the identification process. Two anonymous referees made suggestions that greatly improved a previous version.

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