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Melanism in the Brazilian pampas cat and range extension in the Atlantic Forest, Brazil

The biogeographical and natural history of the *Leopardus colocola braccatus* (Carnivora, Felidae), known as Brazilian pampas cat, including its coat colouration are poorly understood. Here we report new records of melanism in the Brazilian pampas cat, obtained from three localities in central Brazil. We also provide the southernmost known record, extending its known distribution range by approximately 300 km into the Atlantic Forest domain. During the fieldwork for a mammal survey (2010–2020) we searched for records of melanistic individuals at ten sites spread across three Brazilian domains: Atlantic Forest, Cerrado, and Pantanal. We collected 50 Brazilian pampas cat observations. We obtained in total eight records of melanistic individuals in three protected areas: one site was located in the Atlantic Forest and two sites in the Cerrado (all located in Mato Grosso do Sul state). Despite the long-term camera-trap survey (29,000 nights of camera traps), only 16% of the records were of Brazilian pampas cat showing polymorphic phenotypes. Our findings provide important contributions to our understanding of the species and have potential ecological and evolutionary significance. We strongly encourage further research on this species.

The Brazilian pampas cat is according to the revised taxonomy of the Felidae classified as a subspecies of *Leopardus colocola* occurring in Brazil and Paraguay (Kitchener et al. 2017). However, according to a more recent study, it is suggested to be a separate species *Leopardus braccatus* inhabiting open habitats of Brazil, eastern Paraguay and Bolivia (Nascimento et al. 2020). It is one of the smallest cats that occur in Brazil. It has a total length of 60–100 cm, nose-to-tail, and a body mass of 2.4–4.0 kg (García-Perea 1994, Barstow & Leslie 2012). Approximately 30 observations have been recorded in Brazil, all in the Cerrado (i.e. tropical savannah) and the Pantanal (i.e. tropical wetland) ecosystems (Bagno et al. 2004, Nascimento et al. 2020). The species occurs at low densities (0.01–0.05 individuals/km^2), even in the few places where it is relatively common (Queirolo et al. 2013). Hence, it is listed as Vulnerable in the Brazilian Red List (Queirolo et al. 2013, ICMBio 2018) and as Near Threatened in the IUCN Red List of Threatened Species™ (Lucherini et al. 2016).

The Brazilian pampas cat typically exhibits a largely brown pelage, with white or pale-yellow mandible and medial intranasal areas, a dark brown or black spinal crest, indistinct dark-brown lines on the sides of the body, blackish feet and a uniform brown tail lacking rings and with a black tip (see Nascimento et al. 2020). Melanism (i.e. an increase of dark pigmentation in skin or fur) is a relatively common phenomenon in other *Leopardus* species (Graipel et al. 2019). Only one report of melanism in a wild Brazilian pampas cat has been published in scientific literature, across its entire range (Silveira et al. 2005). However, there are other records in north-eastern Brazil (https://www.wildcatsbrazil.com/melanistic-pampas-cats).

Compared to other Neotropical cats, there is little knowledge regarding the biogeography and natural history of the Brazilian pampas cat (Barstow & Leslie 2012). Recent studies addressed these knowledge gaps, focusing on the distribution of the species. New records of occurrence have been recorded in the last five years in south-eastern Brazil, where there is a predominance of the Atlantic Forest and transition areas to the Cerrado (Breviglieri et al. 2018). Nascimento et al. (2016) described a new observation that was considered the easternmost known record, extending the species' range by 300 km. Here we present new records of the Brazilian pampas cat including a case of melanism and an extension of its known range in central Brazil.

We carried out mammal surveys between 2010 and 2020 at ten sites across three different domains (Atlantic Forest, Cerrado and Pantanal), including Protected Areas, forest fragments and human dominated areas of central Brazil. Eight sites were located in Mato

Grosso do Sul state (MS), one site was located in in Mato Grosso state (MT), and one site in Goiás state (GO). Data were obtained via direct observation and using remote-sensing camera-traps (Bushnell Trophy Cam HD Essential E2 12MP Trail Camera) that were placed about 30 cm above the ground, in places where we previously identified mammal footprints, faces and other traces, like on dirt roads, trails associated with native vegetation and areas with intensive agriculture. Total sampling effort was 28,733 camera-trap nights (Table 1).

A total of 50 observations of the Brazilian pampas cat were recorded across four sites (Table 1). We collected eight melanistic records (six times of an adult and once of an adult with a cub) at three sites all located in Mato Grosso do Sul state: Varzeas do Rio Ivinhema State Park – VRISP (733,45 km²; Emas National Park – ENP (1,320 km²); and Nascentes do Rio Taquari State Park – NRTSP (306,18 km² (Table 1, Fig. 1). VRISPs protects large areas of Atlantic Forest including seasonal semi-deciduous forest, an important ecological corridor between Atlantic Forest and Cerrado (IMASUL 2008). The other two Protected Areas (ENP and NRTSP) are located less than 20 km away from each other over an extensive area of mixed habitats, including Cerrado, native grasslands, and forest, that forms an important ecological corridor between Cerrado and Pantanal.

All detections in the VRISP were recorded by only one camera trap positioned along a dirt road that crosses a secondary forest fragment surrounded by pastures. Detections of melanistic individuals were recorded on 19 March 2019 (mother and cub), 8 April 2019, and 8 June 2020 (twice a solitary individual; Fig. 2A-2D). In the ENP 141 camera traps were used in different sites and we recorded three times a melanistic individual inside a sugar cane monoculture, on 8 October 2019, 25 October 2019 and on 26 November 2019 (Fig. 2E-2H). The most recent detection of a melanistic individual was recorded on 12 June 2020 close to the limits of the NRTSP and to a monoculture of corn. Total of 15 camera traps were installed in this park. Both melanistic and typically-coloured individuals were detected in the park (Table 1). Despite the eight records, there can be only one adult female and cub in the VRISP and one individual in each of the two other protected areas.

Polymorphic phenotypes in coat colouration may occasionally occur in vertebrates, due to variation in melanin synthesis which includes the excess (i.e. melanism), the absence (i.e. albinism) and deficit in some parts of the body (i.e. piebaldism) or over almost the entire body, except in the extremities of members and the eyes (i.e. leucism; Hofreiter & Schöneberg 2010). In Neotropical mammals, the most frequently reported cases are albinism, melanism and leucism, cases of piebaldism are more rarely reported (Abreu et al. 2013, Aximoff & Rosa 2016, Lucati & Lopez-Baucells 2016, Cronemberger et al. 2018, Aximoff et al. 2020a, Aximoff et al. 2021). Melanism is genetically controlled by recessive genes often associated causally with a selective advantage for hunting and can play adaptive roles in certain ecological conditions (Eizirik et al. 2003, Caro 2005, Silva 2017, Utzeri 2017). Melanism is also common in other *Leopardus* species and has been interpreted as an adaptive advantage, associated with biological factors such as camouflage, communication, thermoregulation, parasites, and sexual selection (Caro 2005, Schneider et al. 2015, Graipel et al. 2019).

The occurrence of occasional melanistic individuals and the sympatric records of both phenotypes suggests that melanism may not be as rare in the Brazilian pampas cat as the historical data suggests. It is not possible to infer from our data how melanism affects individual fitness and performance in this species. However, much is unknown and further studies are required to explore the persistence of melanism over time and abundance and ecology of melanistic individuals in local pop-ulations. The scarcity of melanistic Brazilian pampas cat records across its distribution may reflect knowledge gaps in open ecosystems (e.g. Cerrado, Caatinga) and tropical forests (e.g. Atlantic Forest and Amazon) in Brazil.

Our records of the Brazilian pampas cat at VRISP extend the southernmost limit of its distribution range about 300 km to the south in the Brazilian territory (for details of distribution see Nascimento et al. 2020). In the last years, new records have been obtained (Breviglieri et al. 2018, Nascimento et al. 2020), including the easternmost known record (Nascimento et al. 2016). Additionally, the location where the records were obtained in the VRISP is inside Atlantic Forest domain and surrounded by pastures with close presence of savannas environments, similar to the recent records in south-eastern Brazil (Nascimento et al. 2016, Breviglieri et al. 2018). BPC typically inhabits open habitats, hence records in the Atlantic Forest environment are considered unusual and rare (see Nascimento et al. 2020). However, it is possible that the species is exhibiting niche plasticity, expanding its geographical distribution due to land-use changes. Similar behaviour has been recorded for the maned wolf *Chrysocyon brachyurus* (Aximoff et al. 2020b).

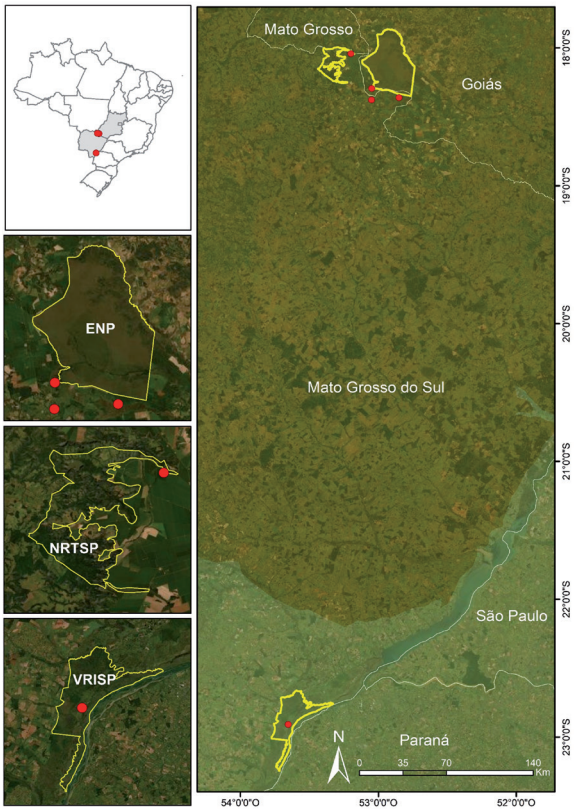

Fig. 1. Location of melanistic individual records of the Brazilian pampas cat (red dot) inside and around Emas National Park – ENP and Nascentes do Rio Taquari State Park – NRTSP, and in Várzeas do Rio Ivinhema State Park – VRISP* in Mato Grosso do Sul State, Central Brazil. The slightly darker area in the map is the current distribution range. *In VRISP all records (n= 4) were made in the same location, represented by a single red dot.

Fig. 2. Records of the Brazilian pampas cat from Várzeas do Rio Ivinhema State Park (A-C, Photos D. Sales) and Emas National Park (D-F; Photos E. Painkow).

Our findings represent important additions to our understanding of Brazilian pampas cat distribution and ecology. Further, our data contribute to the existing literature on melanism across the Felidae. These findings have considerable potential ecological and evolutionary implications and provide a sound basis for further investigation. We suggest that further, focal studies are undertaken to elucidate the true distribution and southernmost limit of the species and to explore the population and ecological implications of melanism in this poorly-understood species.

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Table 1. Brazilian pampas cat detections across several studies using camera traps in Central Brazil. Detections are separated according to pelage colouration (i.e. typical vs melanistic). States: Goias (GO), Mato Grosso (MT), and Mato Grosso do Sul (MS).

Domain/Year	Trap-night	Detections of pelage colour		Location/State	Reference
		Typical	Melanistic		
Atlantic Forest					
2019–2020	345	35	4*	Ivinhema State Park (MS)	This study
Cerrado					
2011–2016	5,005	-	-	Corguinho (MS)	unpublished data
2018–2018	120	-	-	Campo Grande and Rio Brilhante (MS)	This study
2017–2020	9,840	5	3	Emas National Park (MS)	This study
2020–2020	1,440	1	1	Nascentes do Rio Taquari State Park (MS)	This study
2020	840	-	-	Serra do Bom Jardim Natural Monument (MS)	This study
2020–2021	1,350	-	-	Itapaci and Guarinos (GO)	This study
Pantanal					
2010–2013	7,431	1	-	SESC private Reserve (MT)	unpublished data
2019–2019	240	-	-	Coxim (MS)	This study
2012–2015	2,122	-	-	Aquidauana (MS)	unpublished data
Total	**28,733**	**42**	**8**		

*three times an adult and one cub

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Supporting Online Material SOM Figure F1 and F2 are available at www.catsg.org.

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SOM F1. Record of the Brazilian pampas cat from Várzeas do Rio Ivinhema State Park (Photo D. Sales).

SOM F2. Record of the Brazilian pampas cat from Emas National Park (Photo E. Painkow).