Wellington Hannibal*, Mauricio Neves Godoi, Walfrido Moraes Tomas, Grasiela Porfirio, Vanda Lúcia Ferreira and Nilton Cáceres

Biogeography and conservation of non-volant mammals from the Urucum Mountains: a Chiquitano dry forest ecoregion in western Brazil

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Abstract: The distributional data of mammalian fauna are important to reach a comprehensive overview of biogeographic patterns and to highlight regional conservation status, especially in a poorly known region such as the Chiquitano dry forest in western Brazil. Our aims were to survey the mammal species occurring in the Urucum Mountains, located in the southeast end of the Chiquitano forest, compare its species composition to areas elsewhere in different ecoregions, and discuss their conservation statuses. Small mammals were sampled using pitfall and live traps, and medium and large mammals were sampled by direct observation, indirect evidence (e.g. faeces and tracks), and camera traps. Patterns of species composition were compared to other surrounding areas of different ecoregions in South America using multivariate analyses. The results indicated that both faunas have similar biogeographical influences. The Urucum Mountains have an influence on the faunas from the Cerrado, Chaco and Pantanal ecoregions, and only secondarily from forested ecoregions (e.g. Amazon forest). The Urucum harbours a rich non-volant mammalian fauna with species that are widely and restrictedly distributed. The conservation of Urucum Mountains is important because these mountains harbour threatened plant, invertebrate, and vertebrate (mammals) species, which could be suffering due to the mining activity carried out in the region. We stress that the Chiquitano dry forest is unique to western Brazil, situated in a complex biogeographical region, and harbouring a rich and diversified mammal fauna.

Keywords: Amazonian influence; Cerrado; Chaco; faunal comparison; habitat loss; Pantanal wetlands; species gradient.

***Corresponding author: Wellington Hannibal,** Laboratório de Ecologia e Biogeografia de Mamíferos, Universidade Estadual de Goiás, Avenida Brasil, nº 435, CEP 75860-000, Quirinópolis, Goiás, Brazil; and Programa de Pós-Graduação em Ecologia e Conservação, Universidade Federal de Mato Grosso do Sul. Avenida Costa e Silva, s/n, CEP 79070-900, Campo Grande, Mato Grosso do Sul, Brazil, e-mail: wellingtonhannibal@gmail.com
Mauricio Neves Godoi: Programa de Pós-Graduação em Ecologia e Conservação, Universidade Federal de Mato Grosso do Sul. Avenida Costa e Silva, Campo Grande, Mato Grosso do Sul, Brazil
Walfrido Moraes Tomas: Programa de Pós-Graduação em Ecologia e Conservação, Universidade Federal de Mato Grosso do Sul. Avenida Costa e Silva, Campo Grande, Mato Grosso do Sul, Brazil; and Laboratório de Vida Selvagem, Embrapa Pantanal, Bairro Nossa Senhora de Fátima, Corumbá, Mato Grosso do Sul, Brazil
Grasiela Porfirio: Universidade Católica Dom Bosco, Avenida Tamandaré 6000, Jardim Seminário, Campo Grande, Mato Grosso do Sul, Brazil
Vanda Lúcia Ferreira: Centro de Ciências Biológicas e da Saúde, Universidade Federal de Mato Grosso do Sul. Avenida Costa e Silva, Campo Grande, Mato Grosso do Sul, Brazil
Nilton Cáceres: Department of Ecology and Evolution, CCNE, Universidade Federal de Santa Maria, Camobi, Santa Maria, Rio Grande do Sul, Brazil

Introduction

The Urucum Mountain range, located in the Chiquitano dry forest ecoregion, shows a rich and diverse vegetation in part driven by different phytogeographical influences (Pott et al. 2011) of the main surrounding ecoregions: the forested (Amazon rainforest, Atlantic forest), and grassland or scrubland (Cerrado, Chaco and Pantanal) ecoregions (Ab'Saber 1977, Olson et al. 2001). Therefore, the regional biodiversity is thought to be high, and the fauna includes forest and savanna-grassland dwelling species (Cáceres et al. 2011). Moreover, the region is crossed by the Paraguay River which appears not to be a geographical barrier for the dispersal of mammals (Myers 1982), and the Chiquitano dry forest ecoregion finds its eastern limit just in the right margin of this river, while the Pantanal wetlands predominate in the opposite margin. Thus, we can expect that some small-sized species have limited dispersal due to biome differences rather than the river

(Myers 1982). This and other biogeographic processes are responsible for the singularity of the regional biodiversity (WWF 2006, Pott et al. 2011).

The Upper Paraguay River Basin, ranging from Brazil to Bolivia and Paraguay, has a rich mammalian fauna with 211 species. Although some inventories have been conducted in these upland areas (Cáceres et al. 2007a, Cáceres et al. 2011, Santos-Filho et al. 2012, Porfirio et al. 2014), the mammalian fauna is still insufficiently known as these studies rarely sampled all groups of non-volant mammals. For the Urucum Mountains, e.g. 19 small mammal species were already described (Cáceres et al. 2011), known only for two localities in that region. Moreover, surveys of medium and large mammals have not yet been published.

Besides, these mountains have been affected by the expansion of cattle and mining activities such as iron and limestone extraction (Harris et al. 2005). These activities have reduced or modified the natural habitats of the region, especially the most sensitive habitats such as the altitudinal grasslands and mountain slopes where forests and savannas are located, compromising the occurrence of species linked to these habitats.

Distribution data from mammalian fauna are important to reach a comprehensive biogeographical overview of the upland areas surrounding the Pantanal wetlands, which are still not sufficiently sampled (Tomas et al. 2010a,b). Thus, we aim to understand the affinities of the Urucum Mountains' mammalian fauna and compare it to the data on non-volant mammals from several sampling sites along the NE-SW diagonal of South American open areas (Caatinga, Cerrado, Pantanal, Chaco and Pampa) and its adjacent forest areas (Amazon and Atlantic forests). Biogeographical patterns are analysed separately for small- and large-sized mammal assemblages of the Urucum Mountains. We test the hypothesis that the mammal species composition (mainly the large one) in this region is constituted mainly by forest representatives, as the Chiquitano forest is primarily a forested biome (Veloso et al. 1991, Olson et al. 2001). For small mammals, we expected the same, as forest-dweller small mammals predominate at least in woodland habitats of this ecoregion (Cáceres et al. 2011). Further, the Paraguay River, which limits the Urucum Mountains in the east, is thought to not be a significant barrier for small-mammal dispersal (Myers 1982), and so we expected only a secondary influence of the Cerrado and Pantanal ecoregions which are mostly on the opposite side of this river (our primary hypothesis is the forest one). Furthermore, we discuss the main threats affecting the conservation of mammalian fauna in that region.

Materials and methods

Study area

The Urucum mountain range is located in the southeast border of the Chiquitano dry forest, on the western edge of Pantanal wetland, near the Brazilian-Bolivia border, in the Corumbá municipality, Mato Grosso do Sul state, Brazil (Figure 1). This region is delimitated by the Paraguay River in the north, the border with Bolivia to the west, and by the floodplains in the south and east, constituting a 1300 km^2 forested "peninsula" entering the Pantanal wetland. The mountains of the region range in altitude from 150 to 1130 m above sea level, and are covered by deciduous and semideciduous dry forests on the slopes, riparian forests in the valleys, and patches of woodland savannas (*cerradão*), shrubby savanna (*cerrado stricto sensu*) and altitudinal grasslands (*campos de altitude*) on the mountain tops (Pott et al. 2000).

Sampling design

We collected data between 2000 and 2014 in six localities which covered the important subsets of the Urucum Mountains and its surroundings, sampling different vegetation types (Table 1). The minimum distance between the sampling sites was 6 km between Urucum and the Santa Cruz-2 Hills, whereas the maximum distance was 27 km between Santa Cruz-1 Hills and Porto Morrinho.

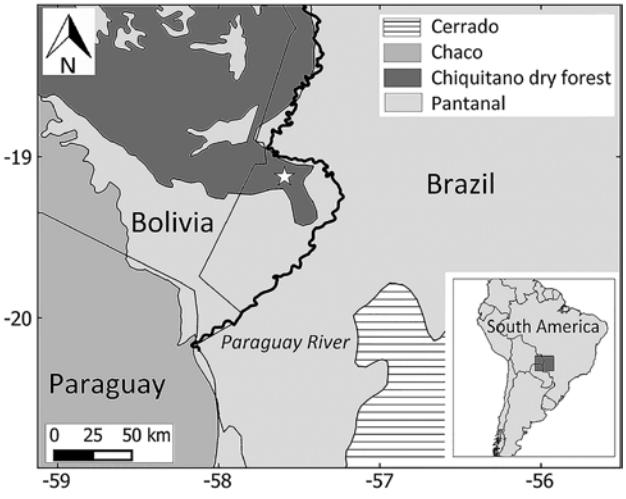

Figure 1: Localisation of the Urucum Mountains (star) in the Chiquitano dry forest ecoregion in western Brazil. Ecoregions are according to Olson et al. (2001).

Table 1: Site locations and sampling efforts of studies implemented at the Urucum Mountains and their surroundings, Corumbá municipality, Mato Grosso do Sul state, Brazil, from 2000 to 2014.

Localities	Coordinates	Sampling effort	Vegetation type[a]	Source
BR – 262	–	64 sampling hours	AH, FO, HF, SS	This study
Pedreira Lajinha	19°07′09.9″S; 57°38′38″W	36 sampling hours	FO	This study
Urucum	19°11′57,5″S; 57°38′8.3″W	3500 live traps and 1120 pitfall traps	AG, FO, SS	Cáceres et al. (2011)
Urucum	19°11′57,5″S; 57°38′8.3″W	350 live traps, 224 pitfall traps and 792 camera trap-day	AG, FO	This study
Santa Cruz-1	19°17′22.34″S; 57°35′29.88″W	900 live traps	FO, HF	This study
Santa Cruz-2	19°12′19.90″S; 57°34′34.38″W	16,992 pitfall traps	AG, FO, SS	Cáceres et al. (2011)
Porto Morrinho	19°28′7.09″S; 57°25′9.46″W	120 live traps, 36 pitfall traps, 48 sampling hours and 144 camera traps-day	HF, FO	This study
Rabicho Hills	19°11′40.4″S; 57°30′17.3″W	340 camera trap-day	FO	This study

[a]Vegetation types: AG, altitudinal grasslands; AH, anthropogenic habitats; FO, deciduous and semideciduous forests, riparian forests, and woodland savannah (*cerradão*); HF, humid and floodplain areas; SS, shrubby savanna (*cerrado stricto sensu*).

The study area comprised a maximum linear distance of 50 km between Rabicho Hills and Porto Morrinho sites.

Each sampling unit was considered a local landscape, i.e. a set of forest fragments close to each other or a particular altitudinal grassland. The medium- and large-sized mammals were sampled in each vegetation type (Table 1), through active searching, within a radius of 1 km centred in our camp, and linear transects (2.5–3 km). During these active surveys (and even during the small-mammal capture sessions using live-traps and pitfall-traps), larger-sized mammals were sampled by their direct observation in the field (in part done by using binoculars), vocalisations (Primates, for example), faeces, and by recording their tracks and other signs (such as carcasses, isolated body parts, teeth and antler remains, and burrows). Faeces, tracks and other signs were identified according to Lima Borges and Tomas (2004).

Medium- to large-sized mammals were also surveyed using camera traps (Bushnell Trophy Cam, Bushnell Corporation, Overland Park, Kansas, USA) installed along dirt roads and forest trails in seven different sites at Urucum (deciduous and semi-deciduous forests, riparian forests and woodland savannah), three different sites at Rabicho Hills (riparian forests and woodland savannah) and two different sites at Porto Morrinho (riparian forests and semideciduous forests) (Table 1). Two camera traps were installed in each capture station, in tree trunks at a distance of 40 cm from the ground, without baits, and spaced at least 2 km from each other. Cameras were programmed to operate for 24 h/day and to take photos at an interval of 5 s during seven consecutive days. Camera trap effort was repeated with 3-month intervals, from November 2012 to May 2014. Camera-trap records were identified according to Lima Borges and Tomas (2004). Total camera-trap effort comprised 1276 camera traps-day.

Non-volant small mammals (adults<1 kg) were sampled by captures using pitfall and live traps (Sherman and wire-mesh live traps). Pitfall traps were composed of four buckets of 60–108 l separated by 10 m from each other, and disposed in "Y" (one in the centre and the other three in its three extremities) or in line transects (with four buckets by transect). The buckets were connected by drift fences (80 cm high).

Five to ten live traps were disposed in the transect lines, separated 10 m from each other. Wire-mesh traps were placed alternately on the ground and Sherman in the understory (1.5–2 m high) in each transect line. Live traps were baited with a mixture of bananas, pumpkins, bacon, sardine or peanut butter and/or cod-liver oil. Traps were active during 3–10 consecutive nights in ten field expeditions, totalling 18,372 bucket-nights and 4870 trap-nights. Captured small mammals were photographed, identified, and released at the same location where they were captured. Vouchers were only collected when there were doubts regarding the species identification. Voucher specimens were deposited in the Mammal Collection of the Universidade Federal de Santa Maria-UFSM, in Brazil (Appendix 1).

Biogeographical pattern analyses

From the literature, we selected 29 and 23 studies on small-and medium- to large-sized mammals, respectively, to compare with species composition found in the Urucum Mountains. Study sites were from the Amazon, Atlantic forest, Caatinga, Cerrado, Chaco, Chiquitano dry forest, Pantanal and Pampas ecoregions (see Appendix 2 for further geographic information on selected sites) following Olson et al. (2001). For taxonomic

classification, we followed Paglia et al. (2012), except for the genus *Micoureus*, for which we followed Gutiérrez et al. (2010), and *Leopardus* for which we followed Nascimento (2010).

Two binary matrices were constructed based on the presence (1) or absence (0) of all the small- and large-mammal species occurring in the selected sampling sites plus the Urucum Mountains. Only species occurring in at least two sites were considered (see Chao et al. 2005). A Jaccard similarity matrix by the principal coordinate analysis was created in the PAST statistical software (Hammer et al. 2001) for both of the faunas. As a result, we explored a possible biogeographic gradient involving different sites where mammals were surveyed in South America, compared to the mammal fauna found in the Urucum Mountains. We separated all the areas by their vegetation type, in order to compare what ecoregions have faunas that are more similar to that of Urucum. In order to analyse the role of the geographical distance on the ecological gradient of these two faunas (small and large), we applied a Mantel test between the geographical position (latitude and longitude of each area) and the first two PCoA axes resulting from the species composition analyses done separately for the small and large mammal faunas. These PCoA axes show the species compositional similarity among all of the areas sampled, including the Urucum Mountains.

Results

Species composition

Fifty-four non-volant mammal species were recorded at the Urucum Mountains, comprising nine orders and 24 families. Rodentia (18 species), Carnivora (13) and Didelphimorphia (8) were the richest orders, and Cricetidae (11) and Didelphidae (8) were the richest families (Table 2). Medium and large mammals were represented by 32 species while small mammals (marsupials and small rodents) comprised 22 species.

Some large species occurring in the study region are threatened at a national or worldwide level. The giant anteater (*Myrmecophaga tridactyla*), oncilla (*Leopardus guttulus*), puma (*Puma concolor*), jaguarondi (*Puma yagouaroundi*), jaguar (*Panthera onca*), and giant otter (*Pteronura brasiliensis*) are threatened species in Brazil (ICMBio 2014). The tapir (*Tapirus terrestris*) and white-lipped peccary (*Tayassu pecari*) are also considered endangered, but on a global scale (IUCN 2015).

Biogeographical patterns

A matrix of 30 sampling sites (29 areas plus the Urucum) yielded a total of 90 species of small mammals, including 30 marsupials and 60 small rodents in the following family: Echimyidae, Caviidae, Cricetidae and Sciuridae. For large mammals, a matrix of the 24 sampling sites (23 areas plus the Urucum) yielded a total of 75 species, including 23 carnivores, 22 primates, 14 xenarthrans, eight ungulates, seven rodents and one lagomorph.

The small mammals of Urucum Mountains showed a higher similarity to the faunas of the Cerrado and Pantanal ecoregions, in contrast to our predictions, and secondarily with the fauna of the Chaco and Caatinga. Importantly, the Amazon forest had a greater influence than the Atlantic forest on the small-mammal faunal composition in the Urucum Mountain fauna (Figure 2).

The medium and large mammals of the Urucum Mountains also showed a high similarity with the faunas of the Cerrado and Pantanal ecoregions, besides the adjacent area in the Chiquitano dry forest (Amolar region). In a general overview, the Urucum Mountains harbour a mixed composition of large-mammal species, with the Amazon and Atlantic forests having weaker (but still important) influences (Figure 3).

The spatial analyses carried out with the Mantel correlations revealed that there is some influence of the geographical distance on both the small- and large-mammal faunas. However, such an effect was slightly higher for the large mammals ($r=0.42$; $p<0.001$) than the small mammals ($r=0.36$; $p<0.001$).

Discussion

Species composition

The Urucum Mountains maintain 36% and 67% of all non-volant mammalian fauna recorded in the Cerrado and Pantanal, respectively (Paglia et al. 2012). This richness is represented especially by the orders Rodentia, Carnivora and Didelphimorphia. The richness of non-volant mammals (22 small and 32 medium- and large-sized mammals) found in Urucum Mountains is in the same range as those found in the other ecoregions: Cerrado (Rodrigues et al. 2002, Cáceres et al. 2007a), Pantanal (Trolle 2003, Aragona and Marinho-Filho 2009), Atlantic forest (Chiarello 1999, Pardini and Umetsu 2006), and Amazon (Stone et al. 2009). Although there could be some sampling bias in a number of the studies considered here,

Table 2: Species of non-volant mammals detected in the Urucum Mountains, Corumbá, Mato Grosso do Sul state, Brazil, and their occurrence in adjacent ecoregions.[a]

Taxon	Threatened[b]		Vegetation type[c]	Ecoregions[d]							Record type[e]
	Brazil	IUCN		Am	Af	Ce	Ch	Cf	Pa	Pp	
Didelphimorphia (8)											
Didelphidae											
Cryptonanus chacoensis (Tate 1931)	DD		AG, FO				X	X			PI
Didelphis albiventris (Lund 1840)			FO		X	X	X	X	X	X	PI, S, W
Marmosa murina (Linnaeus 1758)			FO	X	X	X	X	X	X		PI
Marmosa (*Micoureus*) *constantiae* (Thomas 1904)	DD		FO	X		X	X	X	X		PI, S
Marmosops ocellatus (Tate 1931)	NT		FO					X			PI
Monodelphis domestica (Wagner 1842)			AG, FO			X	X	X	X		W
Monodelphis kunsi (Pine 1975)			AG, FO	X		X	X	X	X		PI
Philander opossum (Linnaeus 1758)			FO	X		X		X	X		W
Cingulata (2)											
Dasypodidae											
Euphractus sexcinctus (Linnaeus 1758)			AH, FO, SS	X	X	X	X	X	X	X	B, D, T, CT
Dasypus novemcinctus (Linnaeus 1758)			FO	X	X	X	X	X	X	X	B, D, T, CT
Pilosa (2)											
Myrmecophagidae											
Myrmecophaga tridactyla (Linnaeus 1758)	VU	VU	AH, FO, HF, SS	X	X	X	X	X	X	X	T
Tamandua tetradactyla (Linnaeus 1758)			AH, FO	X	X	X	X	X	X	X	D, T, CT
Primates (5)											
Callitrichidae											
Mico melanurus (É. Geoffroy in Humboldt 1812)	NT		FO	X		X		X	X		D, V
Cebidae											
Sapajus cay (Illiger 1815)			FO			X		X	X		D, V, CT
Aotidae											
Aotus azarae (Humboldt 1812)			FO	X				X	X		D, CT
Piteciidae											
Callicebus cf. *pallescens* (Thomas 1907)			FO					X	X		D, V
Atelidae											
Alouatta caraya (Humboldt 1812)	NT		FO		X	X	X	X	X	X	D, V
Lagomorpha (1)											
Leporidae											
Sylvilagus brasiliensis (Linnaeus 1758)			AG, AH, FO, SS	X	X	X	X	X	X	X	D, F, T, CT
Carnivora (13)											
Felidae											
Leopardus pardalis (Linnaeus 1758)			FO	X	X	X	X	X	X	X	T, CT
Leopardus guttulus (Schreber 1775)	EN	VU	FO	X	X	X	X	X	X	X	T
Puma concolor (Linnaeus 1771)	VU		AH, FO	X	X	X	X	X	X	X	T, CT
Puma yagouaroundi (É. Geoffroy 1803)	VU		AH, FO	X	X	X	X	X	X	X	C, T, CT
Panthera onca (Linnaeus 1758)	VU	NT	FO	X	X	X	X	X	X	X	VO, CT
Canidae											
Cerdocyon thous (Linnaeus 1766)			AH, FO, SS	X	X	X	X	X	X	X	D, T, CT
Mephitidae											
Conepatus semistriatus (Boddaert 1785)			FO	X	X	X	X	X	X		T
Mustelidae											
Eira barbara (Linnaeus 1758)			AH, FO	X	X	X	X	X	X		D, T
Galictis cf. *cuja* (Schreber 1776)			FO		X	X	X	X		X	T
Lontra longicaudis (Olfers 1818)	NT	NT	HF	X	X	X	X	X	X	X	F
Pteronura brasiliensis (Gmelin 1788)	VU	EN	HF	X	X	X	X	X	X		D
Procyonidae											
Nasua nasua (Linnaeus 1766)			AG, AH, FO, SS	X	X	X	X	X	X	X	D, T, CT
Procyon cancrivorus (G. Cuvier 1798)			AH, HF, FO	X	X	X	X	X	X	X	T, CT

Table 2 (continued)

Taxon	Threatened[b]		Vegetation type[c]	Ecoregions[d]							Record type[e]
	Brazil	IUCN		Am	Af	Ce	Ch	Cf	Pa	Pp	
Perissodactyla (1)											
Tapiridae											
Tapirus terrestris (Linnaeus 1758)	VU	VU	AH, FO, HF, SS	X	X	X	X	X	X	X	F, D, T, CT
Artiodactyla (4)											
Tayassuidae											
Pecari tajacu (Linnaeus 1758)			FO	X	X	X	X	X	X	X	CT, D, T
Tayassu pecari (Link 1795)	VU	VU	FO	X	X	X	X	X	X	X	D, T
Cervidae											
Mazama americana (Erxleben 1777)	DD	DD	FO	X	X	X	X	X	X	X	CT, D, T
Mazama gouazoubira (Fischer 1814)			AH, FO, SS	X	X	X	X	X	X	X	CT, D, T
Rodentia (18)											
Sciuridae											
Urosciurus spadiceus (Olfers 1818)			FO	X			X	X	X		D, W, CT
Cricetidae											
Calomys cf. *callosus* (Rengger 1830)			AG, FO, SS			X	X	X	X		PI, S
Euryoryzomys nitidus (Thomas 1884)			FO	X				X			PI
Holochilus chacarius (Thomas 1906)			FO	X		X		X			
Hylaeamys megacephalus (Fischer 1814)			FO	X	X	X		X	X		PI
Necromys lasiurus (Lund 1841)			AG, FO, SS	X	X	X	X	X	X	X	PI
Nectomys rattus (Pelzeln 1883)			FO	X		X	X	X	X		W
Oecomys bicolor (Thomas 1860)			FO	X		X		X	X		PI, S
Oecomys mamorae (Thomas 1906)			FO			X		X	X		PI
Oecomys cf. *paricola* (Thomas 1904)			FO	X				X			PI
Oligoryzomys chacoensis (Myers and Carleton 1981)			AG, FO, SS			X	X	X	X		PI
Oligoryzomys nigripes (Olfers 1818)			FO		X	X		X	X	X	PI
Caviidae											
Hydrochoerus hydrochaeris (Linnaeus 1766)			AH, FO, HF	X	X	X	X	X	X	X	F, D, T
Cuniculidae											
Cuniculus paca (Linnaeus 1758)			FO	X	X	X	X	X	X	X	T
Dasyproctidae											
Dasyprocta azarae (Lichtenstein 1823)		DD	FO	X	X	X	X	X	X	X	CT, D, T
Erethizontidae											
Coendou prehensilis (Linnaeus 1758)			FO	X	X	X	X	X	X	X	D, T
Echimyidae											
Proechimys longicaudatus (Rengger 1830)			FO			X	X	X	X		PI, W
Thrichomys fosteri (Thomas 1903)			FO			X	X	X	X		W
Frequency (%)				74.1	61.1	87.0	75.9	100	88.9	50.9	

[a]Number in parentheses indicates the species richness.
[b]Threatened categories follow ICMBio (2014) and IUCN (2015): DD, data deficient; NT, near threatened; VU, vulnerable; EN, endangered.
[c]Vegetation types: AG, altitudinal grasslands; AH, anthropogenic habitats; FO, deciduous and semideciduous forests, riparian forests, and woodland savannah (*cerradão*); HF, humid and floodplain areas; SS, shrubby savanna (*cerrado stricto sensu*).
[d]Distribution in South America ecoregions: Am, Amazon forest; Af, Atlantic forest; Ce, Cerrado; Ch, Chaco; Cf, Chiquitano dry forest, Pa, Pantanal and Pp, Pampas.
[e]Record types: B, burrow; C, carcasses; CT, camera trap; D, direct observation; F, faeces; W, wire-mesh traps; PI, pitfall traps; S, Sherman traps; T, tracks; V, vocalisation.

and because we are using a simple measure of diversity (richness), our current comparison is more general (biome level) than local, accepting some bias in particular studies.

The Urucum Mountains are composed of a mixed vegetation, with elements of deciduous forests and woodland savanna (Veloso et al. 1991). Therefore, the regional biodiversity is expected to be increased, and the faunal composition is formed by both forest and savanna-grassland dweller species. This is particularly important for small mammals (Cáceres et al. 2007b, 2011), which are highly endemic or

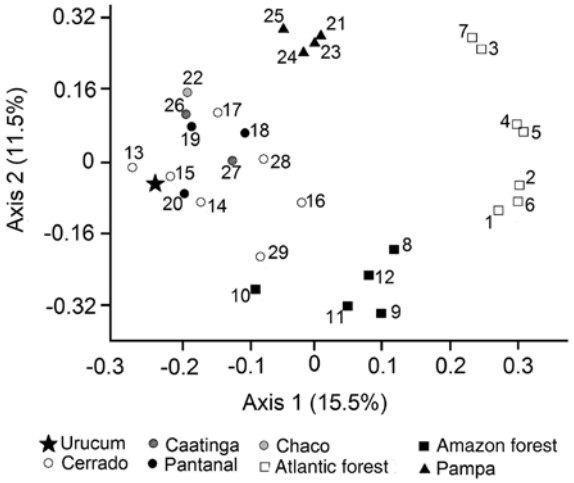

Figure 2: Principal Coordinate Analysis of the similarity (Jaccard) between the small-mammal fauna of the Urucum Mountains (star) compared to other 29 surveyed sites in South America. (See Appendix 2 for studies' descriptions.)

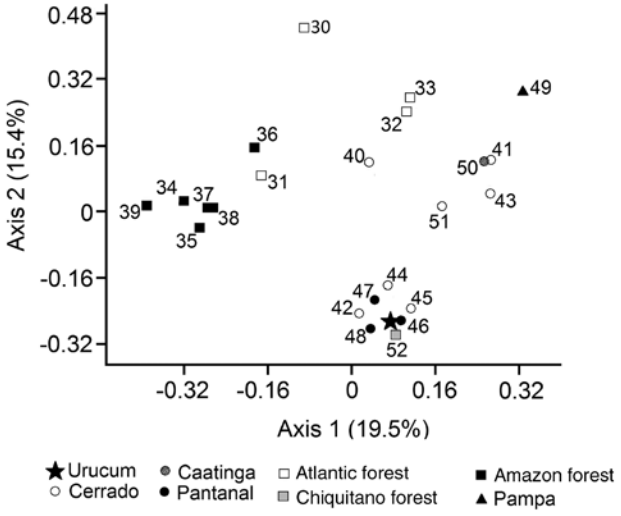

Figure 3: Principal Coordinate Analysis of the similarity (Jaccard) between the large-mammal fauna of the Urucum Mountains (star) compared with the other 23 surveyed sites in South America. (See Appendix 2 for studies' descriptions.)

restricted in their distributions (Paglia et al., 2012). Future systematic surveys should reveal still more species for the region, such as those which are arboreal and nocturnal.

Biogeographical patterns

Contrary to our expectations, the small-mammal community in the Urucum is more similar to that present in the NE-SW diagonal of South America's open areas, comprising the Cerrado, Pantanal and Chaco. Among forested ecoregions, the Amazon forest showed more influence than the Atlantic forest on the Urucum fauna (see Costa 2003 for a molecular perspective). In fact, located in the right margin of the Paraguay River, the Urucum Mountains have direct connection with the southern Amazon dry forests via the northern portion of the Chiquitano dry forest (Emmons and Feer 1997, Olson et al. 2001). The open-area influence at the Urucum is noted by the presence of *Cryptonanus chacoensis*, *Marmosa constantiae*, *Monodelphis domestica*, *Calomys callosus*, *Oecomys mamorae* and *Oligoryzomys chacoensis* (Smith 2009, Bonvicino et al. 2008, Gardner 2008, IUCN 2015), and the Amazon influence is represented by the occurrence of *Philander opossum*, *Euryoryzomys nitidus*, and *Proechimys longicaudatus* (Costa 2003, Cáceres et al. 2008, Gardner 2008). The Atlantic forest representatives of these last genera (e.g. *Philander* and *Euryoryzomys*) do not reach the Urucum.

The small-mammal community of the Urucum Mountains is also composed of species with broad distribution in South America (Tomas et al. 2010a). On the other hand, species with restricted distribution also occur in these mountains, such as the marsupial *Marmosops ocellatus* and the rodent *Oecomys mamorae*, both occurring mainly in the Chiquitano forest and Pantanal wetlands, respectively (Cáceres et al. 2007b, Gardner 2008, Bonvicino et al. 2008).

The large mammal fauna of the Urucum Mountains is similar to those found in the Cerrado, Pantanal and Chiquitano dry forest, in a pattern quite similar to that found for small mammals. The fauna of large mammals at the Urucum Mountains is represented mostly by species with wide distribution in the central portion of South America, except for the Azara's night monkey (*Aotus azarae*), the Chacoan titi monkey (*Callicebus* cf. *pallescens*), the black-tailed marmoset (*Mico melanurus*) and the southern Amazon red squirrel (*Urosciurus spadiceus*) (Reis et al. 2011) which are related to the Amazon forest (Emmons and Feer 1997). Because some large-sized species show restricted distributions for the Chiquitano dry forest domain (as emphasised for some small-mammal species), such as *C.* cf. *pallescens* and *M. melanurus* (Cáceres et al. 2008, Tomas et al. 2010a), this highlights the importance of Urucum Mountains for a regional biodiversity conservation plan (see below).

In general, we believe that the mammal composition of the Urucum Mountains is unique because it has various components (Pott et al. 2000, WWF 2006), but also receives biogeographical influences from adjacent ecoregions, being forest- or grassland-like. This uniqueness is also highlighted by the fact that the region is a kind of peninsula of the Chiquitano dry forest that reaches, in

Brazil, its eastern-most portion, being limited geographically by the Paraguay River and the Pantanal wetlands.

Conservation implications and final considerations

The Chiquitano dry forest is still well preserved when compared to the Atlantic forest in South America (WWF 2006). Furthermore, part of the Chiquitano dry forest was considered a priority area for biodiversity conservation in the Pantanal wetland, known as the "western edge" of the Pantanal B – código 303 (MMA 1999). Although mapped in Brazil by recognised authorities (e.g. Olson et al. 2001, WWF 2006), this ecoregion was not yet recognised as a vegetation formation in this country (see Pott et al. 2000), being treated simply as "deciduous forest", "seasonal forest" or "dry forest" (Vasconcelos and Hoffmann 2006). We stress here that, biogeographically, Chiquitano dry forest is unique and a true part of what is recognised as "Chiquitano dry forest" globally (e.g. Olson et al. 2001, WWF 2006).

This set of extensive and preserved natural areas offer shelter and protection for threatened species, which are dependent on the preservation of large forest patches, such as the tapir (*Tribulus terrestris*), jaguar (*Panthera onca*), puma (*Puma concolor*), white-lipped peccary (*Tayassu pecari*) and oncilla (*Leopardus guttulus*) (Costa et al. 2005, Cáceres and Seidel 2010). Besides, the Urucum Mountains and surroundings still harbour 39 plant species, one invertebrate, one fish, three amphibians, 13 reptiles and 11 bird species, which are noteworthy due to their characteristics, degree of threat, and restricted distribution (Tomas et al. 2010b).

The main threats for mammals of the Urucum Mountains are the loss of habitats by the expansion of cattle ranching and mainly mining activities, especially iron and limestone (Harris et al. 2005, Tomas et al. 2010b). Compensation of impacts from mining is almost non-existent, despite the huge economic importance of this activity directed mainly for export to the international market (Tomas et al. 2010b). The only protected area in the region is a 1.2 km^2 Municipality Park (Piraputangas), which is inadequate in size to guarantee the conservation of the mammal diversity and viable populations of the most area-demanding species, such as the tapir, the white-lipped peccary, and the large carnivores (Tomas et al. 2010b).

The conservation of altitudinal grasslands and shrubby savanna is very critical. These vegetation types have restricted distributions on this region, occupying sparse and small patches located just in the most valuable areas for the iron mining. Therefore, the areas occupied by these vegetation types have been intensively exploited, compromising the conservation of their associated fauna (Tomas et al. 2010b). It is necessary and urgent to map and conserve large areas of remaining altitudinal grasslands in the Urucum Mountains, and produce more data on biodiversity of these upland areas.

The Urucum Mountain range is a region that still maintains a rich non-volant mammal fauna composed especially by species broadly distributed in the Cerrado and the Pantanal ecoregions, but presents some Chacoan and Amazonian species with restricted distributions in Brazil and/or in the Mato Grosso do Sul state. The region still maintains extensive patches of natural environments, especially forests, where endangered and rare species occur, despite the threats caused by habitat loss and fragmentation. The establishment of a network of protected areas in the region is fundamental for the conservation of viable populations of species with restricted distribution in Brazil, as well as to maintain populations of those species that are capable of increasing the rate of regeneration in areas that have already been mined.

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Appendix

Appendix 1: Voucher of small mammals collected in the Urucum Mountains, Mato Grosso do Sul state, southwestern Brazil.

Cryptonanus chacoensis: BRAZIL, **Mato Grosso do Sul**: Corumbá (Santa Cruz Mountain), ♀, 15.XII.01, V.L. Ferreira et al. cols. (UFSM-267).

Marmosa (Micoureus) constantiae: BRAZIL, **Mato Grosso do Sul**: Corumbá (Santa Cruz Mountain), ♂, 17.IX.01, V.L. Ferreira et al. cols. (UFSM-656).

Marmosops ocellatus: BRAZIL, **Mato Grosso do Sul**: Corumbá (Santa Cruz Mountain), ♂, 16.VI.10, G.L. Melo, J. Sponchiado and N.C. Cáceres cols. (UFSM-605).

Monodelphis domestica: BRAZIL, **Mato Grosso do Sul**: Corumbá (Albuquerque district), ♂, 08.XI.09, N.C. Cáceres et al. cols. (UFSM-559).

Monodelphis kunsi: BRAZIL, **Mato Grosso do Sul**: Corumbá (Santa Cruz Mountain), ♂, 26.III.02, V.L. Ferreira et al. cols. (UFSM-265).

Calomys callosus: BRAZIL, **Mato Grosso do Sul**: Corumbá (Santa Cruz Mountain), ♂, 20.IX.03, V.F. Ferreira et al. cols. (UFSM-165).

Euryoryzomys nitidus: BRAZIL, **Mato Grosso do Sul**: Corumbá (Santa Cruz Mountain), ♂, 16.XII.01, V.F. Ferreira et al. cols. (UFSM-261).

Holochilus chacarius: BRAZIL, **Mato Grosso do Sul**: Corumbá (Santa Cruz Mountain), ♀, 17.XII.01, V.F. Ferreira et al. cols. (UFSM-266).

Necromys lasiurus: BRAZIL, **Mato Grosso do Sul**: Corumbá (Santa Cruz Mountain), ♂, 28.II.02, V.F. Ferreira et al. cols. (UFSM-264).

Oecomys bicolor: BRAZIL, **Mato Grosso do Sul**: Corumbá (Santa Cruz Mountain), ♀, 27.II.02, V.F. Ferreira et al. cols. (UFSM-273).

Oecomys mamorae: BRAZIL, **Mato Grosso do Sul**: Corumbá (Santa Cruz Mountain), ♂, 14.XII.01, V.F. Ferreira et al. cols. (UFSM-620).

Oecomys paricola: BRAZIL, **Mato Grosso do Sul**: Corumbá (Santa Cruz Mountain), ♂, 13.XII.01, V.F. Ferreira et al. cols. (UFSM-621).

Oligoryzomys chacoensis: BRAZIL, **Mato Grosso do Sul**: Corumbá (Santa Cruz Mountain), ♂, 20.IX.03, V.F. Ferreira et al. cols. (UFSM-174).

Oligoryzomys nigripes: BRAZIL, **Mato Grosso do Sul**: Corumbá (Urucum Mountain), ♀, 14.VI.10, G.L. Melo, J. Sponchiado and N.C. Cáceres cols. (UFSM-604).

Proechimys longicaudatus: BRAZIL, **Mato Grosso do Sul**: Corumbá (Santa Cruz Mountain), ♀, 30.V.04, L.Z. Prates, C.S. Goulart and N.C Cáceres cols. (UFSM-259).

Appendix 2: List of the decimal coordinate (latitude/longitude) of 29 and 23 study sites used in the similarity analyses for small and large mammals, respectively. Localities are listed by South American countries or Brazilian states. References of each sampling site are given after each geographical coordinates.

Atlantic forest. 1. Rio Casca, Ipanema, Caratinga and Rio Doce State Park 18°–20°S 41°43°W, Minas Gerais (Brazil) – Fonseca and Robinson (1990); **2.** Poço das Antas Biological Reserve 22°30′S 42°15′W, Rio de Janeiro (Brazil) – Castro and Fernandez (2004); **3.** Parque Municipal Lagoa do Peri 27°43′S 48°32′W, Santa Catarina (Brazil) – Graipel et al. (2006); **4.** Parque Estadual Invervales 24°12′S 48°03′W and Serra da Paranapicaba 24°25′S 48°30′W, São Paulo (Brazil) – Vieira and Monteiro-Filho (2003); **5.** Serra da Bocaina National Park 22°40′–23°20′S 44°24′–44°54′W, Rio de Janeiro (Brazil) – Delciellos et al. (2012); **6.** Uma Biological Reserve 15°10′S 39°07′W, Bahia (Brazil) – Pardini (2004); **7.** Parque Estadual do Turvo 27°00′–27°20′S 53°40′–54°10′W, Rio Grande do Sul (Brazil) – Melo et al. (2011); **30.** Atlantic forest reserve 18°12′–19°48′S 39°50′–40°15′W), Espirito Santo (Brazil) – Chiarello (1999); **31.** Reserva Ecológica do Caraguatá 27°25′S 48°51′W and Parque Estadual da Serra do Tabuleiro 27°51S 48°38′W, Santa Catarina (Brazil) – Goulart et al. 2009; **32.** Delciellos et al. (2012); **33.** RPPN Estação Veracel 16°18′S–16°24′S 39°06′–40°00′W, Bahia (Brazil) – Falcão et al. (2012).

Amazon. 8. Peixe-Boi 01°11′S 47°19″W, Paragominas 02°59′–03°39′S 47°25–48°33′W, Santa Bárbara 01°13′S 48°17′W, Pará (Brazil) – Stone et al. (2009); **9.** Kayapó Indigenous Area 7°46′S 51°57′W, Pará (Brazil) – Lambert et al. (2005); **10.** Jauru and Cabaçal rivers 15°15′–15°43′S 58°56′–58°00′W, Mato Grosso (Brazil) – Santos-Filho et al. (2012); **11.** Research near Manaus 03°07S 60°01′W, Manaus (Brazil) – Malcolm (1991); **12.** Provincia de Pachitea 9°37′S 74°56′W, Departamento Ucayali (Peru) – Hutterer et al. (1995); **34.** Carajás National Forest 05°52′–06°33′S 49°53′–50°45′W, Pará (Brazil) – Carvalho et al. (2014); **35.** Humaitá Forest Reserve 9°43′–9°48′S 67°33′–67°48′W, Acre (Brazil) – Botelho et al. (2012); **36.** Maracá Ecological Station 3°15′–3°35′S 61°22′–61°58′W, Roraima (Brazil) – Mendes Pontes (2004). **37.** Stone et al. (2009); **38.** Base Operacional Geólogo Pedro de Moura 04°53′S 65°20′W, Amazonas (Brazil) – Santos and Mendes-Oliveira (2012); **39.** Hutterer et al. (1995).

Cerrado. 13. Dois Irmãos do Buriti and Terenos municipalities 20°30′S 55°18′W, Mato Grosso do Sul (Brazil) – Cáceres et al. (2010); **14.** Emas National Park 18°15′S 52°53′W, Goiás (Brazil) – Rodrigues et al. (2002); **15.** Chapada dos Veadeiros National Park 14°08′S 47°39′W, Goiás (Brazil) – Bonvicino et al. (2005); **16.** Ponte Branca 16°39′S 52°47′W, Mato Grosso and Baliza 16°24′S 52°27′W, Goiás (Brazil) – Bonvicino et al. (1996); **17.** Bodoquena Mountains 21°05′–20°50′S 57°29′–56°37′W, Mato Grosso do Sul (Brazil) – Cáceres et al. (2007a); **28.** Chapada Diamantina 12°38–13°02′S 41°23′–41°18′W, Bahia (Brazil) – Pereira and Geise (2009); **29.** Chapada dos Guimarães 15°27′S 55°45′W, Mato Grosso (Brazil) – Lacher Jr and Alho (2001); **40.** Cáceres et al. (2010); **41.** Rodrigues et al. (2002); **42.** Três Rios farm 16°56′S 46°16′W, Minas Gerais (Brazil) – Lessa et al. (2012); **43.** Jatobá farm 13°40′S 45°35′W, Bahia (Brazil) – Bocchiglieri et al. (2010); **44.** Cáceres et al. (2007a); **45.** Estação Ecológica Serra das Araras 15°27–15°48′S 57°03′–57°19′W, Mato Grosso (Brazil) – Santos-Filho and Silva (2002); **51.** Pereira and Geise (2009).

Pantanal. 18. São Sebastião do Borba farm 16°40′S 56°28′W, Mato Grosso (Brazil) – Layme et al. (2012); **19.** Rio

Negro farm 19°48′–19°57′S 56°19′56°26′W, Mato Grosso do Sul (Brazil) – Andreazzi et al. (2011); **20.** Nossa Senhora do Livramento 16°14′S 56°22′, Mato Grosso (Brazil) – Aragona and Marinho-Filho (2009); **46.** Santa Emília farm 19°30′S 55°36′W, Mato Grosso do Sul (Brazil) – Trolle (2003); **47.** Instituto de Pesquisa do Pantanal 18°30′S 55°18′W, Mato Grosso do Sul (Brazil) – Mamede and Alho (2006); **48.** Descalvados farm 16°43′S 57°44′W and Taiamã Ecological Station 16°50′S 57°35′W, Mato Grosso (Brazil) – Lázari et al. (2013).

Pampa. 21. Taim Ecological Station 32°32′S 52°32′W, Rio Grande do Sul (Brazil) – Sponchiado et al. (2012); **23.** Parque Nacional Lihué Calel 37°53′S 65°33′W, La Pampa-Province (Argentina) – Teta et al. (2009); **24.** Universidade Federal de Santa Maria 29°42′S 53°42′W, Rio Grande do Sul (Brazil) – Santos et al. (2008); **25.** La Poligonal 37°21′S 59°07′W, Buenos Aires-Province (Argentina) – Velasco et al. (2013); **49.** Santos et al. (2008).

Chaco. 22. Fortin Toledo 22°53′S 58°33′W and Filadelfia 22°19′S 60°01′W, Boquerón (Paraguay), Cruce Los Pioneros 22°59′S 59°12′W, Pres. Hayes (Paraguay) – Yahnke (2006).

Chiquitano dry forest. 52. Serra do Amolar 18°18′S 57°30′W and Engenheiro Eliezer Batista Natural Heritage Reserve 18°05′S 57°28′W, Mato Grosso do Sul (Brazil) – Porfirio et al. (2014).

Caatinga. 26. Curaçá 8°59′S 39°54′W, Bahia (Brazil) – Freitas et al. (2005); **27.** A review study – Mares et al. (1985); **50.** Mares et al. (1985).

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