Reptile surveys reveal high species richness in areas recovering from mining activity in the Brazilian Cerrado

Article *in* Biologia · November 2017

DOI: 10.1515/biolog-2017-0138

10 authors, including:


Fabrício Hiroiuki Oda
Universidade Estadual de Maringá


Robson Waldemar Ávila
Universidade Regional do Cariri


Leandro Oliveira Drummond
Federal University of Rio de Janeiro


Danusy Lopes
Universidade Federal de Goiás

DE GRUYTER

Biologia 72/10: 1194—1210, 2017
Section Zoology
DOI: 10.1515/biolog-2017-0138

Reptile surveys reveal high species richness in areas recovering from mining activity in the Brazilian Cerrado

Fabrício H. ODA[1,2], Robson W. ÁVILA[3], Leandro de O. DRUMMOND[4], Danusy L. SANTOS[5], Priscilla G. GAMBALE[5,6], Vinicius GUERRA[5,6], Raísa Romênia S. VIEIRA[7], Tiago S. VASCONCELOS[8], Rogério P. BASTOS[5] & Fausto NOMURA[5]

[1] *Centro Universitário Cesumar, Programa de Pós-Graduação em Promoção da Saúde, 87050-390, Maringá, Paraná, Brazil; e-mails: fabricio_oda@hotmail.com, fabricio.oda@gmail.com*
[2] *Laboratório de Ictioparasitologia, Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura, Universidade Estadual de Maringá, 87020-900, Maringá, Paraná, Brazil*
[3] *Universidade Regional do Cariri, Departamento de Ciências Biológicas, 63105-100, Crato, Ceará, Brazil*
[4] *Universidade Federal do Rio de Janeiro, Programa de Pós-Graduação em Ecologia, 21941-902, Rio de Janeiro, Rio de Janeiro, Brazil*
[5] *Universidade Federal de Goiás, Departamento de Ecologia, Instituto de Ciências Biológicas, Laboratório de Herpetologia e Comportamento Animal, Goiânia, Goiás, Brazil*
[6] *Universidade Estadual de Maringá, Programa de Pós-graduação em Ecologia de Ambientes Aquáticos Continentais, 87020-900, Maringá, Paraná, Brazil*
[7] *Universidade Federal de Goiás, Departamento de Ecologia, Instituto de Ciências Biológicas, Laboratório de Biogeografia da Conservação, 74001-970, Goiânia, Goiás, Brazil*
[8] *Universidade Estadual Paulista, Departamento de Ciências Biológicas, Faculdade de Ciências, 17033-360 Bauru, São Paulo, Brazil*

Abstract: Our study determines the reptile species richness, composition, and habitat use in three areas recovering from mining activity in addition to the adjacent pristine and anthropized areas of a priority region for biodiversity conservation of the Brazilian Cerrado. We also compared our data with published surveys on the Cerrado domain in order to identify areas with unique species composition and/or areas where the reptile composition is more homogeneous. The survey was conducted in the municipality of Niquelândia, northern Goiás state, central Brazil, and involved reptile samplings from different physiognomies and water bodies. We found 47 species, including one crocodilian, one chelonian, two amphisbaenians, 17 lizards, and 26 snakes. The list includes 37 species with large geographic distribution, occurring in other morphoclimatic domains, as well as 10 species which are endemic to the Cerrado. Some species recorded for the region are listed in the Appendices I and II of the CITES. Many reptile species were frequently associated with anthropogenic habitats, while others seem to depend on remnants of pristine habitats. Low similarity was found among the 32 sites considered across the Cerrado domain. Ten sites located in Cerrado regions in contact with the adjacent domains have unique reptile composition, whereas most sites largely located in the central area of the domain have reptile communities which are more homogeneous among them. It is important to conduct long-term studies to have patterns of reptile species composition recognized as well as population decline and/or local extinctions and effective reptile conservation actions, with focus on these sites considering their unique species.

Key words: amphisbaenians; biodiversity conservation; chelonian; crocodilian; lizards; reptile communities; snakes

Abbreviations: ACA, adjacent Cerrado areas; ANA, anthropic areas; ARM, areas recovering from mining activity; VSM, visual search method; PTD, pitfall traps with drift-fences method; BA, Bahia state; DF, Distrito Federal; GO, Goiás state; MA, Maranhão state; MG, Minas Gerais state; MS, Mato Grosso do Sul state; MT, Mato Grosso state; PI, Piauí state; SP, São Paulo state; TO, Tocantins state

Introduction

The Cerrado morphoclimatic domain is among the 35 priority areas for global biodiversity conservation and is regarded as a hotspot for its high amount of endemic and endangered species (Mittermeier et al. 2004). This morphoclimatic domain has a heterogeneous complex of vegetation physiognomies that is essential to determine their rich biota, which has been severely threatened by human activities (Oliveira & Marquis 2002; Mittermeier

* Electronic supplementary material. The online version of this article (DOI: 10.1515/biolog-2017-0138) contains supplementary material, which is available to authorized users.

et al. 2004; Klink & Machado 2005). The current loss of biodiversity in the context of the Cerrado results from activities such as mining, construction of hydroelectric dams, and agricultural expansion (Silvano & Segalla 2005).

Despite the intensive habitat loss and fragmentation, recent studies based on systematic data have revealed that the Cerrado ecoregion has a rich herpetofauna, containing at least 209 amphibian species (108 endemics) and 282 reptile species (103 endemics) (Nogueira et al. 2011; Valdujo et al. 2012). However, this herpetofauna richness is considered underestimated and still poorly understood with most of its areas remaining inadequately sampled (Nogueira et al. 2010).

Studies on environmental impact analysis and wildlife monitoring in hydroelectric projects, despite the enormous environmental and social impacts of dam constructions, often provide valuable information on regional herpetofauna in the context of the affected areas (e.g., Vaz-Silva et al. 2007; Santos et al. 2011; Tavares et al. 2012; Silva et al. 2015). This is the case for the Serra da Mesa mountain range, in northern Goiás state, central Brazil. Regarded as a priority area for Cerrado biodiversity conservation (MMA 2007), new species have been continuously described for Serra da Mesa, such as *Amphisbaena anaemariae* (Vanzolini, 1997), *A. mensae* (Castro-Mello, 2000), *Apostolepis cerradoensis* (Lema, 2003), and *Proceratophrys bagnoi* (Brandão, Caramaschi, Vaz-Silva & Campos, 2013). The filling of the Serra da Mesa hydroelectric power plant reservoir has led the region to lose a total of 1,784 km^2 of a mosaic of Cerrado physiognomies. However, studies on environmental impacts, faunal rescue operations, and monitoring programs have identified a rich herpetofauna in the affected area (Silva Jr. et al. 2005). After the complete flooding of the reservoir, approximately 280 islands were formed with the isolation of hill tops, leading to negative changes in species richness as well as abundance of amphibian anurans and lizards in these new habitats (Brandão & Araújo 2008).

The municipality of Niquelândia is located at Serra da Mesa and known for its nickel ore richness, which implies a modification in its natural landscape by intensive mining activities (Fernandes & Pessôa 2011). Recent studies on anuran diversity encompassing areas recovering from mining activity on Niquelândia have

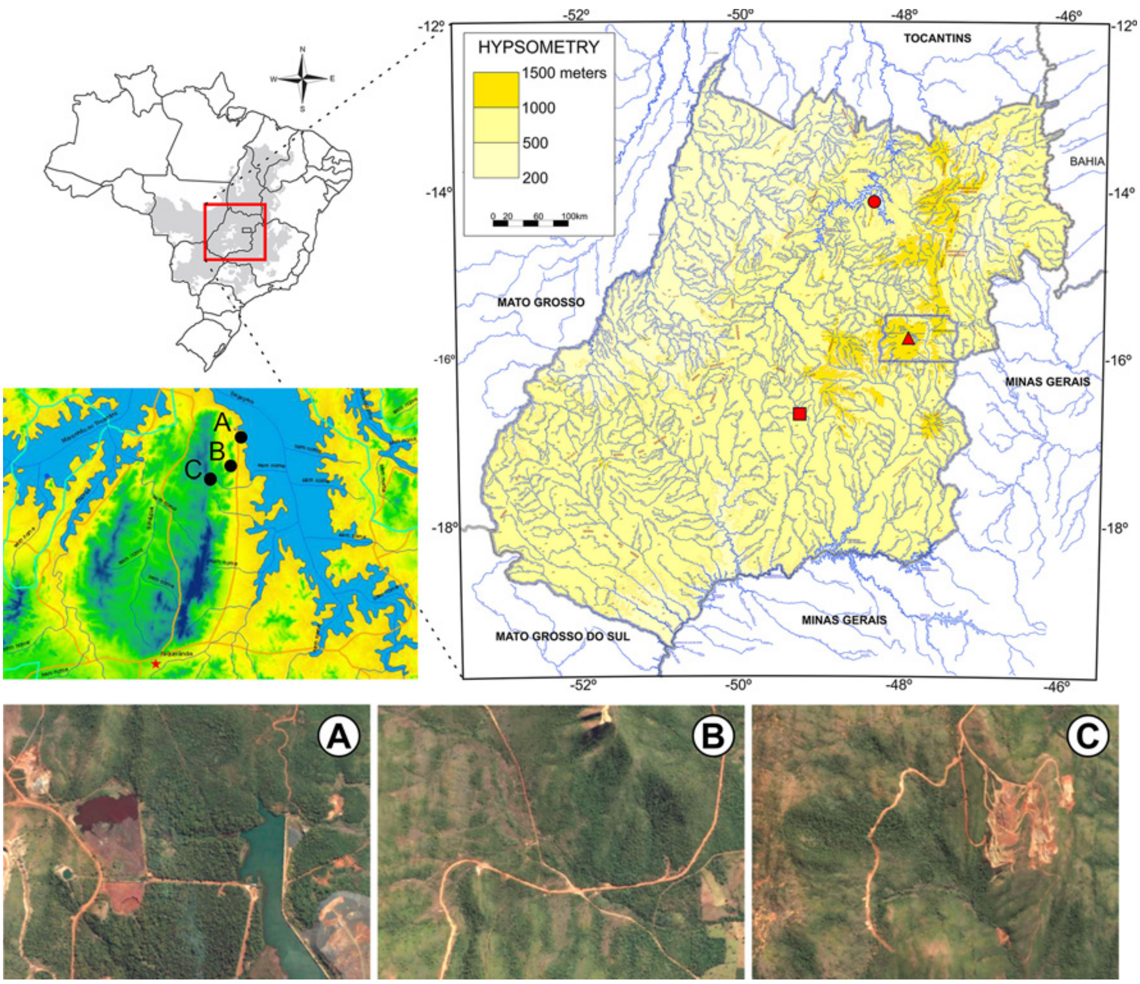

Fig. 1. Schematic map showing the municipalities of Niquelândia (red circle), Brasília (red triangle, Distrito Federal), and Goiânia (red square). Sites surveyed in 2005/2006 and 2009/2010 for areas recovering from mining activity: ARM 1 (A), ARM 2 (B), ARM 3 (C). See surveyed sites descriptions in Table S1 (electronic supplementary material). Map of Goiás state modified from Mapa Físico IBGE (2015).

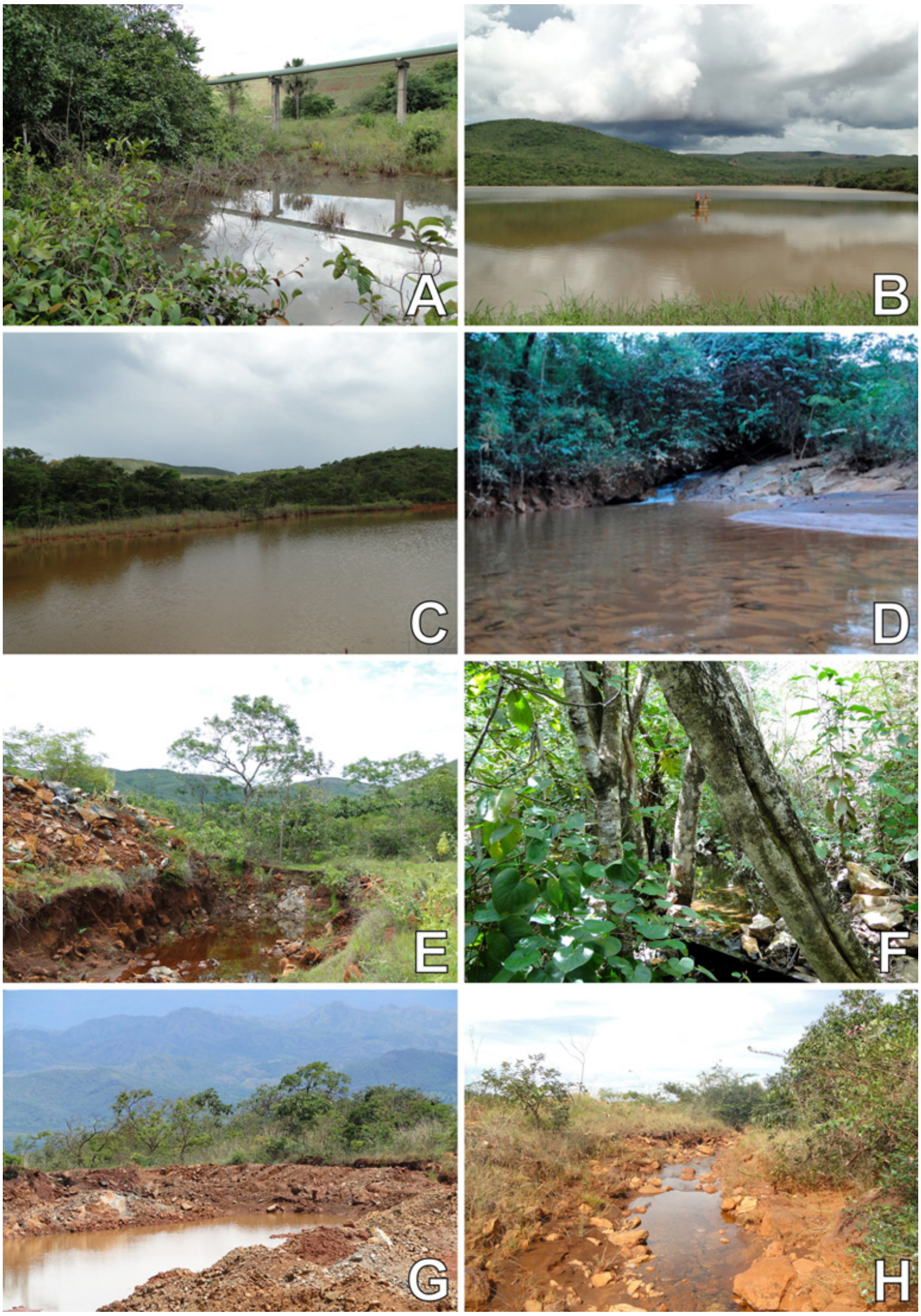

Fig. 2. Cerrado physiognomies, anthropized areas, and water bodies surveyed using visual search method in February and May 2014 in adjacent Cerrado areas in the Serra da Mesa region, municipality of Niquelândia, northern Goiás state, central Brazil: VSM 1.3 (A), VSM 1.4 (B), VSM 1.5 (C), VSM 2.1 (D), VSM 2.2 (E), VSM 2.3 (F), VSM 2.4 (G), VSM 2.5 (H). See surveyed sites descriptions in Table S2 (electronic supplementary material). Photos: Drummond L.O. (all photos).

found high species richness due to habitat heterogeneity provided by the recovering vegetation associated with the natural water bodies and artificial ponds formed inside exhausted mines (Oda et al. 2009; Nomura et al. 2012). However, there is no record of ecological information regarding the reptiles found in areas recovering from mining activity in this region.

Our study brings information on the species richness, composition, habitat use, and conservation status of reptile species obtained from surveys in areas recovering from mining activity as well as from an environmental impact study encompassing the municipality of Niquelândia, Serra da Mesa region, northern Goiás state, central Brazil. We also surveyed the herpetofaunal list of species in the literature along the Cerrado domain in order to understand the structuring of the species composition across the area, identifying areas with unique species composition and/or areas where the herpetofaunal composition is more homogeneous among the selected sites.

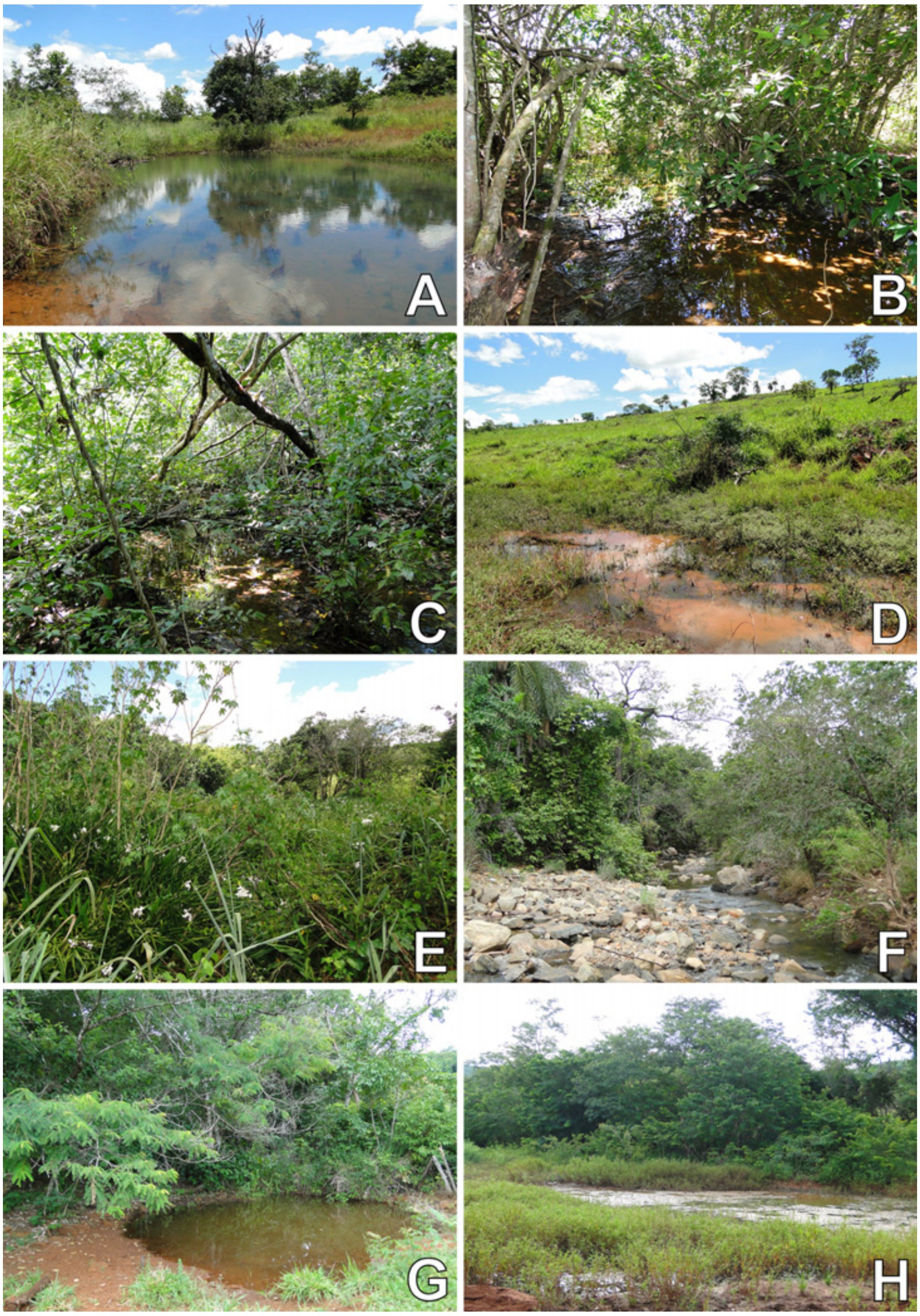

Fig. 3. Cerrado physiognomies, anthropized areas, and water bodies surveyed using visual search method in February and May 2014 in adjacent Cerrado areas in the Serra da Mesa region, municipality of Niquelândia, northern Goiás state, central Brazil: VSM 3.1 (A), VSM 3.2 (B), VSM 3.3 (C), VSM 3.4 (D), VSM 3.5 (E), VSM 4.1 (F), VSM 4.3 (G), VSM 4.4 (H). See surveyed sites descriptions in Table S2 (electronic supplementary material). Photos: Drummond L.O. (all photos).

Material and methods

Study areas

Our study was conducted in the municipality of Niquelândia (14°09′34″ S, 48°20′06″ W), located in the Serra da Mesa region, Upper Tocantins River basin, northern Goiás state, central Brazil (Fig. 1). This region presents great variety of rocks from its crystalline base with high levels of laterites (Latrubesse 2005). It has a tropical climate marked with two well-defined seasons (wet summer and dry winter), classified as Aw in the Köppen classification system (Peel et al. 2007). The original vegetation in the region consisted of different Cerrado physiognomies (Oliveira-Filho & Ratter 2002) and a structure highly influenced by the variation in concentrations of nickel, cobalt, chromium, and magnesium in soil (Brooks et al. 1990).

Reptile surveys

In order to analyze the reptile fauna of three areas recovering from mining activity (ARM), we surveyed water bodies and the following physiognomies within areas: cerrado *sensu stricto* (CE), valley-side marshy grasslands – *veredas* (VE), hydromorphic grassland (HG), rocky grassland – *campo rupestre* (RG), mesophytic semideciduous forest (SF), and closed woodland – *cerradão* (CW; see detailed description of sampled points in supplementary Table S1).

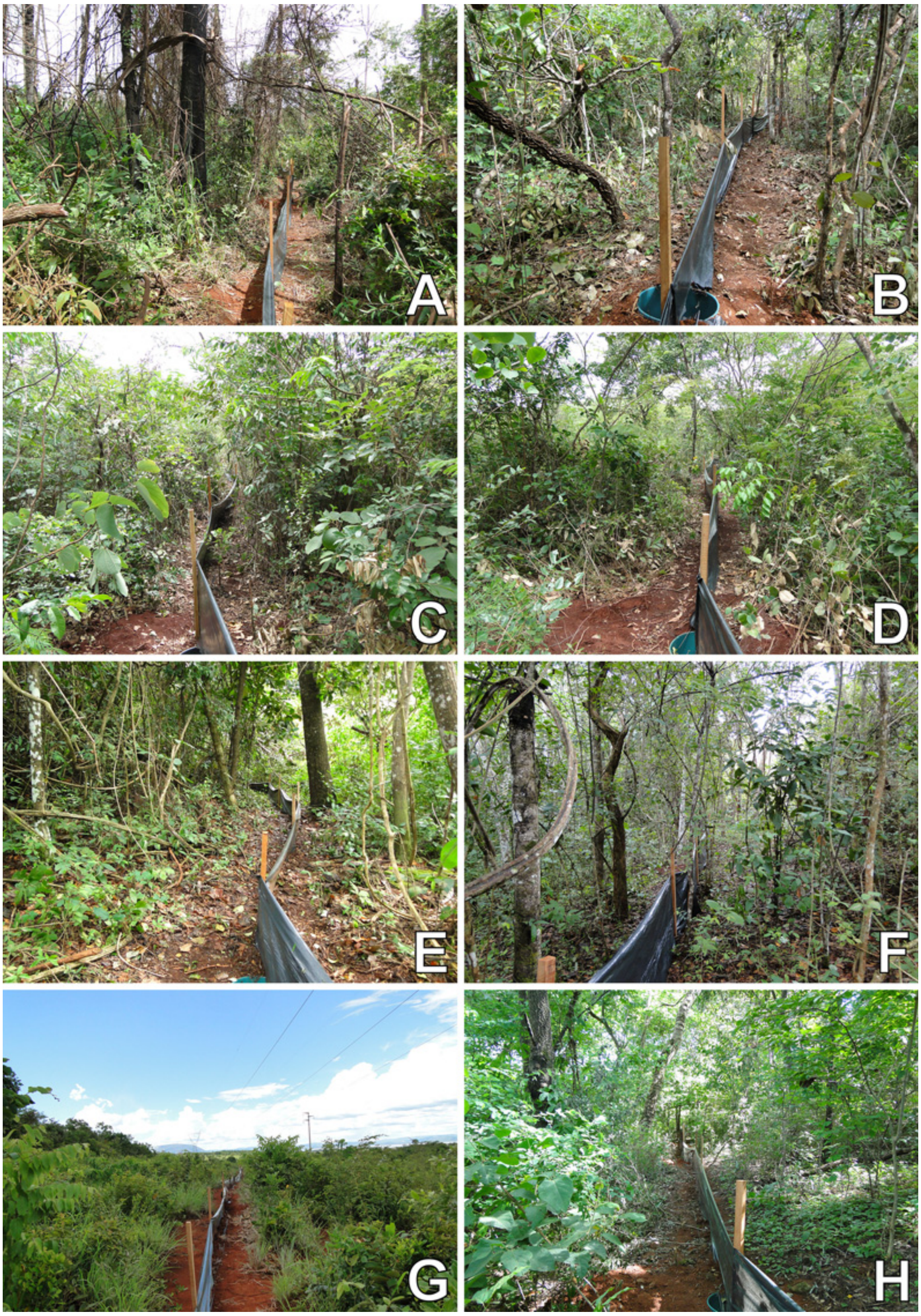

Fig. 4. Cerrado physiognomies and anthropized areas surveyed using pitfall traps with drift-fences in February and May 2014 in adjacent Cerrado areas in the Serra da Mesa region, municipality of Niquelândia, northern Goiás state, central Brazil: PTD 1.1 (A), PTD 1.2 (B), PTD 2.1 (C), PTD 2.2 (D), PTD 3.1 (E), PTD 3.2 (F), PTD 4.1 (G), PTD 4.2 (H). See surveyed sites descriptions in Table S3 (electronic supplementary material). Photos: Drummond L.O. (all photos).

These areas had been explored along approximately 30 years for extraction of soil with high nickel concentrations. The nickel extraction was conducted through the surface mining method (i.e., open pit mining), which is used to extract minerals found near the surface by means of a surface pit, excavated with one or more horizontal benches (Hartman & Mutmansky 2002). Mining activity in Niquelândia has not only changed its local landscape and topography due to soil extraction, it has also led to habitat loss with the deforestation of the mining areas (Nomura et al. 2012). Since 2007, though, the exhausted mines have been reconstituted and reforested (Nomura et al. 2012).

We performed the surveys over two time periods. The first inventory occurred between October 2005 and August 2006 and included eight field surveys of six days each, totalizing 48 days of sampling. The second inventory occurred

Table 1. Locations within the Cerrado domain with comparison of its reptile assemblages and the respective record for the municipality of Niquelândia, Goiás state, central Brazil. Only squamata reptile species were considered in the analyses.

N	Location	Ns	Ch	Cr	Lz	Am	Sn	Source
1	Serra do Gado Bravo, MA	29	2	-	12	2	13	Barreto et al. (2007)
2	Paquetá farm, PI	31	1	1	14	1	14	Silva et al. (2015)
3	Uruçuí-Una Ecological Station, PI	64	1	1	19	4	39	Dal Vechio et al. (2013)
4	Serra das Confusões National Park, PI	47	2	–	21	4	20	Dal Vechio et al. (2016)
5	Grande Sertão Veredas National Park, BA/MG	50	–	–	18	2	9	Recoder & Nogueira (2007)
6	Campo das Vertentes and Serra das Vertentes, MG	31	2	–	9	2	18	Sousa et al. (2010)
7	Unilavras-Boqueirão Biological Reserve, MG	17	–	–	11	–	6	Novelli et al. (2012), Lucas et al. (2016)
8	Serra do Ouro Branco, MG	43	–	–	15	–	28	São Pedro & Pires (2009), Rosário Cruz et al. (2014)
9	Serra de São José, MG	29	–	–	12	1	16	Rios et al. (2017)
10	Batalha Hydroeletric Power Plant, MG/GO	54	2	1	17	2	32	Lagos et al. (2017)
11	Assis Ecological Station and municipality of Assis, SP	53	–	–	10	4	39	Araujo & Almeida-Santos (2011)
12	Aporé-Sucuriú Complex, MS/SP/MG/GO	36	–	1	17	4	14	Uetanabaro et al. (2006)
13	Serra da Bodoquena National Park, MS	25	1	1	15	1	7	Uetanabaro et al. (2007)
14	Ponte de Pedra Hydroeletric Power Plant, MT/MS	72	2	1	23	8	40	Silva Jr. et al. (2009)
15	Middle Aporé River, MS/GO	33	–	1	14	–	18	Ramalho et al. (2014)
16	Meandros do rio Araguaia Environmental Protection Area, GO/MT	28	–	–	13	15	–	Santos et al. (2008)
17	Manso Hydroeletric Power Plant region, MT	78	2	2	26	4	44	Strüssmann (2000)
18	Entre Rios Hydroelectric Power Plant, MT	24	1	–	12	11	–	Silva et al. (2015)
19	Municipality of Alto Araguaia, MT	13	1	–	8	4	–	Mendes-Pinto & Miranda (2011)
20	Municipality of Nobres, MT	28	–	–	13	14	1	Santos et al. (2011)
21	Santa Edwiges I and II Hydroeletric Power Plant, GO	45	–	–	14	3	28	Cintra et al. (2009)
22	Southeastern Goiás state, GO	40	2	1	13	21	3	Santos et al. (2014)
23	National Forest Silvânia, GO	32	1	–	14	17	–	Morais et al. (2012)
24	Upper Tocantins River, GO	47	–	–	13	27	7	Moreira et al. (2009)
25	Emas National Park, GO	87	–	–	27	54	6	Valdujo et al. (2009)
26	Espora Hydroeletric Power Plant, GO	71	2	1	18	45	5	Vaz-Silva et al. (2007)
27	Areas recovering and municipality of Niquelândia, GO	47	1	1	17	2	26	This study
28	Luís Eduardo Magalhães Hydroeletric Power Plant, TO	111	6	2	26	7	70	Pavan & Dixon (2004)
29	Jalapão region, TO	88	1	2	27	6	52	Vitt et al. (2005), Recoder et al. (2011)
30	Águas Emendadas Ecological Station, DF	52	2	2	17	2	29	Brandão & Araújo (1998)
31	Cafuringa Environmental Protection Area, DF	48	3	–	19	2	24	Brandão et al. (2006)
32	IBGE Biological Reserve, DF	63	1	–	20	5	37	Colli et al. (2011)

Abbreviations: Ns – number of species; Ch – Chelonian; Cr – Crocodilian; Lz – Lizard; Am – Amphisbaenian; Sn – Snake.

between October 2009 and April 2010 and involved seven field surveys of six days each, numbering 42 days of sampling.

Reptile specimens were surveyed using diurnal and nocturnal visual searches (VSM; Crump & Scott Jr. 1994), pitfall traps with drift–fences (PTD; Cechin & Martins 2000), and occasional encounters. We conducted the visual searches at the margin of water bodies (streams, ponds, and reservoirs) as well as in both open and forested areas. We used ten groups of pitfall traps per area, each consisting of three buckets (60 L) arranged in three "Y"-shaped drift–fences (50 cm × 10 m), numbering 30 buckets. Incidental encounters corresponded to records of reptiles found alive or dead both inside and outside the studied areas, as well as in anthropic areas (ANA): access roads (AR), vicinity of human habitations (VH), pasture areas (PT), eucalypt forest (EF), and water bodies (WB). In addition to the reptiles found during our study, we improved our species list by using records based on the specimens collected (with the same above mentioned survey methods, but including pitfalls arranged in linear transects constituted of 10 buckets; see detailed description and photos of the sampling areas in electronic supplementary Table S2 and S3 and Figs 2–4) from an environmental impact study performed between February and May 2014, which took place in adjacent Cerrado areas (both pristine and anthropized; ACA) to the study site. Voucher specimens were housed at the Zoological Collection of the Universidade Federal de Goiás (ZUFG).

Conservation status, reptile species list surveys and data analysis
We obtained the conservation status of each reptile species from the Appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2015) as well as from the red list of threatened Brazilian Fauna (MMA 2014).

In order to assess the similarity between the compositions of reptile communities in other surveyed sites of the Brazilian Cerrado, we established a comparison of our data

Table 2. Reptile species recorded in areas recovering from mining activity and adjacent Cerrado areas in the municipality of Niquelândia, northern Goiás state, central Brazil.

Species	Surveyed areas					Regions	Conservation status	
	2005/2006 and 2009/2010				2014			
	ANA	ARM 1	ARM 2	ARM 3	ACA		CITES	Brazil
Chelonia								
Chelidae								
Phrynops geoffroanus (Schweigger, 1812)	WB	WB	WB	WB	WB	Am, Af, Ca	NA	LC
Crocodylia								
Alligatoridae								
Paleosuchus palpebrosus (Cuvier, 1807)	WB	WB	WB		WB	Am, Af, Ca, Pn*	II	LC
Squamata								
Anguidae								
Ophiodes sp. (aff. *striatus*)	AR					Ca, Af, Ch	NA	NA
Dactyloidae								
Norops brasiliensis (Vanzolini & Williams, 1970)		SF, CE	SF, CE		SF, CE	Am, Ca	NA	LC
Gekkonidae								
Hemidactylus mabouia (Moreau de Jonnès, 1818)	VH				VH	Am, Af, Ch, Ca, Pn	NA	NA
Gymnophthalmidae								
Micrablepharus atticolus Rodrigues, 1996			CE	CE, VE	CE	END	NA	LC
Micrablepharus maximiliani (Reinhardt & Luetken, 1862					CE	Ca, Ch	NA	LC
Colobosaura modesta (Reinhardt & Luetken, 1862)		SF		VE	SF, CE	Am	NA	LC
Cercosaura ocellata Wagler, 1830					PT	Am, Af	NA	LC
Iguanidae								
Iguana iguana (L., 1758)	VH				AR	Am, Ca	II	LC
Mabuidae								
Copeoglossum nigropunctatum (Spix, 1825)		SF, CE	SF, CE		SF	Am	NA	LC
Notomabuya frenata (Cope, 1862)		SF, CE	SF, CE			Ch, Af	NA	LC
Phyllodactylidae								
Gymnodactylus amarali Barbour, 1925					SF	END	NA	NA
Polychrotidae								
Polychrus acutirostris Spix, 1825		SF		HG	SF	Ca, Ch	NA	NA
Sphaerodactylidae								
Coleodactylus brachystoma (Amaral, 1935)		SF, CE	SF, CE		SF, RF	END	NA	NA
Teiidae								
Ameiva ameiva (L., 1758)		SF, CE	SF, CE	VE, HG	EF, PT	Am, Af, Ch, Ca	NA	NA
Ameivula ocellifera (Spix, 1825)				RG	PT	Am, Af, Ch, Ca	NA	NA
Salvator merianae (Duméril & Bibron, 1839)		SF, CE	SF, CE	RG		Af, Am, Ca	II	NA
Tropiduridae								
Tropidurus oreadicus Rodrigues, 1987		SF, CE	SF, CE	VE	SF, RF, CE, PT	Am	NA	NA
Amphisbaenidae								
Amphisbaena alba L., 1758	VH, AR				VH	Am, Ca, Af, Ch	NA	LC
Amphisbaena anaemariae Vanzolini, 1997					SF	END	NA	LC
Aniliidae								
Anilius scytale (L., 1758)					SF	Am	NA	NA
Anomalepididae								
Liotyphlops cf. *beui*					SF	Af	NA	NA
Boidae								
Boa constrictor (Stull, 1932)	VH					Am, Ca, Ch, Af,	I/II	NA
Epicrates crassus Cope, 1862					PT	END	NA	NA
Eunectes murinus (L., 1758)	WB					Am, Ch	II	NA
Colubridae								
Chironius flavolineatus (Jan, 1863)					PT	END	NA	NA
Drymarchon corais (Boie, 1827)			CE			Am, Af, Ca	NA	NA
Mastigodryas boddaerti (Sentzen, 1796)			CE			Am	NA	NA
Oxybelis aeneus (Wagler in Spix, 1824)				CW		Am, Ca	NA	NA
Spilotes pullatus (L., 1758)	VH		CE	VE		Am, Af	NA	NA

Table 2. (continued)

Species	Surveyed areas					Regions	Conservation status	
	2005/2006 and 2009/2010				2014			
	ANA	ARM 1	ARM 2	ARM 3	ACA		CITES	Brazil
Dipsadidae								
Atractus pantostictus Fernandes & Puorto, 1994	VH					Af	NA	NA
Sibynomorphus mikanii (Schlegel, 1837)	AR				SF	Pp, Af	NA	NA
Taeniophallus occipitalis (Jan, 1863)	AR					Ch, Ca	NA	NA
Philodryas olfersii (Liechtenstein, 1823)	VH			VE	PT	Am, Af, Ch, Ca, Pp	NA	NA
Oxyrhopus trigeminus Duméril, Bibron & Duméril, 1854		SF			VH, AR	Ca, Ch	NA	NA
Phimophis guerini (Duméril, Bibron & Duméril, 1854)	PT					Ch, Pn	NA	NA
Pseudoboa nigra (Duméril, Bibron e Duméril, 1854)					AR	Ca	NA	NA
Erythrolamprus almadensis (Wagler in Spix, 1824)	AR					Ch, Ca	NA	NA
Erythrolamprus poecilogyrus (Wied, 1825)			CE			Am, Af, Ca, Ch	NA	NA
Erythrolamprus reginae (Amaral, 1935)					EF	Am, Af, Ca, Ch	NA	NA
Xenodon merremii (Wagler, 1824)	VH		CE	VE	SF	Ch, Ca	NA	NA
Xenopholis undulatus (Jensen, 1900)		SF				END	NA	NA
Leptotyphlopidae								
Trilepida fuliginosa (Passos, Caramaschi & Pinto, 2006)		SF			PT	END	NA	NA
Viperidae								
Bothrops moojeni Hoge, 1966			CE		SF, RF	END	NA	NA
Bothrops pauloensis Amaral, 1925	VH					END	NA	NA
Crotalus durissus L., 1758	AR		CE	HG	PT	Ca, Am	III	NA
Species richness by area	18	15	18	13	31			

Surveyed areas: ANA – anthropic areas; ARM – areas recovering from mining activity; ACA – adjacent Cerrado areas (pristine and anthropic areas). Surveyed habitats: WB – water bodies; AR – access roads; PT – pastures areas; VH – vicinity of human habitations; EF – eucalypt forest; SF – mesophytic semideciduous forest; RF – riparian forest; CE – cerrado *sensu stricto*; VE – valley-side marshy grasslands; HG – hydromorphic grassland; CW – closed woodland; RG – rocky grassland. Regions: Am – Amazonia; Af – Atlantic Forest; Ca – Caatinga; Ch – Chaco; Pn – Pantanal (* = Pantanal surrounding areas); Pp – Pampas; END – Cerrado endemic (Distribution patterns of squamate reptiles based on Nogueira et al. 2011; crocodilian on Campos et al. 2013; and chelonian based on Vogt et al. 2015). Conservation status: Appendices CITES: I – containing species threatened with extinction (trade in specimens of these species is permitted only in exceptional circumstances); II – containing species not necessarily threatened with extinction, but whose trade must be controlled in order to avoid utilization incompatible with their survival; NA – not assessed.

and published surveys on this same morphoclimatic domain (Table 1). Specifically, we generated a presence/absence matrix derived from the nominal reptile species found at each site, ignoring species which had not been identified until specific level. This database was used to calculate the "local contribution to beta diversity" (LCBD; sensu Legendre & De Cáceres 2013) of each site. In summary, the LCBD values represent the degree of uniqueness of the sampling units in terms of community composition (Legendre & De Cáceres 2013). Later on, sites which contribute more (large LCBD values) or less (lower LCBD values) to the overall reptile composition in the Cerrado domain could be detected among the selected sites. Since the variation in species composition among sites can be related to either species turnover or loss of species, we decomposed the LCBD values into turnover and nestedness components (Legendre 2014) in order to enable the identification of the beta diversity components pronounced on the beta diversity structure of the reptile species composition. The LCBD values, as well as the turnover and nestedness indices, were derived from the Jaccard dissimilarity index of the Baselga family presence-absence data, as described in Legendre (2014). These analyses were run in R using the scripts provided in Legendre & De Cáceres (2013) and Legendre (2014).

Results

Areas surveyed between 2005/2006 and 2009/2010 (ARM and ANA), presented local species richness varying from 13 to 18 (mean ± standard deviation: 16 ± 2.45 species), numbering 37 species. Areas surveyed in 2014 (ACA) presented 31 reptile species. Considering all inventories, we recorded a total of 47 reptile species distributed in 20 families, including 26 snakes, 17 lizards, two amphisbaenians, one chelonian (*Phrynops geoffroanus*), and one crocodilian (*Paleosuchus palpebrosus*) (Table 2; Fig. 5). Regarding lizards, the most speciose families were Gymnophthalmidae and Teiidae, with four species each, followed by Mabuyidae, and Amphisbaenidae, with two species each, as well as Anguidae,

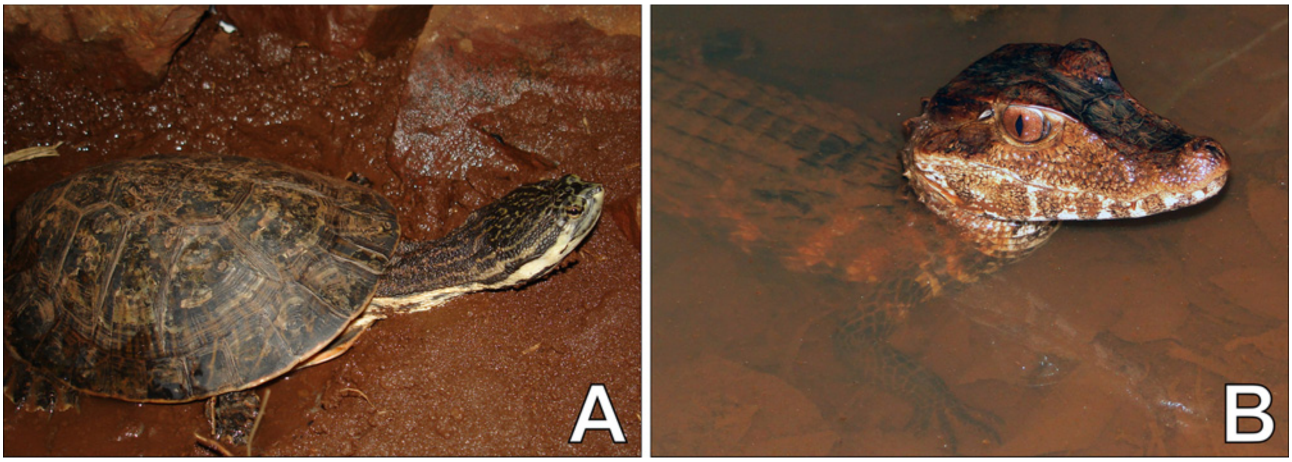

Fig. 5. Chelonian and crocodilian species recorded in the municipality of Niquelândia, northern Goiás state, central Brazil. *Phrynops geoffroanus* (A), *Paleosuchus palpebrosus* (B). Photos: Oda F.H. (A), Drummond L.O. (B).

Dactyloidae, Gekkonidae, Phyllodactylidae, Polychrotidae, and Sphaerodactylidae, with a single species each (Table 2; Fig. 6). Amongst the snakes, the family with the highest species richness was Dipsadidae (12 species), followed by Colubridae (five species), Viperidae (three species), Boidae (three species), Leptotyphlopidae, Aniliidae, and Anomalepididae (one species each) (Table 2; Figs 7–8).

Regarding habitat use, we found chelonians (*Phrynops geoffroanus*) and crocodilians (*Paleosuchus palpebrosus*) associated only with water bodies of different types (e.g., ponds, streams and reservoirs) within pristine and anthropic areas. *Amphisbaena alba* was found exclusively in anthropic areas (VH, AR), and *A. anaemariae* only in pristine areas (SF). Amongst lizards, five species (29%) were recorded in only one type of environment (AR, VH, CE, PT, SF). Anthropic areas had the lowest species richness – only seven species, including four recorded exclusively in this type of environment, while pristine areas had 10 out of 13 species in the same condition. Open and forested pristine environments presented similar species richness, with respectively three and one species being exclusively recorded in each, and nine species recorded in both types of environments (Table 2).

Most of the snake species (69%) were recorded in only one type of environment (VH, PT, WB, CE, CW, AR, EF, SF). Anthropic areas had the highest species richness – 11 out of 18 species recorded exclusively for this environment, while pristine areas had slightly lower species richness, with 15 species, including eight recorded only in this type of environment. Open and forested environments presented similar species richness, with respectively six and seven species recorded exclusively for each, and two species recorded in both open and forest environments (Table 2).

Our list of reptiles included 37 species (79%) with distribution encompassing more than one morphoclimatic domain, and 10 species (21%) endemic to the Cerrado (*Micrablepharus atticolus*, *Gymnodactylus amarali*, *Coleodactylus brachystoma*, *Amphisbaena anaemariae*, *Epicrates crassus*, *Chironius flavolineatus*, *Xenopholis undulatus*, *Trilepida fuliginosa*, *Bothrops moojeni*, and *Bothrops pauloensis*). None of the species registered are listed in the current Brazilian official list of endangered species, but some of the medium and large reptile species recorded in the region, such as *Paleosuchus palpebrosus*, *Iguana iguana*, *Salvator merianae*, *Boa constrictor amarali*, *Eunectes murinus*, and *Crotalus durissus*, are listed in the Appendices I and II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Table 2).

Local herpetofauna composition in the inventories inside the Cerrado domain surveyed in this study was found to have low similarity (Fig. 9), which is mainly determined by species turnover among areas, with low contribution of species loss (Fig. 9). Among the 32 sites considered across the Cerrado domain, ten have differentiated species composition, i.e. higher number of exclusive reptile species occurring at these sites, as indicated in their high and significant Local Contribution to Beta Diversity values (pLCBD < 0.05) (Fig. 10). These sites are mainly located in Cerrado regions in contact with the adjacent domains, such as the Pantanal floodplain, Atlantic and Amazon Forests (Fig. 10). In contrast, most sites, especially those in the central region of Cerrado, have low LCBD values, meaning that the reptile communities are more homogeneous (Fig. 10).

Discussion

Our study has a reptile richness corresponding to about 46% of the regional species pool (103 species) known to inhabit the Tocantins River Valley (Silva Jr. et al. 2005). Considering that the size of the surveyed areas or the sampling effort may influence the amount of species surveyed, our records on species richness are similar to those from termite mounds in contiguous reservoir areas of the Serra da Mesa and Cana Brava hydroelectric power plant (47 species; Moreira et al. 2009) as well as other areas in the Cerrado (Recoder et al. 2011). Some of the surveyed sites in Cerrado have been reported to show lower reptile richness than recovering

Fig. 6. Lizard and amphisbaenian species recorded in the municipality of Niquelândia, northern Goiás state, central Brazil: *Ophiodes* sp. (aff. *striatus*) (A), *Norops brasiliensis* exhibiting the dewlap (B), *Norops brasiliensis* (C), *Micrablepharus maximiliani* (D), *Colobosaura modesta* (E), *Cercosaura ocellata* (F), *Iguana iguana* (G), *Copeoglossum nigropunctatum* (H), *Notomabuya frenta* (I), *Gymnodactylus amarali* (J), *Polychrus acutirostris* (K), *Coleodactylus brachystoma* (L), *Ameiva ameiva* (M), *Ameivula ocellifera* (N), *Salvator merianae* (O), *Tropidurus oreadicus* (P), *Amphisbaena alba* (Q), *Amphisbaena anaemariae* (R). Photos: Kopp K.A. (A), Oda F.H. (C, H, I, P), Drummond L.O. (B, D, E, F, J, K, L, M, N, Q, R), Pinheiro D.G. (G), Heming N.M. (O).

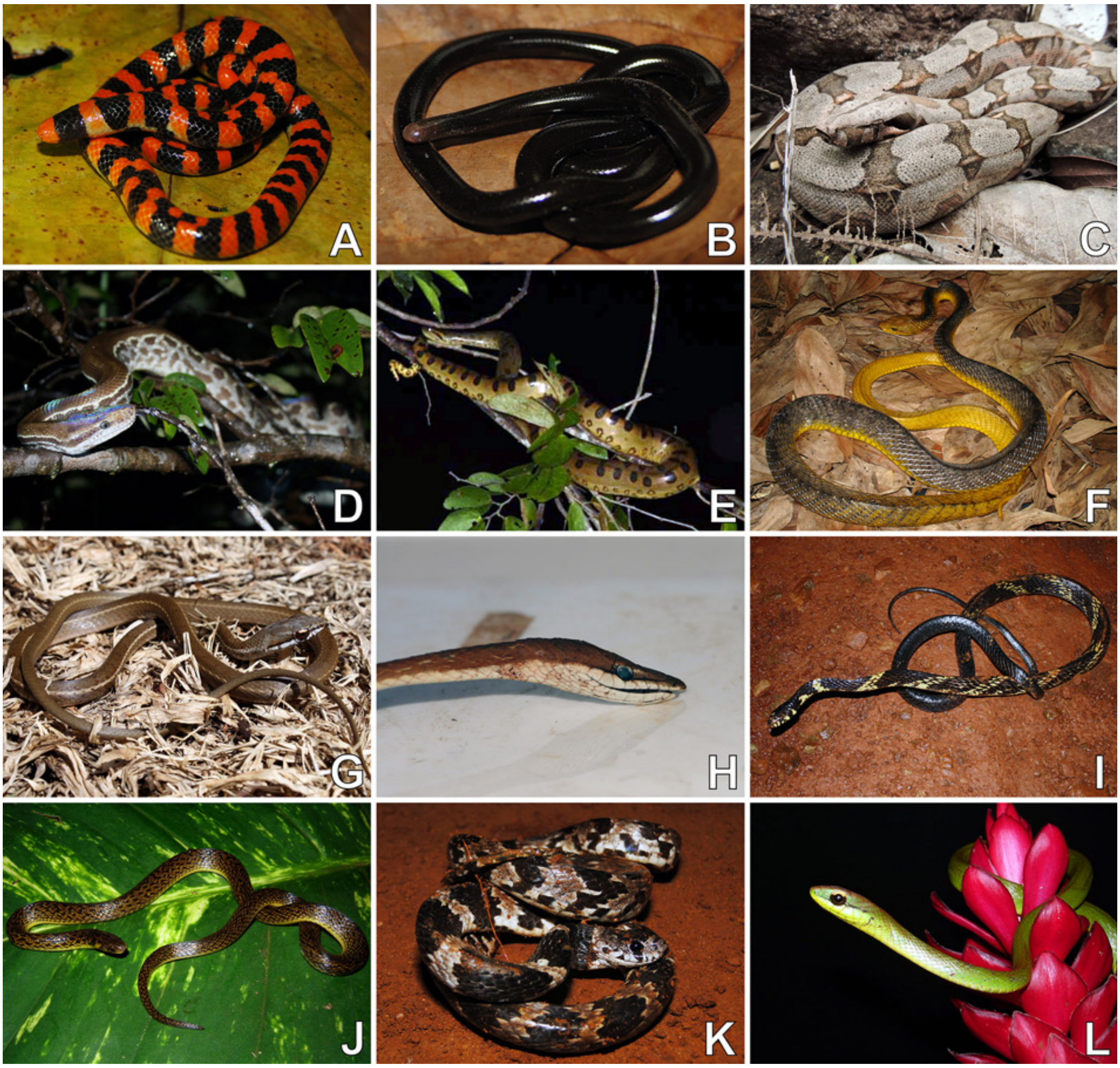

Fig. 7. Snake species recorded in the municipality of Niquelândia, northern Goiás state, central Brazil: *Anilius scytale* (A), *Liotyphlops* cf. *beui* (B), *Boa constrictor amarali* (C), *Epicrates crassus* (D), *Eunectes murinus* (E), *Drymarchon corais* (F), *Mastigodryas boddaerti* (G), *Oxybelis aeneus* (H), *Spilotes pullatus* (I), *Atractus pantostictus* (J), *Sibynomorphus mikanii* (K), *Philodryas olfersii* (L). Photos: Drummond L.O. (A, B, K), Assis T. (C), Guerra V. (D, G, I), Heming N.M. (E), Oda F.H. (F, H, J, L).

areas in Niquelândia (Uetanabaro et al. 2007; Morais et al. 2012; Ramalho et al. 2014; Santos et al. 2014; Silva et al. 2015), while other studies have reported higher richness against our results (Silva Jr. et al. 2005, 2009; Valdujo et al. 2009; Araujo & Almeida-Santos 2011). Nevertheless, as most species of reptiles, particularly snakes, tend to have low population densities and/or secretive habitats, the complete inventory of a given place demands a great amount of time and collection effort; consequently, it is highly possible that all above mentioned studies collected only a fraction of the total reptile richness of their study areas.

The reptile species richness in Niquelândia are probably underestimated considering that some species which are widely distributed in the Cerrado domain have not been recorded, such as the lizard species *Norops meridionalis*, the snake *Leptodeira annulata*, and the tortoises of the genus *Chelonoidis* (Vaz-Silva et al. 2007; Morais et al. 2012; Guarnizo et al. 2015). Moreover, fossorial reptiles are expected to present a higher amount of species than actually found, including lizards of the genus *Bachia* and snakes of the genus *Typhlops*. Colli et al. (2002) suggested that only two sympatric species of amphisbaenians are expected to locally occur in Cerrado areas (such as our record); however, Strüssmann & Mott (2009) argued for a larger number (5–9) of sympatric species. Likewise, other aquatic reptiles recorded in nearby areas are expected to occur in the studied areas, such as snakes of the genus *Helicops* and *Hydrodynastes* (Ramalho et al. 2014; Silva Jr. et al. 2005).

Even though specimens of the dwarf caiman *Paleosuchus palpebrosus* can be found in anthropogenic areas, the construction of artificial pounds for human activities, such as mining, may be unfavorable for this species, differently from other crocodilians for which

Fig. 8. Snake species recorded in the municipality of Niquelândia, northern Goiás state, central Brazil. *Oxyrhopus trigeminus* (A), *Phimophis guerini* (B), *Erythrolamprus almadensis* (C), *Erythrolamprus poecilogyrus* (D), *Erythrolamprus reginae* (E), *Xenodon merremii* (F), *Xenopholis undulatus* (G), *Trilepida fuliginosa* (H), *Bothrops moojeni* (I), *Bothrops pauloensis* (J), *Crotalus durissus* (K). Photos: Drummond L.O. (A, E, H), Guerra V. (B, I, J), Oda F.H. (C, G), Ribeiro R. (D), Heming N.M. (K), Nunes A.V. (F).

impoundments allows the establishment of higher densities (Borteiro et al. 2008). Habitat requirements for *P. palpebrosus* in the Cerrado generally include closed-canopy areas, with springs and headwaters of fast-running streams, which tends to turn rapidly destroyed after human occupation (Carvalho Jr. & Batista 2013; Campos et al. 2013). Thus, habitat restoration in degraded areas of mining activity, mostly in gallery forests, may favor the maintenance of populations of the dwarf caiman.

Many reptile species found in this study are frequently associated with anthropogenic habitats, such as the exotic gekkonid *Hemidactylus mabouia* and the native lizards *Ameiva ameiva*, *Cercosaura ocellata*, *Iguana iguana*, *Tropidurus oreadicus*, as well as the snakes *Boa constrictor*, *Epicrates crassus*, *Chironius flavolineatus, Sibynomorphus mikanii*, and *Oxyrhopus trigeminus* (Carvalho & Nogueira 1998; Sousa et al. 2012; França & Braz 2013). Nevertheless, some species depend on remnants of pristine habitats, such as the fossorial reptiles *Amphisbaena anaemariae*, *Anilius scytale*, and *Trilepida fuliginosa*, reinforcing the importance of the recovering areas in the maintenance of local reptile diversity.

As observed in other studies encompassing the Cerrado domain, most species of lizards were found in open habitats (Colli et al. 2002; Nogueira et al. 2005), although some species were also associated, exclusively or not, with forest formations. Cerrado lizards are habitat specialists with abundance varying among habitats resulting in low overlap of species found in open and forested environments (Nogueira et al. 2009). Most lizards were observed in foraging activity or at rest while sunbathing during the day. In contrast, snakes were observed generally at low density during the day with many species exhibiting cryptic or secretive habits,

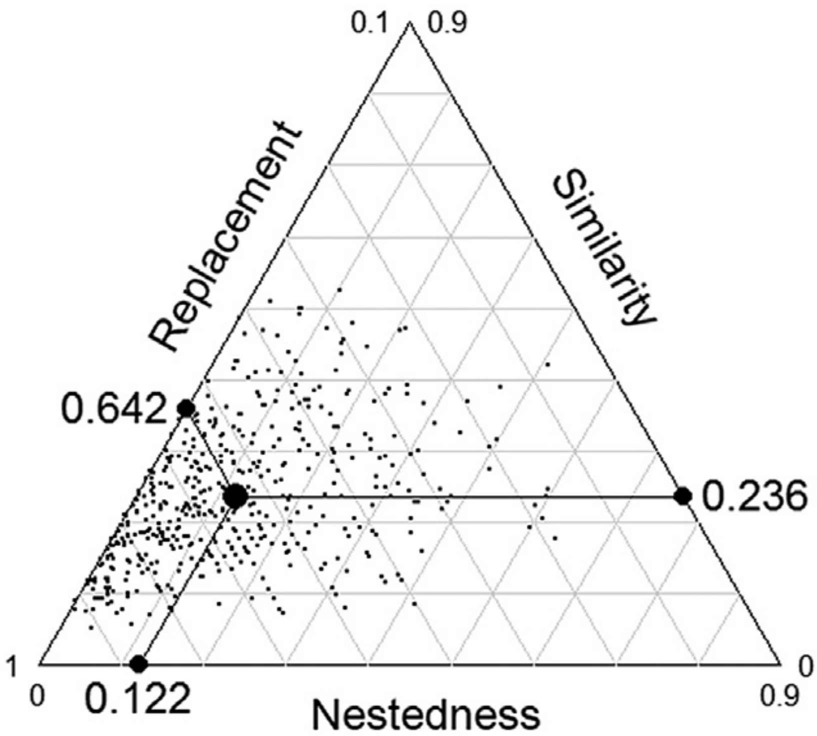

Fig. 9. Triangular plot of the relationships among the 496 pairs of sites selected along the Cerrado domain. Each point represents a pair of selected locations and its position is determined by a triplet of values from the S = (1 – dissimilarity) (similarity), replacement and nestedness, determined from the Jaccard index (see Methods).

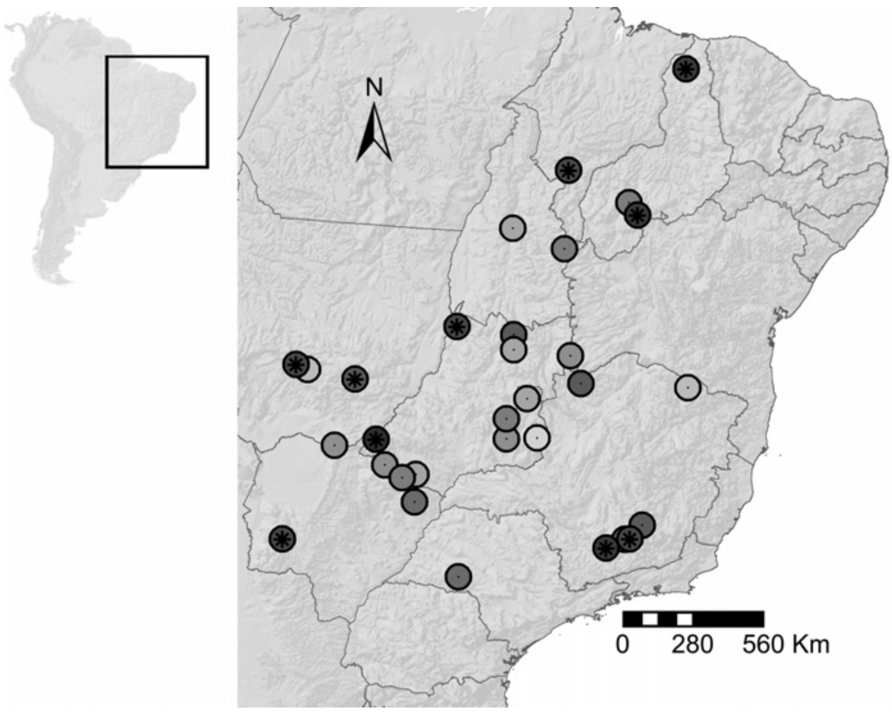

Fig. 10. Map of the selected locations showing the local contributions to beta diversity (LCBD) of the reptile communities. The gradient of light-dark grey is proportional to the LCBD values. * = sites having significant LCBD at the 0.05 significance level (see Legendre & De Cáceres 2013).

which made them relatively difficult to sample (Sazima & Haddad 1992). Previous studies have recorded most snakes associated with forest formations (Ramalho et al. 2014) or with Cerrado physiognomies (Araujo et al. 2010). In Niquelândia, we found most snakes associated with anthropic areas, which is probably related to the conversion of forest habitats into open areas and the simplification of the environment, leading species to be more conspicuous and more easily observed.

Increase in beta diversity is broadly generated by geographical distance and environmental differences, where habitat heterogeneity is usually important and climate conditions explain the geographical variation in composition among regions (Melo et al. 2009). Therefore, low similarity in reptile composition, as found herein, is probably related to habitat heterogeneity among the sites within the Cerrado domain. Locations with unique reptile composition were found to be in contact areas with adjacent domains, whereas more homogeneous reptile composition is found mostly in areas of the central Cerrado, as reported for other animals and plants (Diniz-Filho et al. 2009; Françoso et al. 2016). Valdujo et al. (2013) found amphibian beta-diversity in the Cerrado to be related to environmental conditions of adjacent biomes and endemicity patterns linked to phylogenetic niche conservatism within species groups which had invaded the Cerrado from adjacent domains. In turn, Nogueira et al. (2011) highlighted the importance of elevated savannas in the squamate Cerrado diversity, with higher levels of endemicity in isolated plateaus. Therefore, ecotonal and tableland areas can be considered as relevant for effective reptile conservation because of their unique species compostion.

Conclusions

This study presents important data on the reptiles of areas recovering from mining activity, as well as adjacent pristine and anthropized areas in Upper Tocantins River, central Brazil. It presented high local species richness, reflecting the increase in habitat heterogeneity due to the recovery of vegetation cover associated with the topography reconformation (Leite & Neves 2008), contributing to high diversity of reptiles, as observed to anurans in these same areas (Oda et al. 2009; Nomura et al. 2012). Further research efforts are important to reach an understanding on the ecological processes driving the restoration of the original reptile diversity in recovering areas. Thus, it is necessary have long-term studies carried out in order to recognize patterns of reptile species composition, population decline and/or local extinctions, as well as regarding the development of conservation strategies.

Acknowledgements

We would like to thank the Anglo American Brasil for having provided both financial and logistical support during the fieldwork. The Fundação de Amparo a Pesquisa (FUNAPE) for having granted master's scholarships to Fabrício H. Oda (2005–2006). We would also like to thank Alexandre Curcino, Breno de Assis, Delano G. Pinheiro, Leonardo A. Guimarães, Mariana A. C. Sá Lima, Neander M. Heming, and Fábio Carvalho for their field assistance; Wilian Vaz-Silva and Katia Kopp for having helped with the identification of some reptile species, and Cristiano Nogueira for having provided schematic images of the three study sites. Fabrício H. Oda, Danusy L. Santos, Priscilla G. Gambale, and Vinicius G. Batista received fellowships from CAPES. Robson W. Ávila and Rogério P. Bastos would like to thank Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for having provided a research fellowship (process # 303622/2015-6 and process # 304363/2010-3). T. S. Vasconcelos' research has been supported by Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP: 2011/18510-0). Finally, we would like to thank the Instituto Chico Mendes de Conservação da Biodiversidade/Centro Nacional de Pesquisa e Conservação de Répteis e Anfíbios (ICMBio/RAN) (process #154-05) for providing a collection permit.

References

Araujo C.O. & Almeida-Santos S.M. 2011. Herpetofauna de um remanescente de cerrado no estado de São Paulo, sudeste do Brasil. Biota Neotrop. **11 (3):** 47–62. DOI: 10.1590/S1676-06032011000300003

Araujo C.O., Côrrea-Filho D.T. & Sawaya R.J. 2010. Snake assemblage of Estação Ecológica de Santa Bárbara, SP: a Cerrado remnant in Southeastern Brazil. Biota Neotrop. **10 (2):** 235–245. DOI: 10.1590/S1676-06032010000200026

Barreto L.N., Arzabe C. & Lima Y.C.C. 2007. Herpetofauna da região de Balsas, pp. 213–229. In: Barreto L. (ed.), Cerrado Norte do Brasil, [North Cerrado of Brazil] USEB, Pelotas, RS, 378 pp. ISBN-10: 8589985164, ISBN-13: 978-8589985161

Borteiro C., Gutiérrez F., Tedros M. & Kolenc F. 2008. Conservation status of *Caiman latirostris* (Crocodylia: Alligatoridae) in disturbed landscapes of northwestern Uruguay. South Amer. J. Herpetol. **3 (3):** 244–250. DOI: 10.2994/1808-9798-3.3.244

Brandão R.A & Araújo A. 2008. Changes in anuran species richness and abundance resulting from hydroelectric dam flooding in Central Brazil. Biotropica **40 (2):** 263–266. DOI: 10.1111/j.1744-7429.2007.00356.x

Brandão R.A. & Araújo A.F.B. 1998. A herpetofauna da Estação Ecológica de Águas Emendadas, pp. 9–21. In: Marinho-Filho J., Rodrigues F. & Guimarães M. (eds), Vertebrados da Estação Ecológica de Águas Emendadas, História Natural e Ecologia em um Fragmento de Cerrado do Brasil Central, SEMATEC/IEMA, Brasília, 94 pp.

Brandão R.A, Caramaschi U., Vaz-Silva W. & Campos L.A. 2013. Three new species of *Proceratophrys* Miranda-Ribeiro 1920 from Brazilian Cerrado (Anura, Odontophrynidae). Zootaxa **3750:** 321–347. DOI: 10.11646/zootaxa.3750.4.2

Brandão R.A., Sebben A. & Zerbini G.J. 2006. A herpetofauna da APA de Cafuringa, pp. 241–248. In: Netto P.B., Mecenas V.V. & Cardoso E.S. (eds), APA de Cafuringa: A Última Fronteira Natural do Distrito Federal, Secretaria de Meio Ambiente e Recursos Hídricos, Brasília, 544 pp. ISBN: 8588670046, 9788588670044

Brooks R.R., Reeves R.D., Baker A.J.M., Rizzo J.A. & Diaz Ferreira H. 1990. The Brazilian Serpentine Plant Expedition (BRASPEX), 1988. Natl. Geogr. Res. **6:** 205–219.

Cacciali P. & Scott N.J. 2015. Key to the *Ophiodes* (Squamata: Sauria: Diploglossidae) of Paraguay with the description of a new species. Zootaxa **3980 (1):** 42–50. DOI: 10.11646/zootaxa.3980.1.2

Campos Z., Marioni B., Farias I., Verdade L. M., Bassetti L., Coutinho M.E., de Mendonça S.H.S.T., Vieira T.Q. & Magnusson W.E. 2013. Avaliação do risco de extinção do jacarépaguá *Paleosuchus palpebrosus* (Cuvier, 1807) no Brasil. Biodivers. Bras. **3 (1):** 40–47.

Carvalho E.A.R. Jr. & Batista V.B.G.V. 2013. Distribution and abundance of *Caiman latirostris* and *Paleosuchus palpebrosus* at Grande Sertão Veredas National Park, Central Brazil. Herpetol. Conserv. Biol. **8 (3):** 771–777.

Carvalho M.A. & Nogueira F. 1998. Serpentes da área urbana de Cuiabá, Mato Grosso: aspectos ecológicos e acidentes ofídicos associados. Cad. Saúde Pública **14 (4):** 753–763.DOI: 10.1590/S0102-311X1998000400017

Castro-Mello C. 2000. A new species of *Amphisbaena* from Central Brazil (Squamata: Amphisbaenidae). Pap. Avul. Zool. **41**: 243–246.

Cechin S.Z. & Martins M. 2000. Eficiência de armadilhas de queda (*pitfall traps*) em amostragens de anfíbios e répteis no Brasil. Rev. Bras. Zool. **17 (3):** 729–740. DOI: 10.1590/S0101-81752000000300017

Centeno F.C., Sawaya R.J. & Germano V.J. 2010. A new species of *Liotyphlops* (Serpentes: Anomalepididae) from the Atlantic Coastal Forest in southeastern Brazil. Herpetologica **66 (1):** 86–91. DOI: 10.1655/08-079.1

Cintra C.E.D., Silva H.L.R. & Silva N.J. Jr. 2009. Herpetofauna, Santa Edwiges I and II hydroelectric power plants, state of Goiás, Brazil. Check List **5 (3):** 570–576.

CITES. 2015. Appendices I, II and III – The Convention on International Trade in Endangered Species of Wild Fauna and Flora. https://cites.org/eng/app/appendices.php (accessed 13.03.2016).

Colli G.R., Bastos R.P. & Araújo A.F.B. 2002. The character and dynamics of the Cerrado herpetofauna, pp. 223–241. In: Oliveira P.S. & Marquis R.J. (eds), The Cerrados of Brasil: Ecology and Natural History, Columbia University Press, New York, 424 pp. ISBN: 9780231120432

Colli G.R. Nogueira C., Leite D.L.P., Ledo R.M.D., Costa B.M. & Brandão R.A. 2011. Herpetofauna da Reserva Ecológica do IBGE e seu entorno, pp. 132–145. In: Ribeiro M.L. (ed.), Reserva Ecológica do IBGE – Biodiversidade Terrestre, Vol. 1, Fundação Instituto Brasileiro de Geografia e Estatística, Rio de Janeiro, 302 pp. ISBN: 9788524041853

Dal Vechio F., Recoder R., Rodrigues M.T. & Zaher H. 2013. The herpetofauna of the Estação Ecológica de Uruçuí-Una, state of Piauí, Brazil. Pap. Avulsos Zool. **53 (16):** 225–243. DOI: 10.1590/S0031-10492013001600001

Dal Vechio F., Teixeira M. Jr., Recoder R.S., Rodrigues M.T. & Zaher H. 2016. The herpetofauna of Parque Nacional da Serra das Confusőes, state of Piauí, Brazil, with a regional species list from an ecotonal area of Cerrado and Caatinga. Biota Neotrop. **16 (3):** e20150105. DOI: 10.1590/1676-0611-BN-2015-0105

Diniz-Filho J.A.F., Bini L.M., Rangel T.F., Loyola R.D., Hof C., Nogués-Bravo D. & Araújo M.B. 2009. Partitioning and mapping uncertainties in ensembles of forecasts of species turnover under climate change. Ecography **32 (6):** 897–906. DOI: 10.1111/j.1600-0587.2009.06196.x

Fernandes P.A. & Pessôa V.L.S. 2011. O Cerrado e suas atividades impactantes: uma leitura sobre o garimpo, a mineração e a agricultura mecanizada. Observatorium: Rev. Eletr. Geogr. **3 (7):** 19–37.

França F.G.R. & Braz V.S. 2013. Diversity, activity patterns, and habitat use of the snake fauna of Chapada dos Veadeiros National Park in Central Brazil. Biota Neotrop. **13 (1):** 74–85. DOI: 10.1590/S1676-06032013000100008

Françoso R.D., Haidar R.F. & Machado, R.B. 2016. Tree species of South America central savanna: endemism, marginal areas and the relationship with other biomes. Acta Bot. Bras. **30 (1):** 78–86. DOI: 10.1590/0102-33062015abb0244

Guarnizo C.E., Werneck F.P., Giugliano L.G., Santos M.G., Fenker J., Sousa L., D'Angiolella A.B., dos Santos A.R., Strüssmann C., Rodrigues M.T., Dorado-Rodrigues T.F., Gamble T. & Colli G.R. 2015. Cryptic lineages and diversification of an endemic anole lizard (Squamata, Dactyloidae) of the Cerrado hotspot. Mol. Phylogenet. Evol. **94 (Part A):** 279–289. DOI: 10.1016/j.ympev.2015.09.005

Hartman H.L. & Mutmansky J.M. 2002. Introductory Mining Engineering, 2nd ed., Surface Mining: Mechanical Extraction Methods. John Wiley & Sons, Inc., New Jersey, 584 pp. ISBN: 978-0-471-34851-1

Klink C.A. & Machado R.B. 2005. Conservation of the Brazilian Cerrado. Conserv. Biol. **19 (3):** 707–713. DOI: 10.1111/j.1523-1739.2005.00702.x

Lagos A.R., Fontes A.F., Marques C.A.R., da Silva C.S.P., Cardoso C.A.C., Belote D.F., Machado F.V., Nunes G.E.S.S., Carneiro J.B. & Borde L.Q. 2017. Guia dos Anfíbios e Répteis da área de influçncia da Usina Hidrelétrica de Batalha. Furnas Centrais Elétricas, Rio de Janeiro, 72 pp. ISBN: 978-85-85996-24-6

Latrubesse E.M. (ed.). 2005. Mapa Geomorfológico do Estado de Goiás: Relatório Final. Secretaria de Indústria e Comércio: Superintendęncia de Geologia e Mineração, Goiânia, Sistema Estadual de Geoinformação de Goiás, 81 pp. http://www.sieg.go.gov.br/downloads/geomorfologia.pdf (accessed 13.03.2016)

Legendre P. 2014. Interpreting the replacement and richness difference components of beta diversity. Global Ecol. Biogeogr. **23:** 1324–1334. DOI: 10.1111/geb.12207

Legendre P. & De Cáceres M. 2013. Beta diversity as the variance of community data: dissimilarity coefficients and partitioning. Ecol. Lett. **16 (8):** 951–963. DOI: 10.1111/ele.12141

Leite F.A.S. & Neves M.P. 2008. Reflexões sobre fechamento de mina [Reflections About Mine Closure]. E-Scientia **1 (1):** 1–14.

Lema T. 2003. Descrição de nova espécie de *Apostolepis* Cope do cerrado do Brasil, pertencente ao grupo dimidiata (Serpentes, Elapomorphinae). Acta Biol. Leopold. **25 (1):** 123–131.

Lucas P.S., Novelli I.A. & Sousa B.M. 2016. Assemblage of squamate reptiles in a natural remnnat of Cerrado in southern Minas Gerais, Brazil. Check List **12 (2):** 1–9. DOI: 10.15560/12.2.1866

Melo A.S., Rangel T.F.L.V.B & Diniz-Filho J.A.F. 2009. Environmental drivers of beta-diversity patterns in New-World birds and mammals. Ecography **32:** 226–236. DOI: 10.1111/j.1600-0587.2008.05502.x

Mendes-Pinto T.J. & Miranda I. 2011. Levantamento herpetofaunístico de uma área de Cerrado em Alto Araguaia, Mato Grosso, Brasil. Rev. Biol. Farm. **6 (2):** 129–137.

Mittermeier R.A., Gil P.R., Hoffman M., Pilgrim J., Brooks T., Mittermeier C.G., Lamoreux J. & Fonseca G.A.B. 2004. Hotspots revisited: earth's biologically richest and most endangered terrestrial ecoregions. CEMEX & Agrupación Sierra Madre, Cidade do Mexico, Mexico, 392 pp. ISBN: 968-6397-77-9

MMA. 2007. Cerrado e Pantanal: áreas prioritárias para conservação da biodiversidade. Ministério do Meio Ambiente, Brasília, Brazil, 540 pp. ISBN: 978-85-8766-87-6

MMA. 2014. Lista nacional oficial de espécies da fauna ameaçadas de extinção: espécies terrestres e mamíferos aquáticos. Portaria MMA nş 444, de 17 de dezembro de 2014, pp. 121–126. http://www.icmbio.gov.br/portal/images/stories/biodiversidade/fauna-brasileira/avaliacao-do-risco/PORTARIA_N%C2%BA_444_DE_17_DE_DEZEMBRO_DE_2014.pdf (accessed 13.03.2016)

Morais A.R., Bastos R.P., Vieira R. & Signorelli L. 2012. Herpetofauna of the Floresta Nacional de Silvânia, a Cerrado remnant in Central Brazil. Neotrop. Biol. Conserv. **7 (2):** 114–121. DOI: 10.4013/nbc.2012.72.05

Moreira L.A., Fenolio D.B., Silva H.L.R. & Silva N.J. Jr. 2009. A preliminary list of the herpetofauna from termite mounds of the Cerrado in the Upper Tocantins. Pap. Avulsos Zool. **49 (15):** 183–189. DOI: 10.1590/S0031-10492009001500001

Nekola J.C. & White P.S. 1999. The distance-decay of similarity in biogeography and ecology. J. Biogeogr. **26 (4):** 867–878. DOI: 10.1046/j.1365-2699.1999.00305.x

Nogueira C., Colli G.R., Costa G.C. & Machado R.B. 2010. Diversidade de repteis Squamata e evolução do conhecimento faunístico no Cerrado, pp. 333–375. In: Diniz I.R., Marinho-Filho J., Machado R.B. & Cavalcanti R.B. (eds), Cerrado: conhecimento cientifico quantitativo como subsidio para ações de conservação, Editora UnB, Brasília, 496 pp. ISBN: 9788570629647

Nogueira C., Colli G.R. & Martins M. 2009. Local richness and distribution of the lizard fauna in natural habitat mosaics of the Brazilian Cerrado. Austral. Ecol. **34 (1):** 83–96. DOI: 10.1111/j.1442-9993.2008.01887.x

Nogueira C., Ribeiro S., Costa G.C. & Colli G.R. 2011. Vicariance and endemism in a neotropical savanna hotspot: distribution patterns of Cerrado squamate reptiles. J. Biogeogr. **38 (10):** 1907–1922. DOI: 10.1111/j.1365-2699.2011.02538.x

Nogueira C., Valdujo P.H. & França F.G.R. 2005. Habitat variation and lizard diversity in a Cerrado area of Central Brazil. Stud. Neotrop. Fauna Environ. **40 (2):** 105–112. DOI: 10.1080/01650520500129901

Nomura F., Maciel N.M., Pereira E.B. & Bastos R.P. 2012. Diversidade de anuros (Amphibia) em áreas recuperadas de atividade mineradora e de plantio de *Eucalyptus urophyla*, no Brasil Central [Anura diversity (Amphibia) in recovered areas of mining activity in cerrado and *Eucalyptus urophyla* planting in Central Brazil]. Bioscience J. **28 (2):** 312–324.

Novelli I.A., Lucas P.S., Carvalho R.G., Santos R.C. & Sousa B.M. 2012. Lagartos de áreas de Cerrado na Reserva Biológica Unilavras–Boqueirão, Ingaí, sul de Minas Gerais, Brasil. Biota Neotrop. **12 (3):** 147–153. DOI: 10.1590/S1676-06032012000300017

Oda F.H., Bastos R.P. & Lima M.A.C.S. 2009. Taxocenose de anfíbios anuros no Cerrado do Alto Tocantins, Niquelândia, Estado de Goiás: Diversidade, Distribuição Local e Sazonalidade. Biota Neotrop. **9 (4):** 219–232. DOI: 10.1590/S1676-06032009000400022

Oliveira P.S. & Marquis R.J. (eds). 2002. The Cerrados of Brazil: Ecology and Natural History of a Neotropical Savanna. Columbia University Press, New York, USA, 424 pp. ISBN: 9780231120432

Oliveira-Filho A.T. & Ratter J.A. 2002. Vegetation physiognomies and woody flora of the Cerrado Biome, pp. 91–120. In: Oliveira P.S. & Marquis R.J. (eds), The Cerrados of Brazil: Ecology and Natural History of a Neotropical Savanna, Columbia University Press, New York, 424 pp. ISBN:9780231120432

Pavan D. & Dixo M. 2004. A Herpetofauna da área de influęncia do reservatório da Usina Hidrelétrica Luís Eduardo Magalhães, Palmas, TO. Humanitas **4/6:** 13–30.

Peel M.C., Finlayson B.L. & McMahon T.A. 2007. Updated world map of the Köppen-Geiger climate classification. Hydrol. Earth Syst. Sc. **11:** 1633–1644. DOI: 10.5194/hess-11-1633-2007

Ramalho W.P., Batista V.G. & Lozi L.R.P. 2014. Amphibians and reptiles along the middle Aporé river, central Brazil. Neotrop. Biol. Conserv. **9 (3):** 147–160.

Recoder R. & Nogueira C. 2007. Composição e diversidade de Répteis Squamata na região sul do Parque Nacional Grande Sertão Veredas, Brasil Central. Biota Neotrop. **7 (3):** 267–278. DOI: 10.1590/S1676-06032007000300029

Recoder R.S., Teixeira M. Jr., Camacho A., Nunes P.M.S., Mott T., Valdujo P.H., Ghellere J.M., Nogueira C. & Rodrigues M.T. 2011. Reptiles of Serra Geral do Tocantins Ecological Station, Central Brazil. Biota Neotrop. **11 (1):** 263–281. DOI: 10.1590/S1676-06032011000100026

Rios C.H.V., Novelli I.A., Hudson A.A., Cozendey P., Lima L.C. & Sousa B.M. 2017. Communities and occurrences of Squamata reptiles in different vegetation types of the Serra de São José, Minas Gerais, Brazil. Biota Neotrop. **17 (1):** e20150103. DOI: 10.1590/1676-0611-bn-2015-0103

Rosário Cruz A.J., Drummond L.O., Lucena V.D., Magalhães A.P., Braga C.A.C., Rolin J.M. & Pires M.R.S. 2014. Lizard fauna (Squamata, Sauria) from Serra do Ouro Branco, southern Espinhaço Range, Minas Gerais, Brazil. Check List **10 (6):** 1290–1299. DOI: 10.15560/10.6.1290

Santos D.S., Andrade S.P., Victor E.P. Jr. & Vaz-Silva V. 2014. Amphibians and reptiles from Southeastern Goiás, Central Brazil. Check List **10 (1):** 131–148.

Santos F.J.M., Luz V.L.F., Pena A.P., Júnior S.G.F. & Pires R.A.P. 2008. Relação dos Squamata (Reptilia) da Área de Proteção Ambiental Meandros do Rio Araguaia, Brasil. Estudos **35 (3):** 401–407.

Santos M.M., Ávila R.W. & Kawashita-Ribeiro R.A. 2011. Checklist of the amphibians and reptiles in Nobres municipality, Mato Grosso state, central Brazil. Herpetol. Notes **4:** 455–461.

São Pedro V.A. & Pires M.R.S. 2009. As serpentes da região de Ouro Branco, extremo sul da Cadeia do Espinhaço, Minas Gerais. Rev. Ceres **56 (2):** 166–171.

Sazima I. & Haddad C.F.B. 1992. Répteis da Serra do Japi: notas sobre história natural. pp. 212-236. In: Morellato L.P.C. (ed), História natural da Serra do Japi: ecologia e preservação de uma área florestal no Sudeste do Brasil, Editora da Unicamp/FAPESP, Campinas, 321 pp. ISBN: 8526802232, 9788526802230

Silva M.C., de Oliveira R.H., Morais D.H., Kawashita-Ribeiro R.A., de Brito E.S. & Ávila R.W. 2015. Amphibians and reptiles of a Cerrado area in Primavera do Leste municipality, Mato Grosso State, Central Brazil. Salamandra **51 (2):** 187–194.

Silva N.J. Jr., Cintra C.E.D., Silva H.L.R., Costa M.C., Souza C.A., Pachêco A.A. Jr. & Gonçalves F.A. 2009. Herpetofauna, Ponte de Pedra Hydroelectric Power Plant, states of Mato Grosso and Mato Grosso do Sul, Brazil. Check List **5 (3):** 518–525.

Silva N.J. Jr., Silva H.L.R., Rodrigues M.T., Valle N.C., Costa M.C., Castro S.P., Linder E.T., Johansson C. & Sites J.W. Jr. 2005. A fauna de vertebrados do alto rio Tocantins em áreas de usinas hidrelétricas. Estudos **32 (1):** 57–101.

Silvano D.L. & Segalla M.V. 2005. Conservação de anfíbios no Brasil. Megadiversidade **1 (1):** 79–86.

Sousa B.M., Gomides S.C., Hudson A.A., Ribeiro L.B. & Novelli I.A. 2012. Reptiles of the municipality of Juiz de Fora, Minas Gerais state, Brazil. Biota Neotrop. **12 (3):** 35–49. DOI: 10.1590/S1676-06032012000300002

Sousa B.M., Nascimento A.E.R., Gomides S.C., Rios C.H.V., Hudson A.A & Novelli I.A. 2010. Répteis em fragmentos de Cerrado e Mata Atlântica no Campo das Vertentes, Estado de Minas Gerais, Sudeste do Brasil. Biota Neotrop. **10 (2):** 129–138. DOI: 10.1590/S1676-06032010000200016

Strüssmann C. 2000. Herpetofauna, pp. 153–189. In: Alho C.J.R., Conceição P.N., Constantino R., Schlemmermeyer T., Strüssmann C., Vasconcellos L.A.S., Oliveira D.M.M. & Schneider M. (eds), Fauna silvestre da região de Manso-MT, Ministério do Meio Ambiente/Edições IBAMA/Centrais Elétricas do Norte do Brasil, Brasília, 265 pp.

Strüssmann C. & Mott T. 2009. Sympatric amphisbaenids from Manso Dam region, Mato Grosso state, western Brazil, with the description of a new two-pored species of *Amphisbaena* (Squamata, Amphisbaenidae). Stud. Neotrop. Fauna Environ. **44 (1):** 37–46. DOI: 10.1080/01650520802628295

Tavares J.R., Melo C.E., Campos V.A., Oda F.H. & Strüssmann C. 2012. Snakes from Canoa Quebrada Hydroeletric Power Plant, state of Mato Grosso, Brazil. Herpetol. Notes **5:** 543–546.

Uetanabaro M., Guimarães L.D., Béda A.F., Landgref Filho P., Prado C.P.A., Bastos R.P. & Ávila R.W. 2006. Inventário da herpetofauna do Complexo Aporé-Sucuriú, pp. 105–112. In: Pagotto T.C.S. & Souza P.R. (eds), Biodiversidade do Complexo Jauru, subsídios à conservação e manejo do Cerrado, Editora UFMS, Campo Grande, 308 pp. ISBN: 8576130955

Uetanabaro M., Souza F.L., Landgref Filho P., Beda A.F. & Brandão R.A. 2007. Anfíbios e répteis do Parque Nacional da Serra da Bodoquena, Mato Grosso do Sul, Brasil. Biota Neotrop. **7 (3):** 279–289. DOI: 10.1590/S1676-06032007000300030

Valdujo P.H., Carnaval A.C.O.Q. & Graham C.H. 2013. Environmental correlates of anuran beta diversity in the Brazilian Cerrado. Ecography 36: 708–717. DOI: 10.1111/j.1600-0587.2012.07374.x

Valdujo P.H., Nogueira C.C., Baumgarten L., Rodrigues F.H.G., Brandão R.A., Eterovic A., Ramos–Neto M.B. & Marques O.A.V. 2009. Squamate reptiles from Parque Nacional das Emas and surroundings, Cerrado of Central Brazil. Check List **5 (3):** 405–417.

Valdujo P.H., Silvano D.L., Colli G.R. & Martins M. 2012. Anuran species composition and distribution patterns in Brazilian Cerrado, a neotropical hotspot. South Am. J. Herpetol. **7 (2):** 63–78. DOI: 10.2994/057.007.0209

Vanzolini P.E. 1997. The silvestrii species group of *Amphisbaena*, with the description of two new Brazilian species (Reptilia: Amphisbaenia). Pap. Avulsos Zool. **40:** 65–85.

Vaz–Silva W., Guedes A.G., Azevedo–Silva P.L., Gontijo F.F., Barbosa R.S., Aloísio G.R. & Oliveira F.C.G. 2007. Herpetofauna, Espora Hydroelectric Power Plant, state of Goiás, Brazil. Check List **3:** 338–345. DOI: 10.15560/3.4.338

Vitt L.J., Caldwell J.P., Colli G.R., Garda A.A., Mesquita D.O., França F.G.R., Shepard D.B., Costa G.C., Vasconcellos M.M. & De Novaes e Silva V. 2005. Uma atualização do guia fotográfico de répteis e anfíbios da região do Jalapão no Cerrado Brasileiro. Occas. Pap. / Special publications in Herpetology, Sam Noble, Oklahoma Mus. Nat. Hist. **2:** 1–24.

Vogt R., Fagundes C.K., Bataus Y.S.L., Balestra R.A.M., Batista F.R.Q., Uhlig V.M., Silveira A.L., Bager A., Batistella A.M., Souza F.L., Drummond G.M., Reis I.J., Bernhard R., Mendonça S.H.S.T. & Luz V.L.F. 2015. Avaliação do Risco de Extinção de *Phrynops geoffroanus* (Schweigger, 1812) no Brasil, ICMBio 2015, Processo de avaliação do risco de extinção da fauna brasileira. http://www.icmbio.gov.br/portal/biodiversidade/fauna-brasileira/estado-de-conservacao/7418-repteis-phrynops-geoffroanus-cagado-de-barbicha.html/ (accessed 13.03.2016)

Received July 7, 2016
Accepted September 2, 2017