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Research Article

Checklist of the herpetofauna in an area of the Cerrado Biome, Central Brazil, under strong mining pressure

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Abstract

A checklist of the species of amphibians and reptiles in an area of the Cerrado Biome, in the municipality of Minaçu, state of Goiás, in central Brazil, is presented here. During the works on an access road to a mining enterprise, the work of rescuing fauna along the road took place. Through this work of rescuing fauna, 14 species of amphibians and 45 species of reptiles were recorded. This richness of amphibian and reptile species was recorded in three different fragments of phytophysiognomies of the Cerrado Biome: Mata Seca, Mata de Galeria, and Mata Ciliar and anthropic environment. In addition to the herpetofauna checklist, information regarding the richness and similarity between the three phytophysiognomies and anthropic environment is presented.

Keywords: Amphibians, Reptiles, Fauna Rescue, Neotropics

Introduction

In Brazil, six major biomes are present: Cerrado, Fields and Southern Forests, Atlantic Forest, Caatinga, Amazon Rainforest, and Pantanal. The geographical location of these biomes is conditioned predominantly by climatic factors, such as temperature, rainfall, and relative humidity, and to a lesser extent by the type of substrate (Ribeiro & Walter, 1998). Also, according to Ribeiro and Walter (1998), the Cerrado is located in Brazil's Central Plateau and is the second largest biome in the country by area, only surpassed by the Amazon Rainforest. It is a vegetational complex which has ecological and physiognomic relationships with other savannas in tropical America and continents such as Africa and Australia (Beard, 1953; Cole, 1958; Eiten, 1972, 1994;

Allem & Valls, 1987). The Cerrado corresponds to the "Oreades" in the Martius system and occupies more than 2.000,000 km^2, which represents about 23% of the Brazilian territory. It occurs at altitudes ranging from about 300m, such as the Baixada Cuiabana (MT), to more than 1600m, in Chapada dos Veadeiros (GO) (Ribeiro & Walter, 1998). Regarding the phytophysiognomies of the Cerrado Biome, eleven general phytophysiognomic types are described, framed in forest formations (Mata Ciliar, Mata de Galeria, Mata Seca and Cerradão), savannahs (Cerrado sentido restrito, Parque de Cerrado, Palmeiral and Vereda) and campestres (Campo Sujo, Campo Rupestre and Campo Limpo), many of which have subtypes (Ribeiro & Walter, 1998). The information on the herpetofauna presented in this research is specific to three phytophysiognomies: Mata Seca, Mata de Galeria and Mata Ciliar, and anthropic area consisting of pasture.

The Cerrado is one of the 25 biodiversity hotspots on the planet and one of the biomes with the greatest richness and endemism of amphibians and reptiles (Myers et al., 2000). According to Neves et al. (2019), Brazil harbors the most diverse herpetofauna in the world and such notable species richness is found throughout the different Brazilian morphoclimatic domains, with each domain supporting a singular evolutionary history of its herpetofauna. The species richness of amphibians and reptiles of the Cerrado has already been very well studied and presented by other researchers (Colli et al., 2002; Vaz-Silva et al., 2007; Araujo & Almeida-Santos, 2011; Neves et al., 2019; Fiorillo et al., 2021; Guerra et al., 2022). This study presents the checklist of the herpetofauna recorded during fieldwork in a fauna rescue conducted during deforestation for road opening in a Cerrado area in the municipality of Minaçu, state of Goiás, Brazil, where a strong anthropogenic pressure is observed due to mining. In addition to the list of amphibians and reptiles, diversity analysis was performed through sample rarefaction (Mao's tau) of the observed and expected species richness and multivariate analysis to obtain information on the similarity of the herpetofauna between the three sampled phytophysiognomies and anthropic area.

Material and methods

Study area

The fauna rescue took place in the municipality of Minaçu, state of Goiás, Brazil (Fig. 1A), during work to improve an old access road to a mining area (Fig. 1B). Fauna rescue was conducted along the entire length of this road and adjacent areas, totaling 20 km covered (Fig. 1B). Minaçu is located in the North of the state of Goiás and is part of the Tocantins-Araguaia Hydrographic Basin, specifically in the Alto Tocantins Region, with the Tocantis River as its main river. Several

phytophysiognomies of the Cerrado Biome are found in this municipality (for example: Cerradão, Campo Rupestre, Cerrado sentido restrito, Mata Ciliar, Mata de Galeria, Mata Seca). Amphibians and reptiles were recorded specifically in three phytophysiognomies: Mata Ciliar, Mata de Galeria, and Mata Seca, in addition to anthropogenic environments consisting of pastures. The geographic coordinates of all recorded specimens were obtained *in situ* using a Garmin eTrex 30 GPS, and subsequently, each recording point was plotted using Google Earth Pro v. 7.3.6.9796 (64-bit). The map was built with ArcMap (ArcGis) v. 10.4.1 for desktop using the WGS1984 geodetic datum.

Amphibian and reptile records

The herpetofauna checklist presented here is the result of the fauna rescue during the period from May 10, 2019, to October 28, 2019. The specimens were collected (collection license SECIMA 66208/2019) through an active search on the work fronts and areas that were deforested (Fig. 2). Most of the specimens were captured and later transported to release points far from the deforestation area. The specimens found dead due to the action of machines on deforestation fronts were preserved and later deposited in the Coleção Herpetológica do Centro de Estudos e Pesquisas Biológicas da Pontifícia Universidade Católica de Goiás (CEPB). The list of these specimens is in Appendix 1.

Using the software Past 4.16c (Hammer et al., 2001) for Windows, diversity analysis was performed through sample rarefaction (Mao's tau) of the observed and expected species richness and multivariate analysis to obtain information on the similarity of the herpetofauna between the three sampled phytophysiognomies and anthropic area.

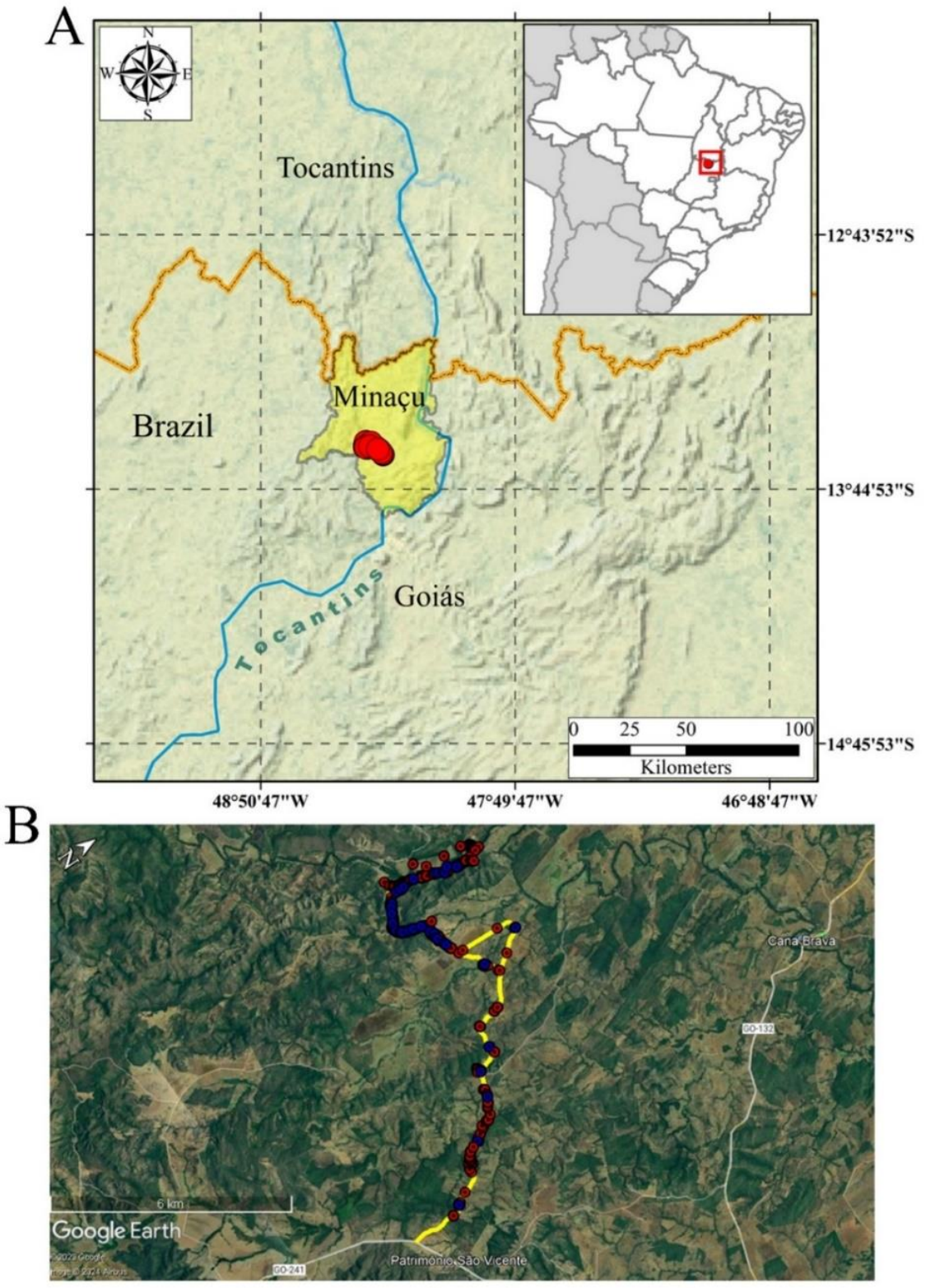

Figure 1. Study area. **A.** Map of the municipality of Minaçu, north of the state of Goiás, Brazil, showing the locality with the herpetofauna record points (red dots). **B.** The route of the road that was traveled during the deforestation and the records of the herpetofauna. Yellow line = road route, red dots = reptiles, blue dots = amphibians.

Figure 2. The author in active search on the deforestation front in the area where the fauna rescue took place in the municipality of Minaçu, north of the state of Goiás, Brazil (Photo by Edilson Pires).

Results

Species composition

In the area where the fauna was rescued, 14 species of amphibians (Fig. 3) and 45 species of reptiles (Figs. 7–9) were recorded. Regarding amphibians, two orders and six families were recorded, as follows: Anura, Bufonidae (1 species), Hylidae (4 species), Leptodactylidae (6 species), Microhylidae (1 species) e Odontophrynidae (1 species); Gymnophiona, Siphonopidae (1 species) (Table 1). As for reptiles, two orders and 15 families were registered, as follows: Squamata, Amphisbaenia, Amphisbaenidae (4 species); Sauria, Anolidae (1 species), Gymnophthalmidae (3 species), Hoplocercidae (1 species), Iguanidae (1 species), Phyllodactylidae (1 species), Polychrotidae (1 species), Scincidae (2 species), Teiidae (4 species), Tropiduridae (1 species); Serpentes, Boidae (2 species), Colubridae (20 species), Leptotyphlopidae (1 species), e Viperidae (2 species); Testudines, Testudinidae (1 species) (Table 4). Among amphibians, the family with the greatest richness and abundance was Leptodactylidae, with six species and 20 specimens (Fig. 4). The result obtained through sample rarefaction (Mao's tau) of the observed and expected species richness showed that among the four areas where there were records of amphibians during the rescue of fauna, one area presented values close to the

observed and estimated species (5 and 7, respectively) which was the anthropic area consisting of pasture (ANT/PAS), while in another area, constituted by the Mata Seca (MTS) phytophysiognomy, the number of species observed was greater than the amount of estimated species (11 and 10, respectively). For the two areas that have watercourses, the difference between the observed and estimated species was greater (6 and 12, respectively) in the area constituted by the Mata de Galeria (MTG) phytophysiognomy and (5 and 14, respectively) in the area constituted by the Mata Ciliar (MTC) phytophysiognomy. This information with the observed and estimated amphibian species for each of the areas is in Table 2 and Figure 5. The multivariate analysis to obtain information on the similarity of the amphibian species between the four areas during the fauna rescue showed the greatest similarity between the two driest areas and between the two wetter areas (Fig. 6). Table 3 presents the indexes for each of the areas.

Among the reptiles, the family with the highest species richness was Colubridae, with 20 species, while the family with the highest abundance was Teiidae with 82 specimens (Fig. 10). The result obtained through sample rarefaction (Mao's tau) of the observed and expected species richness showed that among the four areas where there were records of reptiles during the rescue of fauna, two areas had more species observed than estimated for each area: 25 and 22, respectively, for the anthropic area consisting of pasture (ANT/PAS), while in the Mata Seca phytophysiognomy (MTS) it was 40 and 34, respectively. In the two areas that have watercourses, as observed in relation to amphibians, the difference between the observed and estimated species was greater, being 14 and 41, respectively, in the area constituted by the Mata de Galeria (MTG) phytophysiognomy, while in the Mata Ciliar (MTC) phytophysiognomy it was 9 and 45, respectively. This information, with the estimates of reptile species for each of the areas, is in Table 5 and Figure 11.

Similar to what was observed in amphibians, in relation to reptiles, the multivariate analysis to obtain information on the similarity between the four areas during the rescue of fauna showed the greatest similarity between the two driest areas and these two areas being more similar to the Mata de Galeria phytophysiognomy. In comparison, the Mata Ciliar phytophysiognomy was less similar in relation to the other three areas (Fig. 12). Table 6 presents the indexes for each of the areas.

Table 1. List of amphibians recorded in the Cerrado, municipality of Minaçu, during the rescue of fauna in deforested areas for the opening of a road. **ANT/PAS** = anthropogenic area consisting of pasture; **MTS** = Mata Seca; **MTG** = Mata de Galeria; **MTC** = Mata Ciliar.

TAXON	ABUNDANCE BY PHYTOPHYSIOGNOMY				TOTAL ABUNDANCE
	ANT/PAS	MTS	MTG	MTC	
Amphibia					
Order Anura					
Suborder Neobatrachia					
Family Bufonidae					
Rhinella diptycha (Cope, 1862)				3	3
Family Hylidae					
Boana raniceps (Cope, 1862)			1		1
Pithecopus hypochondrialis (Daudin, 1800)	2	9			11
Scinax fuscovarius (Lutz, 1925)	1	1	1		3
Trachycephalus typhonius (Linnaeus, 1758)		1			1
Family Leptodactylidae					
Leptodactylus fuscus (Schneider, 1799)		1			1
Leptodactylus latrans (Steffen, 1815)	1	7	1	1	10
Leptodactylus mystaceus (Spix, 1824)		1	1	1	3
Leptodactylus mystacinus (Burmeister, 1861)		1			1
Physalaemus cuvieri Fitzinger, 1826		1	1		2
Physalaemus nattereri (Steindachner, 1863)	1	1		1	3
Family Microhylidae					

TAXON	ABUNDANCE BY PHYTOPHYSIOGNOMY				TOTAL ABUNDANCE
	ANT/PAS	MTS	MTG	MTC	
Dermatonotus muelleri (Boettger, 1885)	1	3			4
Family Odontophrynidae					
Proceratophrys goyana (Miranda-Ribeiro, 1937)			1		1
Order Gymnophiona					
Family Siphonopidae					
Siphonops paulensis Boettger, 1892		1			1

Figure 3. Representatives of some of the amphibians recorded in the Cerrado area deforested for road opening. **Bufonidae: 1** *Rhinella diptycha*; **Hylidae: 2** *Boana raniceps*, **3** *Pithecopus hypochondrialis*; **Leptodactylidae: 4** *Leptodactylus latrans*, **5** *Leptodactylus mystaceus*, **6** *Leptodactylus mystacinus*, **7** *Physalaemus nattereri*, **8** *Physalaemus cuvieri*; **Microhylidae: 9** *Dermatonotus muelleri*; **Odontophrynidae: 10** *Proceratophrys goyana*.

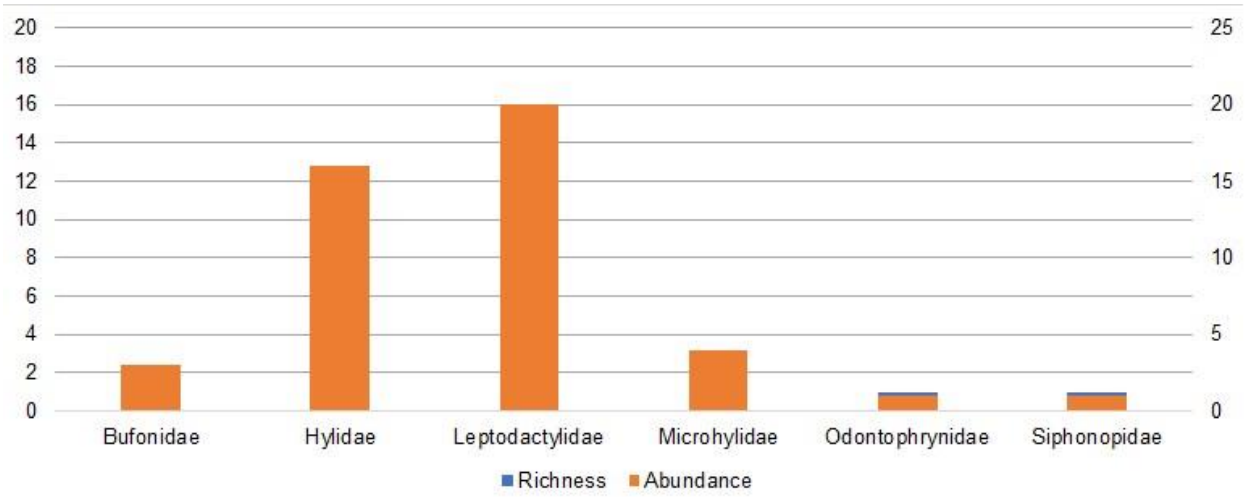

Figure 4. Richness and abundance of amphibian species by family.

Table 2. Observed and estimated amphibian species.

Sampled areas	Observed	Estimated
ANT/PAS	5	7
MTS	11	10
MTG	6	12
MTC	5	14

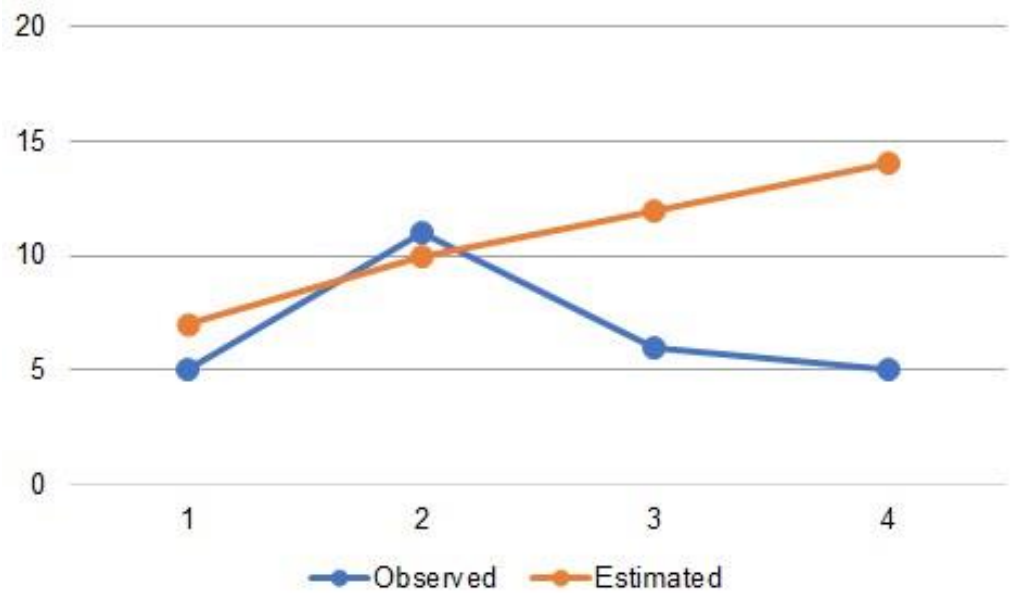

Figure 5. Rarefaction curve of the observed and estimated species richness of amphibians.

Table 3. Similarity index (Bray-Curtis) of amphibian species observed in the four sampled areas. **ANT/PAS** = Anthropogenic area consisting of pasture; **MTS** = Mata Seca; **MTG** = Mata de Galeria; **MTC** = Mata Ciliar.

	ANT/PAS	MTS	MTG	MTC
ANT/PAS	1	0.36	0.33	0.33
MTS	0.36	1	0.24	0.18
MTG	0.33	0.24	1	0.33
MTC	0.33	0.18	0.33	1

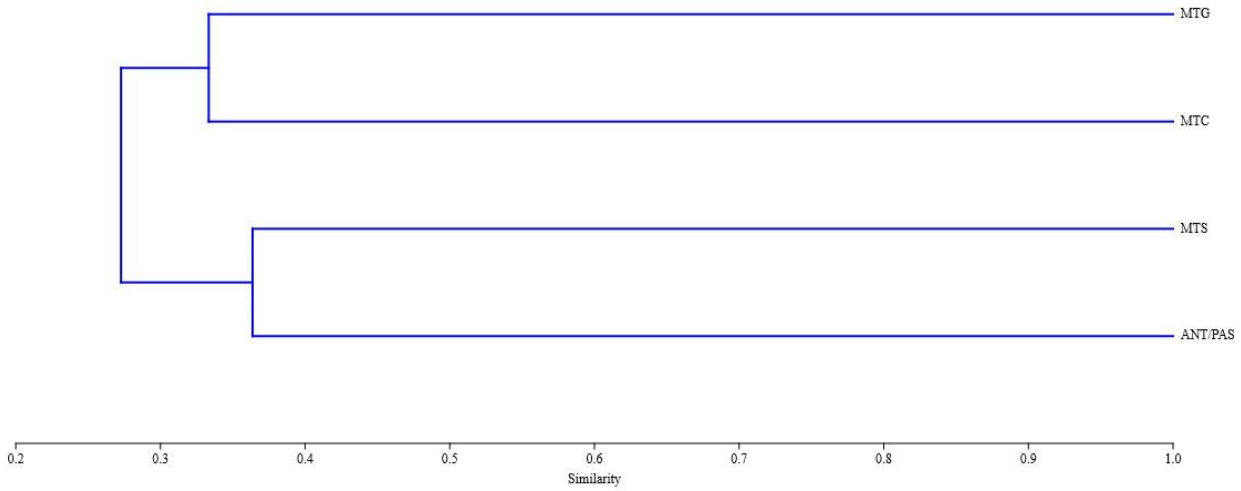

Figure 6. Similarity dendrogram (Bray-Curtis) of the amphibians between the three sampled phytophysiognomies and anthropic area. The unweighted pair-group average (UPGMA) algorithm was used.

Table 4. List of reptiles recorded in the Cerrado, municipality of Minaçu, during the rescue of fauna in deforested areas for the opening of a road. **ANT/PAS** = anthropogenic area consisting of pasture; **MTS** = Mata Seca; **MTG** = Mata de Galeria; **MTC** = Mata Ciliar.

TAXON	ABUNDANCE BY PHYTOPHYSIOGNOMY				TOTAL ABUNDANCE
	ANT/PAS	MTS	MTG	MTC	
Reptilia					
Order Squamata					
Suborder Amphisbaenia					
Family Amphisbaenidae					
Amphisbaena alba Linnaeus, 1758	2				2
Amphisbaena anaemariae Vanzolini, 1997	8	17	9	7	41
Amphisbaena fuliginosa Linnaeus, 1758	2	7			9
Leposternon infraorbitale (Berthold, 1859)		1	1		2
Suborder Sauria					
Family Anolidae					
Anolis brasiliensis Vanzolini & Williams, 1970			4		4
Family Gymnophthalmidae					
Cercosaura schreibersii Wiegmann, 1834		1	4		5
Colobosaura modesta (Reinhardt & Lütken, 1862)	1	1	21		23
Micrablepharus maximiliani (Reinhardt & Lütken, 1862)	9	2	34		46
Family Hoplocercidae					
Hoplocercus spinosus Fitzinger, 1843		2			2
Family Iguanidae					

TAXON	ABUNDANCE BY PHYTOPHYSIOGNOMY				TOTAL ABUNDANCE
	ANT/PAS	MTS	MTG	MTC	
Iguana iguana (Linnaeus, 1758)	2	4		1	7
Family Phyllodactylidae					
Gymnodactylus amarali Barbour, 1925	11	14			25
Family Polychrotidae					
Polychrus acutirostris Spix, 1825	2	10			12
Family Scincidae					
Copeoglossum nigropunctatum (Spix, 1825)	3	5	1		9
Notomabuya frenata (Cope, 1862)	6	20	2	1	29
Family Teiidae					
Ameiva ameiva (Linnaeus, 1758)	5	27	6	1	39
Ameivula ocellifera (Spix, 1825)	15	16		1	32
Salvator merianae Duméril & Bibron, 1839	3	7			10
Tupinambis quadrilineatus Manzani & Abe, 1997		1			1
Family Tropiduridae					
Tropidurus oreadicus Rodrigues, 1987	1	6		2	9
Suborder Serpentes					
Family Boidae					
Boa constrictor Linnaeus, 1758	2	1			3
Epicrates cenchria (Linnaeus, 1758)		2			2

TAXON	ABUNDANCE BY PHYTOPHYSIOGNOMY				TOTAL ABUNDANCE
	ANT/PAS	MTS	MTG	MTC	
Family Colubridae					
Adelphostigma occipitalis (Jan, 1863)	1	2		1	4
Apostolepis adhara França et al., 2018		1			1
Apostolepis sanctaeritae Werner, 1924	1		1	1	3
Chironius flavolineatus Boettger, 1885		1	1		2
Chironius quadricarinatus Boie, 1827		1			1
Dipsas bucephala (Shaw, 1802)		1			1
Dipsas mikanii Schlegel, 1837		3	2		5
Drymoluber brazili (Gomes, 1918)		1			1
Dryophylax phoenix (Franco et al., 2017)	1	1			2
Erythrolamprus almadensis (Wagler, 1824)		2	2		4
Erythrolamprus poecilogyrus (Wied-Neuwied, 1824)		1			1
Erythrolamprus reginae (Linnaeus, 1758)		2			2
Leptodeira annulata (Linnaeus, 1758)				1	1
Oxyrhopus guibei Hoge & Romano, 1977	1	10			11
Oxyrhopus trigeminus Duméril, Bibron & Duméril, 1854	3	7			10
Oxyrhopus rhombifer Duméril, Bibron & Duméril, 1854	1	2			3
Philodryas nattereri (Steindachner, 1870)	1	5			6
Phimophis guerini (Duméril, Bibron & Duméril, 1854)	1	4			5

TAXON	ABUNDANCE BY PHYTOPHYSIOGNOMY				TOTAL ABUNDANCE
	ANT/PAS	MTS	MTG	MTC	
Spilotes pullatus (Linnaeus, 1758)		1	1		2
Xenodon merremii (Wagler, 1824)		4			4
Family Leptotyphlopidae					
Trilepida koppesi (Amaral, 1955)		6			6
Family Viperidae					
Bothrops moojeni Hoge, 1966		2			2
Bothrops neuwiedi Wagler, 1824		1			1
Order Testudines					
Suborder Cryptodira					
Family Testudinidae					
Chelonoidis carbonarius (Spix, 1824)	1				1

Figure 7. Representatives of some of the reptiles recorded in the Cerrado area deforested for road opening. **Amphisbaenia: Amphisbaenidae: 1** *Amphisbaena alba*, **2** *Amphisbaena anaemariae*, **3** *Amphisbaena fuliginosa*, **4** *Leposternon infraorbitale*; **Sauria: Anolidae: 5** *Anolis brasiliensis*; **Gymnophthalmidae: 6** *Cercosaura schreibersii*, **7** *Colobosaura modesta*, **8** *Micrablepharus maximiliani*; **Hoplocercidae: 9** *Hoplocercus spinosus*; **Iguanidae: 10** *Iguana iguana*; **Phyllodactylidae: 11** *Gymnodactylus amarali*; **Polychrotidae: 12** *Polychrus acutirostris*.

Figure 8. Representatives of some of the reptiles recorded in the Cerrado area deforested for road opening. **Scincidae: 13** *Copeoglossum nigropunctatum*, **14** *Notomabuya frenata*; **Teiidae: 15** *Ameiva ameiva*, **16** *Ameivula ocellifera*, **17** *Salvator merianae*, **18** *Tupinambis quadrilineatus*; **Tropiduridae: 19** *Tropidurus oreadicus*; **Serpentes: Boidae: 20** *Boa constrictor*, **21** *Epicrates cenchria*; **Colubridae: 22** *Apostolepis sanctaeritae*, **23** *Apostolepis adhara*, **24** *Chironius flavolineatus*.

Figure 9. Representatives of some of the reptiles recorded in the Cerrado area deforested for road opening. **Colubridae: 25** *Dipsas mikanii*, **26** *Leptodeira annulata*, **27** *Adelphostigma occipitalis*, **28** *Oxyrhopus trigeminus*, **29** *Oxyrhopus rhombifer*, **30** *Philodryas nattereri*, **31** *Xenodon merremii*, **32** *Dryophylax phoenix*; **Leptotyphlopidae: 33** *Trilepida koppesi*; **Cryptodira: Testudinidae: 34** *Chelonoidis carbonarius*.

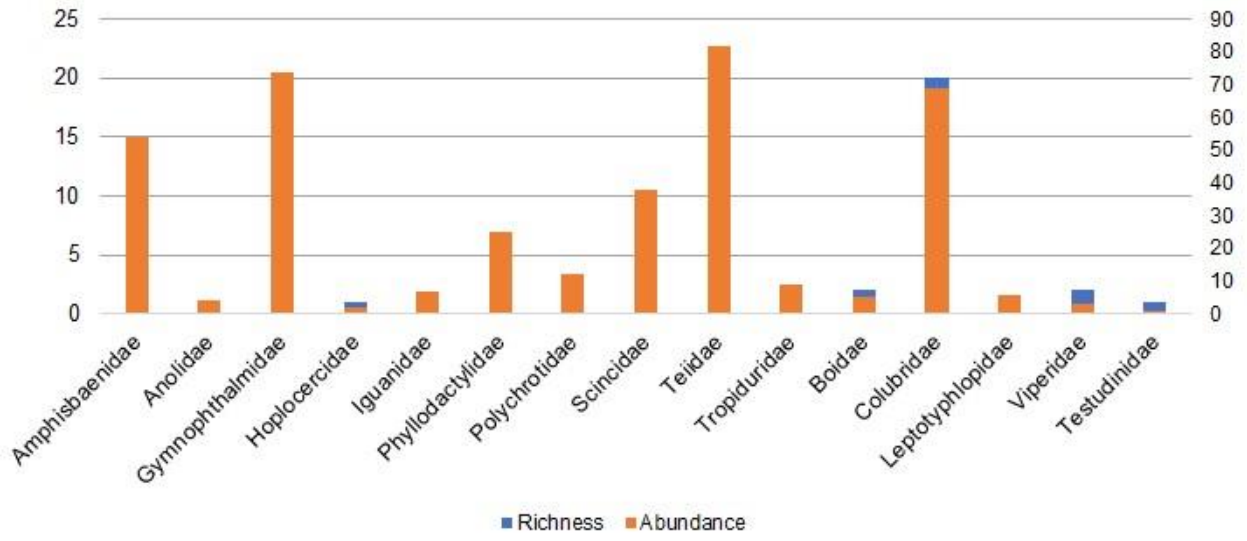

Figure 10. Richness and abundance of reptile species by family.

Table 5. Observed and estimated reptiles species.

Sampled areas	Observed	Estimated
ANT/PAS	25	22
MTS	40	34
MTG	14	41
MTC	9	45

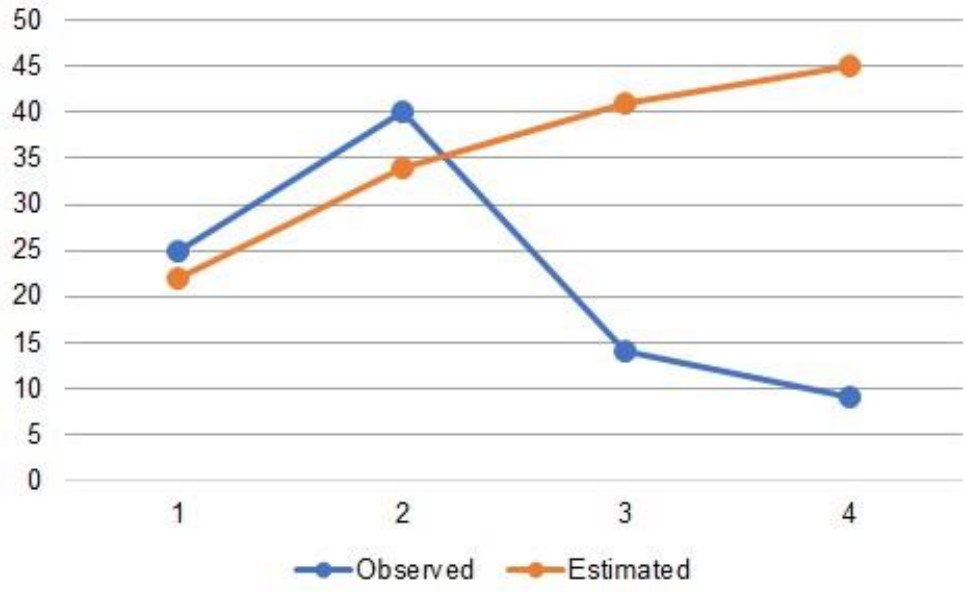

Figure 11. Rarefaction curve of the observed and estimated species richness of reptiles.

Table 6. Similarity index (Bray-Curtis) of reptile species observed in the four sampled areas. **ANT/PAS** = Anthropogenic area consisting of pasture; **MTS** = Mata Seca; **MTG** = Mata de Galeria; **MTC** = Mata Ciliar.

	ANT/PAS	MTS	MTG	MTC
ANT/PAS	1	0.50	0.32	0.28
MTS	0.50	1	0.21	0.13
MTG	0.32	0.21	1	0.19
MTC	0.28	0.13	0.19	1

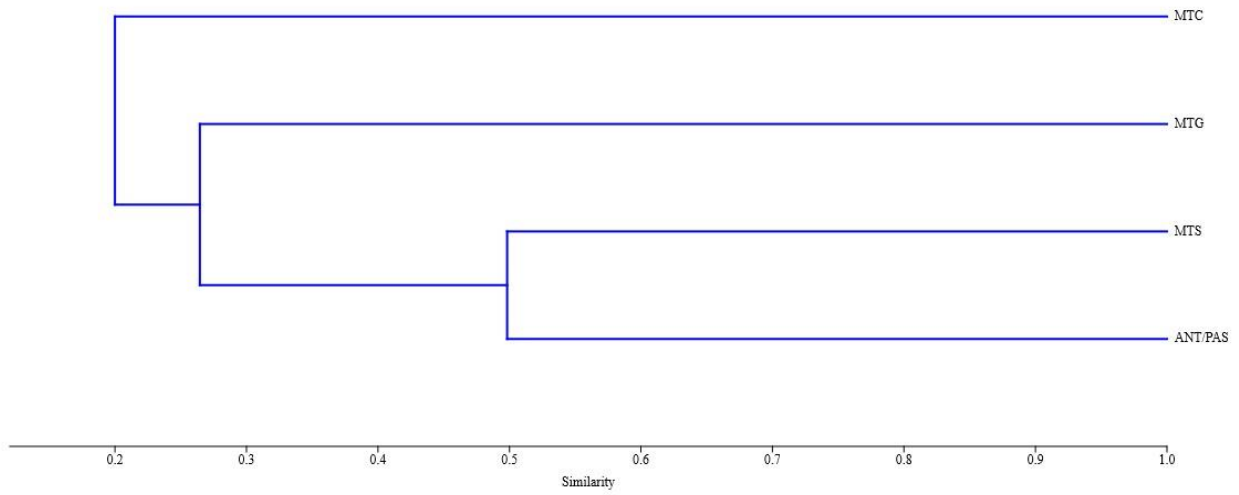

Figure 12. Similarity dendrogram (Bray-Curtis) of the reptiles between the three sampled phytophysiognomies and anthropic area. The unweighted pair-group average (UPGMA) algorithm was used.

Discussion

The herpetofauna checklist presented here comprises a period of just over five months and is the result of the fauna rescue work during the first stage of the works on an access road to a mining company, where the entire route of the road was followed from the starting point on another highway (GO-241) to the end point on the banks of the Cana Brava River. Thus, the species richness data presented here are not definitive, since other studies with temporal variations and a sampling effort concentrated on herpetofauna will possibly provide the record of species not presented here. At the same time, the Cerrado located in this municipality is experiencing strong anthropogenic pressure due to mining. The loss of habitat and contaminating elements from mining may negatively influence the populations of amphibians and reptiles located in this region.

With over 4,800 plant and vertebrate species found nowhere else, the Cerrado is a global biodiversity hotspot (Strassburg et al., 2017) and, despite mining is vital for human sustenance and a crucial sector in the state economy, its impacts on the environment and biodiversity cannot be

underestimated (Rehman et al., 2021). Mineral exploitation threatens wildlife by the contamination of soil and water sources, vegetation suppression, and due to changes in landscape configuration (Martins-Oliveira et al., 2021).

The local economic impact of any mining enterprise is visible in terms of employment and finance, while the impact on biodiversity should not be disregarded in any way. Thus, it is necessary to work on the continuous monitoring of herpetofauna in the region so that it is possible to build a solid database that enables conservation actions.

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Appendix 1. Amphibians and reptiles collected during the rescue of fauna in a Cerrado area in the municipality of Minaçu, Goiás and deposited in the Herpetological Collection of the Center for Biological Studies and Research of the Pontifical Catholic University of Goiás (CEPB).

Amphibia: *Scinax fuscovarius* (CEPB-10148); *Trachycephalus typhonius* (CEPB-10150). **Reptilia: Squamata: Amphisbaenia:** *Amphisbaena alba* (CEPB-2392, 2399); *Amphisbaena anaemariae* (CEPB-2382, 2383, 2384, 2386, 2387, 2389, 2390, 2391, 2393, 2394, 2395, 2396, 2398, 2401, 2403, 2404, 2405, 2406, 2407, 2408, 2409, 2410, 2411, 2413, 2414); *Amphisbaena fuliginosa* (CEPB-2385, 2388, 2397, 2400, 2402, 2412). **Sauria:** *Ameiva ameiva* (CEPB-12269, 12270, 12272, 12274, 12276, 12277, 12278); *Ameivula ocellifera* (CEPB-12273, 12275); *Cercosaura schreibersii* (CEPB-12251); *Colobosaura modesta* (CEPB-12249); *Copeoglossum nigropunctatum* (CEPB-12263, 12264, 12265, 12268); *Gymnodactylus amarali* (CEPB-12260, 12261); *Hoplocercus spinosus* (CEPB-12252); *Iguana iguana* (CEPB-12253, 12254, 12255, 12256); *Micrablepharus maximiliani* (CEPB-12248, 12250); *Notomabuya frenata* (CEPB-12266, 12267); *Polychrus acutirostris* (CEPB-12262); *Salvator merianae* (CEPB-12271). **Serpentes:** *Adelphostigma occipitalis* (CEPB-9277, 9292); *Apostolepis sanctaeritae* (CEPB-9279); *Boa constrictor* (CEPB-9264); *Bothrops neuwiedi* (CEPB-9296); *Chironius flavolineatus* (CEPB-9276); *Dipsas bucephala* (CEPB-9290); *Dipsas mikanii* (CEPB-9271); *Drymoluber brazili* (CEPB-9265); *Dryophylax phoenix* (CEPB-9283); *Erythrolamprus almadensis* (CEPB-9286); *Erythrolamprus reginae* (CEPB-9293); *Oxyrhopus guibei* (CEPB-9267, 9272, 9284, 9295); *Oxyrhopus trigeminus* (CEPB-9288, 9289, 9291); *Philodryas nattereri* (CEPB-9266, 9281, 9282); *Phimophis guerini* (CEPB-9268, 9270, 9285, 9294); *Spilotes pullatus* (CEPB-9269); *Trilepida koppesi* (CEPB-12257, 12258, 12259).