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The herpetofauna of the Estação Ecológica de Uruçuí-Una, state of Piauí, Brazil

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ABSTRACT

This work was carried out with the main objective of sampling the herpetofauna of a Cerrado site in the state of Piauí, Brazil, that is influenced by neighboring biomes and one of the least known regions of the domain. The herpetofauna of the different habitats present at Estação Ecológica de Uruçuí-Una (EEUU) was sampled intensively during three campaigns (two during the wet season and one during the dry season). We recorded 90 species, 64 reptiles and 26 anurans, a high local richness when compared to other well-sampled localities of the Cerrado. The rarefaction curve for both anurans and lizards shows that the observed richness is close to real and the richness estimators indicate that undetected species should be added with higher sampling effort. Analysis of co-occurrence shows that the species are not randomly distributed in the landscape, indicating that they use preferentially particular types of habitat. Despite being located in a transitional area and influenced by neighboring biomes, the cluster analysis of similarity suggests that the herpetofauna of the EEUU is typical of the Cerrado. Thereby, the results of this study indicate that the EEUU presents a rich herpetofauna that plays an important role in the conservation of a regional faunistic pool.

Key-Words: Reptiles; Anurans; Cerrado of Piauí; Conservation.

INTRODUCTION

For a long time, the Cerrado morphoclimatic domain was considered poorly diversified, essentially consisting of species with broad geographic ranges shared with neighboring domains (Sick, 1965; Vanzolini, 1963, 1976, 1988). This simplistic view persisted, but with the accumulation of new species descriptions (Colli *et al.,* 2003; Ferrarezzi *et al.,* 2005; Nogueira & Rodrigues, 2006; Rodrigues *et al.,* 2007, 2008) and extensive inventories in the area (Colli *et al.,* 2002; Rodrigues, 1987; Nogueira *et al.,* 2009; Vitt *et al.,* 2005; França & Araújo, 2006; Silveira, 2006; Recoder & Nogueira, 2007; Recoder *et al.,* 2011), it became clear that the Cerrado herpetofauna is rich both locally and regionally and

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presents high levels of endemism (Nogueira *et al.,* 2010).

The horizontal stratification of habitats in the landscape, especially considering the different physiognomies that form a heterogeneous complex of vegetation types composed by grasslands, savannas and forests (Eiten, 1972; Oliveira-Filho & Ratter, 2002), was suggested as a major factor explaining the herpetofaunal diversity in the domain (Colli *et al.,* 2002; Nogueira *et al.,* 2009). Studies on habitat and microhabitat preferences are essential in assessing the level of ecological fidelity of species, allowing for the formulation and testing of evolutionary scenarios that are thought to have led to its origin and distribution (Vanzolini, 1988). These studies, basically grounded on detailed surveys of broad regional scale, provide subsidies for the development of conservation strategies (Brooks *et al.,* 1992; Greene, 1994; Silva & Bates, 2002).

The Cerrado, along with the neighboring domains of Caatinga and Chaco, form a diagonal belt of dry open areas in South America (Vanzolini, 1988). Originally, the Cerrado covered an area of two million km^2, accounting for 22% of the Brazilian territory, as well as being the second largest South American morphoclimatic domain and the largest neotropical savanna (Eiten, 1972; Ab'Sáber, 1977; Oliveira & Marquis, 2002). Recent data show a substantial loss of original vegetation cover due to human occupation and expansion of agricultural activities in the Cerrado (Myers *et al.,* 2000, Cavalcanti & Joly, 2002; Klink & Machado, 2005; Silva *et al.,* 2006), with estimates of about 30% of its native cover remaining, and only 5.5% protected within conservation units (Mittermeier *et al.,* 2005).

The state of Piauí experienced a fast occupation of its Cerrado portion, initiated between the 1970s and 1980s with the implementation of agricultural megaprojects (Aguiar & Monteiro, 2005). According to Castro (2000), this Brazilian state harbors one of the three centers of biodiversity in the Cerrado, mainly due to its diverse vegetation typical of an ecotonal zone that carries aspects of the Caatinga, Amazon, and Cerrados regions.

Thus, despite its high diversity and status of being one of the 25 priority areas for study and conservation of biodiversity in the world (Myers *et al.,* 2000), a large portion of the Cerrado domain remains unknown. The main objectives of the present study are: 1) to present a list of the species recorded through an intensive survey of the herpetofauna of the Ecological Station of Uruçuí-Una, one of largely unknown areas of the domain; 2) to test if the local distribution of these species is random or structured among different habitats of the landscape; and 3) to analyze patterns of similarity with other herpetofaunal communities surveyed from different Brazilian domains as a way to test the prediction that the Cerrado harbors a typical fauna.

MATERIALS AND METHODS

Study area

The fieldwork was carried out at Estação Ecológica de Uruçuí-Una (EEUU) (approximate coordinates: 08°50'S; 44°10'W), situated in the southwest of the state of Piauí, and located within the region of plateaus of the Parnaíba River basin (Fig. 1). The area is mainly covered by wooded savanna vegetation; the eastern portion of the EEUU is dominated by physiognomies of Cerrado "sensu stricto" (typical savannas), whereas palm marshes are prevalent in the lowlands of the western portion (Castro, 1984). The relief is characterized by dissected plateaus with altitudes ranging from 480 to 620 m and valleys at 380 to 420 m of elevation. The rivers Uruçuí-Una and Riozinho are the most important water courses of the EEUU, containing numerous small tributary streams. The climate is dry sub-humid or sub-humid of transition, with a dry period extending from March to October and a wet season from January to March, with high mean annual temperatures around 24-26°C (Castro, 1984).

Sampling method

Sampling effort was conducted along three campaigns, two during the rainy season (February 10 to March 09, 2000 and January 09 to February 01, 2001), and one during the dry season (July 16-28, 2000). We sampled the main physiognomic subunits present in the region with the use of pitfall traps with drift fences complemented by active visual search. Twelve lines of pitfall traps were installed, each composed of 10 sampling units, consisting of four 30 L buckets arranged in Y-shape, a central one joined to three peripherals by three meter long plastic fences. Active sampling consisted of visual search for individuals in activity or hidden in specific microhabitats (*e.g.,* bark, logs, under rocks, leaf litter, rock crevices). All main physiognomies were sampled by active visual search. This sampling method was complemented with occasional encounters of species during the campaign period and specimens brought by local residents. Types of habitat, exact coordinates of sampling units, campaigns in which traps were opened, and total sampling effort are presented in Table 1. The following habitats were sampled (Fig. 2):

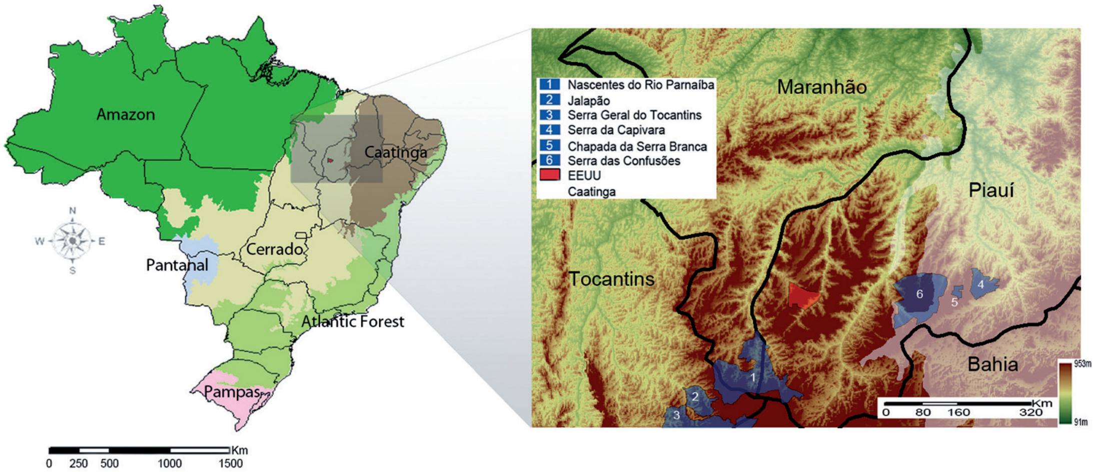

FIGURE 1: Brazilian map with the different morphoclimatic domains (left), and a close-up (right) of altitudinal map of the region that includes the EEUU (in red) and several other adjacent conservation units (in blue).

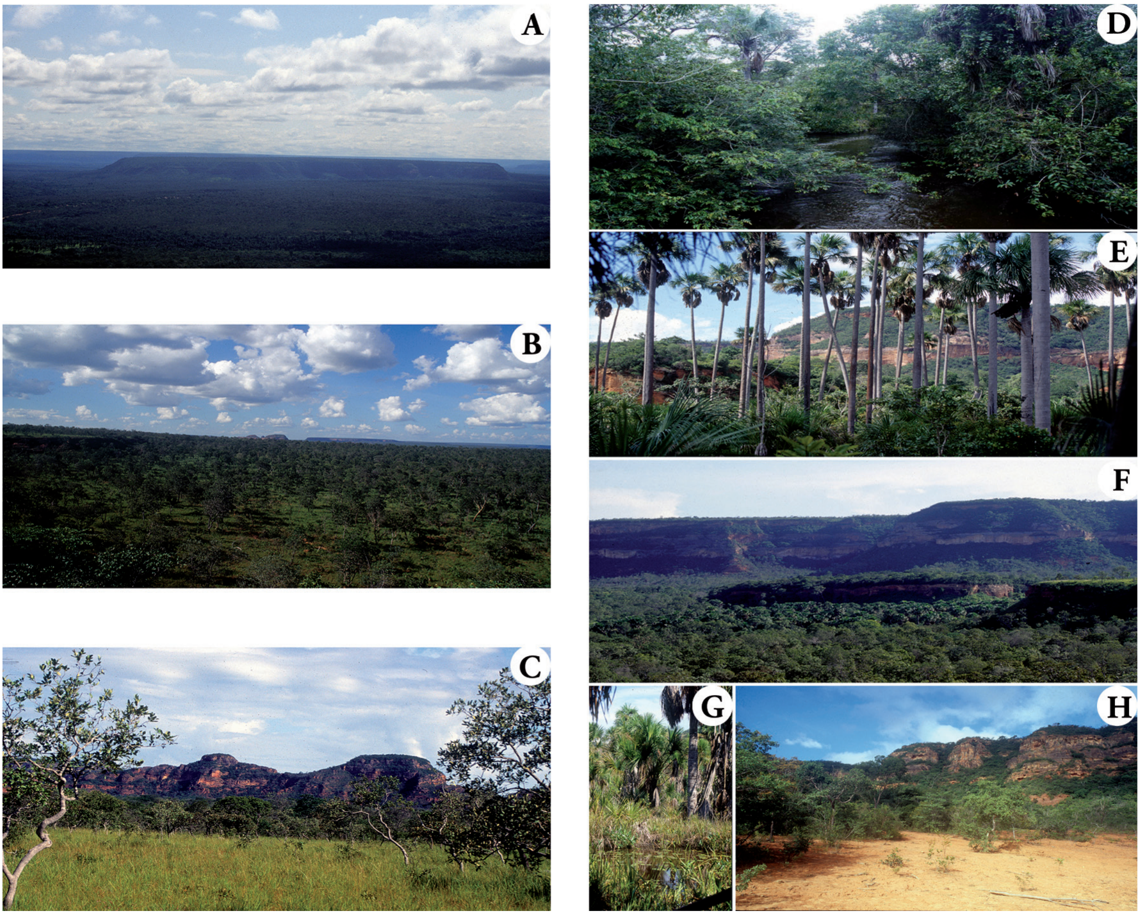

FIGURE 2: Landscapes in the EEUU and some examples of sampled habitats: **(A)** aerial view of the Station, with areas of plateaus in the background; **(B)** Cerrado vegetation in the lowlands; **(C)** Typical savanna (Cerrado); **(D)** Gallery forest; **(E)** Palm marshes; **(F)** Hillside forest; **(G)** Wet field; **(H)** Dry forest.

TABLE 1: Geographical coordinates of the lines of pitfall traps installed in the Estação Ecológica de Uruçuí-Una, and in which campaigns each were opened. The sampling effort is presented in buckets/ days.

Pitfall lines	1st campaign (10 February to 09 March, 2000)	2nd campaign (16-28 July 2000)	3rd campaign (09 January to 01 February, 2001)
Line 1 – Cerrado near the station – 08°53'02"S, 44°58'08"W	560		400
Line 2 – Cerrado near the station – 08°52'81"S, 44°57'88"W		800	440
Line 3 – Cerrado near the station – 08°52'50"S, 44°58'25"W	720		
Line 4 – Cerrado of Ema Flor Farm – 08°47'81"S, 45°06'53"W	360		
Line 5 – Cerrado of Ema Flor Farm – 08°48'65"S, 45°07'29"W	360		
Line 6 – Gallery forest – 08°52'39"S, 44°57'26"W	520	400	440
Line 7 – Gallery forest – 08°52'71"S, 44°57'53"W		320	
Line 8 – Gallery forest – 08°52'77"S, 44°57'68"W			360
Line 9 – Dry forest – 08°54'21"S, 45°00'02"W	640		
Line 10 – Dry forest – 08°54'79"S, 45°00'10"W		680	440
Line 11 – Hillside forest – 08°53'02"S, 44°59'51"W	680		
Line 12 – Hillside forest – 08°54'08"S, 45°01'09"W			400
Sampling effort	3840 buckets/days	2200 buckets/days	2480 buckets/days

1) **Cerrado near the station:** lines 1 to 3. The savanna vegetation around EEUU headquarters is characterized by dense tree and shrub layers, but without a closed canopy. The soil is sandy and covered by significant floral diversity (Figs. 2B, C).

2) **Cerrado of Ema Flor Farm:** lines 4 to 5. The savanna vegetation at the Serra Grande plateau was sampled near the Ema Flor Farm facilities. Mainly bushy grasslands, with a dense herbaceous layer, sparse trees and low shrubs, compose the area. This savanna has a significantly lower canopy with a more sparsely distributed arboreal covering than the savanna observed in the valleys (Fig. 2A).

3) **Gallery forest:** lines 6 to 8. Closed canopy evergreen forests composed of trees averaging 15 meters in height and emergent individuals with 20 meters or more. The soil is less sandy than in the surrounding savannas, and the ground is covered with a significantly denser litter. The gallery forest sampled follows the course of the Uruçuí-Preto River, which delimits one edge of the Ecological Station. The strip of this forest is usually narrow, reaching about 50 m wide at some points. Native bamboo, buriti palms (*Mauritia vinifera*) and temporary ponds, formed during the floods of the Uruçuí-Preto River, also occur within this forested area. Gallery forests sampled in the area of the park and vicinities were moderately impacted by anthropic activities (Fig. 2D).

4) **Dry forest:** lines 9 and 10. This area represents an uncommon type of vegetation within the station. Usually present around rocky outcrops surrounded by savannas, the Dry forest (locally called "caatinga") is characterized by a dense but thin arboreal vegetation with a discontinuous canopy usually ranging between three and eight meters tall, without contact with perennial water bodies. The soil is somewhat sandy and can be characterized as a red latossol with areas of laterite outcrops. The understory is mostly composed of terrestrial bromeliads and cacti in abundance. This type of physiognomy is also found at the top of some isolated hills (Fig. 2H).

5) **Hillside forest:** lines 11 and 12. A forest characterized by a closed canopy and sandy soil, with high deposition of organic matter forming a dense litter. This habitat is restricted to the borders of the plateau and vicinities of a lagoon that is marginal to the Ecological Station. It represents an alternative to the savannas and seems to have colonized the slopes of most plateaus in the area, where arboreal elements of the savanna are absent (Fig. 2F).

6) **Flooded grassland:** habitat sampled only by active search. Open environment, generally used for pasture. Soil very wet and dark, exposed in some places and covered with grasses along most of its length. There are patches of dense vegetation, scattered over the field, presenting individuals buriti palms, shrubs, trees, and taller grasses (Fig. 2G).

7) **Palm marshes:** habitat sampled only with active search. Swamp-like environment with a high density of buriti palm trees (*Mauritia vinifera*) and buritiranas (*Mauritia marti*), with individuals reaching about 25 m tall. The palm marshes are mainly found around small

lagoons and along watercourses, usually associated with stagnant water bodies or temporary streams. The habitat is quite different from the surrounding vegetation in terms of physiognomy and microclimate (Fig. 2E).

Specimens captured were marked with toe clip and released near the capture site. A representative sample of specimens were collected and deposited in the herpetological collection of the Museu de Zoologia, Universidade de São Paulo, São Paulo (MZUSP). Voucher specimens were killed with an injection of anesthetics, fixed in 10% formalin and transferred to 70% alcohol.

Data Analysis

The effectiveness of the sampling effort was estimated based on rarefaction curves, through 10,000 randomizations of a matrix in which each row represents a species and its number of captures while each column represents one day of sampling effort (pitfall traps plus active search). This analysis was performed using EstimateS v.8.0.0 as described in Colwell (2006). The program was also used to estimate species richness through the indicators ACE, Chao2, Jacknife1 and Jacknife2. Snakes were excluded from this analysis because of low capture rates, resulting in an underestimated list for the group that could compromise the behavior of the rarefaction curves. Additionally, a substantial portion of the snakes was sampled by local residents and lacked specific locality information or date of capture.

To analyze the community structure, *i.e.,* verify if the distribution of species is random or structured between the habitats sampled, we used the co-occurrence module of the program EcoSim v.7 (Gotelli & Entsminger, 2008) for a data matrix that included the number of individuals recorded for each species and habitat sampled. The test was performed on a null-model analysis through 10,000 randomizations of the original matrix, using the C-Score index and, "sequential swap algorithm" with columns and rows fixed, considering $p < 0.05$ as significant. To observe the faunal similarity among different habitats sampled, we performed a cluster analysis with the program MVSP v.3.1 (Kovach, 2000), using the Jaccard coefficient (not considering the number of specimens sampled, but only presence or absent) as a measure of faunal similarity and UPGMA as a clustering algorithm.

Since the EEUU is located in a transitional area, in a marginal portion of the Cerrado domain, it is hypothesized that the local fauna may suffer influence from neighboring domains in its species composition (*i.e.,* Caatinga and Amazonia). For this reason, we compared our results through a cluster analysis with information on compiled herpetofaunal inventories from different morphoclimatic domains, using the Jaccard index (Magurran, 2004). Lizards, amphibians and snakes were analyzed separately. Data from different inventories were obtained as follows: **Caatinga:** Planalto da Ibiapaba, Ceará (Loebmann & Haddad, 2010), Serra das Almas, Ceará (Borges-Nojosa & Cascon, 2005), Chapada do Araripe, Ceará, Piauí and Pernambuco (Ribeiro *et al.,* 2008), Parque Nacional do Catimbau, Pernambuco (Moura *et al.,* 2011a, b), Ouricuri- Pernambuco (Moura *et al.,* 2011a, b), Fazenda Saco, Pernambuco (Moura *et al.,* 2011a, b)]; **Cerrado:** Estação Ecológica Serra Geral do Tocantins-EESGT, Tocantins and Bahia (Recoder *et al.,* 2011), Parque Nacional Grande Sertão Veredas-PNGSV, Minas Gerais and Bahia (Recoder & Nogueira, 2007), UHE Espora, Goiás (Vaz-Silva *et al.*, 2007), Reserva Área Alfa do Cerrado-RAAC, Goiás (Nogueira *et al.,* 2009), Parque Nacional das Emas-PNE, Goiás (Nogueira *et al.,* 2009; Valdujo *et al.,* 2009a; Kopp *et al.,* 2010), Northern Tocantins River basin-BTN, Tocantins and Maranhão (*i.e.,* municipalities of Estreito, Babaçulância, Carolina and Palmeirante) (Pavan, 2007), Southern Tocantins River basin-BTS, Tocantins and Goiás(*i.e.,* municipalities of Peixe, São Salvador do Tocantins, Paranã and Minaçu) (Pavan, 2007), São Desidério, Bahia (Valdujo *et al.,* 2009b), Niquelândia, Goiás (Oda *et al.,* 2009); **Atlantic Forest:** Mata do Buraquinho, Paraíba (Santana *et al.,* 2008), Refúgio Ecológico Charles Darwin-RECD, Pernambuco (Cunha, 1994; Rosa, 1994; Moura *et al.,* 2011a), Estação Ecológica do Tapacurá-EET, Pernambuco (Moura *et al.,* 2011a, b), Mata do Engenho Coimbra, Alagoas (Ubiratan, 2008); **Amazon:** Espigão do Oeste, Rondônia (Bernarde & Abe, 2006; Bernarde, 2007; Macedo *et al.,* 2008), Carajás, Pará (Cunha *et al.,* 1985; Pinheiro, 2010), Cacoal, Rondônia (Turci & Bernarde, 2008) Reserva Ducke, Amazonas (Lima *et al.,* 2006; Vitt *et al.,* 2008). As a way of complementing the similarity analyses, distribution patterns of the species on a continental scale were determined from the literature and standardized according to Strüssmann & Mott (2009) and Recoder *et al.* (2011).

The Brazilian list of endangered reptiles and amphibians (Martins & Molina, 2008; Haddad, 2008), as well as the appendices of the Convention on International Trade in Endangered Species (CITES, 2009) and the IUCN Red List of Threatened Fauna (IUCN, 2012), were consulted to evaluate the conservation status of the species sampled in this study.

RESULTS

We sampled a total of 90 species in the EEUU along three campaigns, representing 64 reptiles (19 lizards, 39 snakes, four amphisbaenians, one turtle and one crocodilian) and 26 anurans (Table 2, Figs. 3, 4). The pitfall traps with drift fences accounted for the sampling of 13 species of lizards, five snakes and 16 anurans. Table 3 shows the richness sampled in each campaign and the relative contribution of different sampling methods.

The rarefaction curve for lizards tends to an asymptote after 38 sampling days (Fig. 5A), with richness estimators ACE, Chao2 and Jacknife1 recovering 20, 20 and 22 species, respectively. When analyzing each campaign separately, the curves did not present an evident asymptote (Fig. 5C). For lizard diversity in the first campaign, richness estimators ACE, Chao2 and Jacknife1 recovered values of 19, 20 and 22 species, respectively. The same sequence of estimators recovered values of 13, 12 and 14 species for the second campaign, and 14, 12 and 14 species for the third campaign.

For anurans, the rarefaction curve tends to an asymptote after 38 sampling days (Fig. 5B), with richness estimators ACE, Chao2 and Jacknife1 recovering 26, 27 and 29 species, respectively. However, when each campaign is analyzed separately, the curves show different results (Fig. 5D), with only the curve of the first campaign slightly tending to an asymptote despite the smaller richness recorded compared to the third campaign (Fig. 5D). Richness estimators ACE, Chao2 and Jacknife1 retrieved values of 25, 24 and 27 species for the first campaign and 24, 25 and 29 species for the third campaign, respectively. The same estimators recovered 15, 17 and 17 species for the second campaign, respectively, reaching 21 species for the estimator Jacknife2.

The C-score index observed was statistically greater than the random distribution in 10,000 simulations [observed: 1.421; simulated (average): 1.339; $p < 0.01$], indicating a non-random distribution of species among habitats sampled. The same pattern is observed when analyzing the communities of lizards, snakes and amphibians separately.

The cluster analysis among the sampled habitats shows a separation between the two moist physiognomies ("flooded grassland" and "palm marshes") and the other habitats. However, the similarity based on species shared between these two habitats is low, suggesting the presence of a specialized fauna associated with each habitat (Figs. 6A, B, C). The dendrograms were similar for herpetofauna and lizards (Figs. 6A, B), with "hillside forest" and "dry forest" showing a high similarity in species composition. Nevertheless, the "gallery forest" is not grouped with these other forested environments, sharing more similarity with the fauna of the "cerrado near the station". The open savanna areas of the "cerrado near the station" and "cerrado of Ema Flor Farm" share only about 30% of species of the herpetofauna; but 55% when lizards are considered separately (Figs. 6A, B). For anurans, the pattern was slightly different, with "flooded grassland" and "palm marshes" clustering together but separated from the others physiognomies. "Hillside forest" is clustered with "cerrado near the station", with others habitats ("cerrado of Ema Flor Farm", "gallery forest" and "dry forest") having little similarity (Fig. 6C).

The herpetofauna present at the EEUU is mainly composed of species with wide geographic distribution, and is thus shared mostly with neighboring morphoclimatic domains (Table 2). From the species obtained, 52 (58%) are shared with the Caatinga domain, among which 12 are exclusively shared between those domains; 40 species (44%) are shared with the Amazon, eight being uniquely shared between Cerrado and Amazon; and 20 species (22%) are endemic to the Cerrado domain (Table 2). The cluster analysis of similarity of the herpetofaunal lists shows that communities of lizards and amphibians in the EEUU are more similar in composition to other localities of the Cerrado domain. For both anurans and lizards, the communities are clustered forming "Cerrado", "Northeast Atlantic" and "Caatinga" groups. The group "Amazon" has a lower similarity with other groups, being externally positioned in the dendrograms (Figs. 7A, B).

The lizard community of the EEUU is embedded in the "Cerrado" group of the dendrogram, suggesting a high degree of influence on its composition from the fauna of this domain (Fig. 7A). Despite its insertion in the "Cerrado" group, anurans of the EEUU are positioned rather externally to other Cerrado communities, sharing little similarity with the rest of the group (Fig. 7B). The cluster analysis of similarity for the snake community has not recovered geographical groups such as observed for lizards and anurans (Fig. 7C).

None of the species recorded in this study are present in the Brazilian list of threatened species of reptiles and amphibians (Martins & Molina, 2008; Haddad, 2008). Also, no species is considered threatened according to IUCN Red List of threatened fauna (IUCN, 2012). However, lizards of the genera *Tupinambis, Salvator* and *Iguana,* the boine

TABLE 2: List of the herpetofauna of the EEUU, as well as the local distribution of species among the sampled habitats and their continental occurrences in the different morphoclimatic domains. **N:** number of individual observed. **Habitats of capture:** (Ce) Cerrado near the station; (EF) Cerrado of Ema Flor Farm; (GF) Gallery forest; (HF) Hillside forest; (DF) Dry forest; (WF) Wet field; (PM) Palm marshes, (?) Without information. **Continental distribution:** (CE) Cerrado; (CA) Caatinga; (AF) Atlantic Forest; (AM) Amazon; (CH) Chaco; (PA) Pampa. The conservation status in relation to CITES (2009) is superscript in the species name.

	N	Habitat of capture	Continental distribution
REPTILIA			
SQUAMATA			
“LIZARDS”			
HOPLOCERCIDAE			
Hoplocercus spinosus Fitzinger, 1843	**13**	DF, HF	CE
IGUANIDAE			
Iguana iguana (Linnaeus, 1758) [CITES II]	**7**	GF, PM	CE, CA, AF, AM
TROPIDURIDAE			
Tropidurus oreadicus Rodrigues, 1987	**301**	Ce, GF, DF, HF, EF	CE
Tropidurus semitaeniatus (Spix, 1825)	**45**	HF	CE, CA
DACTYLOIDAE			
Norops meridionalis (Boettger, 1885)	**15**	Ce, GF, DF	CE
Norops brasiliensis (Vanzolini & Williams, 1970)	**2**	DF	CE
Polychrus acutirostris Spix, 1825	**4**	Ce, EF	CE, CA, CH
PHYLLODACTYLIDAE			
Phyllopezus pollicaris (Spix, 1825)	**25**	DF, EF	CE, CA, AF, CH
SPHAERODACTYLIDAE			
Coleodactylus brachystoma (Amaral, 1935)	**19**	Ce, GF, EF	CE
GEKKONIDAE			
Hemidactylus brasilianus (Amaral, 1935)	**15**	Ce	CE, CA
Hemidactylus mabouia (Moreau de Jonnès, 1818)	**3**	EF	CE, CA, AF, AM, CH
SCINCIDAE			
Copeoglossum nigropunctatum (Spix, 1825)	**10**	Ce, GF, EF	CE, CA, AF, AM
GYMNOPHTHALMIDAE			
Colobosaura modesta (Reinhardt & Lütken, 1862)	**44**	Ce, GF, DF, HF, EF	CE
Micrablepharus maximiliani (Reinhardt & Lütken, 1862)	**85**	Ce, GF, DF, HF, EF	CE, CA, AF, CH
TEIIDAE			
Ameiva ameiva (Linnaeus, 1758)	**109**	Ce, GF, DF, HF,EF	CE, CA, AF, AM, CH
Ameivula cf. *mumbuca*	**162**	Ce, GF, DF, HF, EF	CE
Kentropyx calcarata Spix, 1825	**5**	Ce, GF, PM	CE, AF, AM
Salvator merianae (Duméril & Bibron, 1839) [CITES II]	**1**	Ce	CE, CA, AF, AM, CH, PA
Tupinambis quadrilineatus Manzani & Abe, 1997 [CITES II]	**12**	Ce, GF, PM	CE
“AMPHISBAENIANS”			
AMPHISBAENIDAE			
Amphisbaena alba Linnaeus, 1758	**8**	GF	CE, CA, AF, AM
Amphisbaena polystega (Duméril, 1851)	**14**	?	CE, CA
Amphisbaena miringoera Vanzolini, 1971	**5**	?	CE, AM
Amphisbaena vermicularis Wagler, 1824	**17**	EF	CE, CA, AF, AM
“SNAKES”			
TYPHLOPIDAE			
Typhlops brongersmianus Vanzolini, 1972	**5**	GF	CE, CA, AF, AM, CH
LEPTOTYPHLOPIDAE			
Tricheilostoma brasiliensis (Laurent, 1949)	**4**	EF	CE
BOIDAE			
Boa constrictor Linnaeus, 1758 [CITES II]	**6**	GF	CE, CA, AF, AM, CH
Corallus hortulanus (Linnaeus, 1758) [CITES II]	**6**	HF, PM	CE, CA, AF, AM
Epicrates assisi Machado, 1945 [CITES II]	**3**	Ce	CE, CA
Eunectes murinus (Linnaeus, 1758) [CITES II]	**4**	PM	CE, AM, CH
COLUBRIDAE			
Chironius exoletus (Linnaeus, 1758)	**1**	?	CE, CA, AF, AM

	N	Habitat of capture	Continental distribution
Chironius flavolineatus (Boettger, 1885)	**14**	Ce, GF	CE, CA, AF, AM, CH
Leptophis ahaetulla (Linnaeus, 1758)	**2**	Ce	CE, CA, AF, AM
Mastigodryas bifossatus (Raddi, 1820)	**6**	Ce	CE, CA, AF, AM, CH, PA
Mastigodryas boddaerti (Sentzen, 1796)	**2**	Ce	CE, AM
Spilotes pullatus (Linnaeus, 1758)	**6**	Ce	CE, CA, AF, AM, CH
Tantilla melanocephala (Linnaeus, 1758)	**5**	Ce, EF	CE, CA, AF, AM
DIPSADIDAE			
Apostolepis cearensis Gomes, 1915	**11**	EF	CE, CA
Apostolepis polylepis Amaral, 1921	**1**	Ce	CE
Boiruna sp.	**2**	Ce	CE, CA
Helicops angulatus (Linnaeus, 1758)	**7**	Ce	CE, AF, AM
Hydrops triangularis (Wagler, 1824)	**3**	?	CE, AM
Hydrops triangularis (Wagler, 1824)	**5**	Ce	CE, AF, AM
Erythrolamprus poecilogyrus (Wied, 1825)	**62**	Ce, GF, HF, EF	CE, CA, AF, AM, CH, PA
Erythrolamprus reginae (Linnaeus, 1758)	**17**	GF	CE, CA, AM
Erythrolamprus taeniogaster (Jan, 1863)	**3**	?	CE, CA, AM
Lygophis paucidens Hoge, 1953	**2**	PM	CE
Oxyrhopus rhombifer Duméril, Bibron & Duméril, 1854	**14**	?	CE, AM, CH
Oxyrhopus trigeminus Duméril, Bibron & Duméril, 1854	**20**	Ce, DF, EF	CE, CA, CH
Philodryas nattereri Steindachner, 1870	**30**	Ce, EF	CE, CA
Philodryas olfersii (Lichtenstein, 1823)	**17**	Ce	CE, CA, AF, AM, CH
Rodriguesophis iglesiasi (Gomes, 1915)	**4**	Ce	CE, CA
Pseudoboa nigra (Duméril, Bibron & Duméril, 1854)	**2**	?	CE, CA, AF
Psomophis joberti (Sauvage, 1884)	**15**	Ce, GF, PM	CE, CA
Sibynomorphus mikanii (Schlegel, 1837)	**1**	?	CE, CA, AF
Taeniophallus occipitalis (Jan, 1863)	**3**	?	CE, AM
Thamnodynastes sp.	**17**	Ce	CE, CA
Xenodon merremii (Wagler, 1824)	**110**	Ce, GF	CE, CA, AF, CH, PA
Xenodon nattereri (Steindachner, 1867)	**1**	?	CE
ELAPIDAE			
Micrurus ibiboboca (Merrem, 1820)	**7**	Ce, HF, WF	CE, CA
VIPERIDAE			
Bothrops lutzi (Miranda-Ribeiro, 1915)	**2**	Ce	CE, CA
Bothrops moojeni Hoge, 1966	**104**	Ce, GF, PM, WF	CE
Crotalus durissus (Linnaeus, 1758)	**15**	EF	CE, CA, CH
ARCHOSAURIA			
CROCODYLIA			
ALLIGATORIDAE			
Caiman crocodilus [CITES II] (Linnaeus, 1758)	**3**	PM	CE, CA, AF, AM
ANAPSIDA			
TESTUDINES			
CHELIDAE			
Phrynops cf. *tuberosus*	**4**	GF, PM	CE, CA, AF
AMPHIBIA			
ANURA			
HYLIDAE			
Dendropsophus minutus (Peters, 1872)	**3**	PM, WF	CE, CA, AF, AM, CH, PA
Dendropsophus nanus (Boulenger, 1889)	**20**	PM	CE, CA, AF, AM, CH, PA
Dendropsophus rubicundulus (Reinhardt & Lütken, 1862)	**12**	DF, PM, WF	CE
Dendropsophus soaresi (Caramaschi & Jim, 1983)	**42**	EF	CE, CA, AF
Hypsiboas multifasciatus (Günther, 1859)	**28**	PM	CE, AM
Osteocephalus taurinus Steindachner, 1862	**7**	PM	CE, AM
Phyllomedusa azurea Cope, 1862	**44**	DF, EF	CE
Scinax fuscomarginatus (A. Lutz, 1925)	**12**	PM	CE, CA, AF
Scinax gr. *ruber* sp.1	**24**	Ce, EF	—

	N	Habitat of capture	Continental distribution
Scinax gr. *ruber* sp.2	**60**	PM, WF, EF	—
Trachycephalus typhonius (Linnaeus, 1758)	**14**	PM, WF, EF	CE, AF, AM
LEPTODACTYLIDAE			
Adenomera sp. nov.	**50**	Ce, GF, DF, HF	—
Leptodactylus fuscus (Schneider, 1799)	**12**	Ce, EF	CE, CA, AF, AM, CH
Leptodactylus podicipinus (Cope, 1862)	**1**	PM	CE, AM, CH
Leptodactylus troglodytes Lutz, 1926	**33**	Ce, GF, DF, HF, EF	CE, CA, AF
Leptodactylus vastus Lutz, 1930	**23**	GF, DF, PM, EF	CE, CA, AF
LEIUPERIDAE			
Physalaemus centralis Bokermann, 1962	**5**	Ce, PM,WF	CE
Physalaemus cuvieri Fitzinger, 1826	**191**	Ce, DF, HF, PM, EF	CE, CA, AF, AM, CH, PA
Pseudopaludicola cf. *mystacalis*	**27**	GF, PM	CE
BUFONIDAE			
Rhaebo guttatus (Schneider, 1799)	**7**	GF	CE, AM
Rhinella veredas (Brandão, Maciel & Sebben, 2007)	**9**	Ce, DF, HF	CE
Rhinella jimi (Stevaux, 2002)	**20**	Ce, GF, DF, HF, PM	CE, CA, AF
Rhinella mirandaribeiroi (Gallardo, 1965)	**60**	Ce, GF,DF, PM, EF	CE
Rhinella ocellata (Günther, 1858)	**37**	Ce, GF, PM	CE
MICROHYLIDAE			
Dermatonotus muelleri (Boettger, 1885)	**20**	GF, EF	CE, CA, CH
Elachistocleis carvalhoi Caramaschi, 2010	**18**	Ce, GF, HF	CE, AM

snakes *Corallus, Epicrates, Boa* and *Eunectes* and the Crocodylia species are present in the Appendix II of CITES (Table 2), which contains species that are under pressure from illegal trade and can be threatened if commercial exploitation is not controlled (CITES, 2009).

DISCUSSION

The species richness recorded for the EEUU herpetofauna is high when compared to other well-sampled areas of the Cerrado. Colli *et al.* (2002) and Nogueira *et al.* (2009) estimate that local communities in the Cerrado may present between 13 to 28 species of lizards, as evidenced in several intensive inventories in the domain (Pavan & Dixo, 2004; Pavan, 2007; Recoder & Nogueira, 2007; Vaz-Silva *et al.,* 2007; Valdujo *et al.,* 2009a, Silva Junior *et al.,* 2009; Recoder *et al.,* 2011). The observed richness of snakes and amphisbaenians in the EEUU is also high when compared to other well sampled locations with local richness ranging from 36 to 70 snake species and four to eight amphisbaenians (Strüssmann, 2000; Pavan & Dixo, 2004; Silva Junior *et al.,* 2005; Recoder & Nogueira, 2007; Vaz-Silva *et al.,* 2007; Sawaya *et al.,* 2008; Strüssmann & Mott, 2009; Valdujo *et al.,* 2009a; Recoder *et al.,* 2011). With regard to anurans, the richness of 26 species recorded are not so high when comparable to others Cerrado regions, however this richness is in the range from 24 to 38 species of regions well sampled (Pavan & Dixo, 2004; Uetanabaro *et al.,* 2007; Vaz-Silva *et al.,* 2007; Araújo *et al.,* 2009; Silva-Junior *et al.,* 2009; Valdujo *et al.,* 2009b).

The observed richness of lizards and anurans might be close to the real numbers, since species rarefaction curves for both groups tend toward an asymptote after 38 sampling days and richness estimators recover close values to those obtained. For lizards, the rarefaction curve of the second campaign is the one reaching an asymptote, with a slight reduction in error bars, even showing lower richness than the first campaign. Although the effort expended in this second campaign apparently resulted in a list of species that might be close to the real local diversity, the richness sampled from the first campaign indicates the importance of longer samplings in distinct seasons. With respect to anurans, it is probable that our sampling results came close to the real local richness, although it is likely that our list still lacks some of the amphibian species with fossorial or cryptic habits, or with an explosive reproductive strategy. Only 12 species of anurans were sampled during the second campaign, which represents a very low number when compared to the other two campaigns, and almost half of the diversity observed in relation to the third campaign, in which a similar effort was expended. This indicates that there is a conspicuous decrease in activity of anurans during the dry season.

Despite the high richness observed for lizards and anurans, it is likely that new records will be added in future inventories, as is commonly the case in long-term surveys (*e.g.,* Vitt *et al.,* 2005; Recoder *et al.,* 2011). This fact, allied to the difference in species richness recorded in each campaign of this study, highlights the importance of conducting long-term, intensive sampling efforts during several years

FIGURE 3: (1-12) Some reptile species sampled in the EEUU. **(1)** *Hoplocercus spinosus;* **(2)** *Iguana iguana;* **(3)** *Tropidurus oreadicus;* **(4)** *Norops meridionalis;* **(5)** *Polychrus acutirostris;* **(6)** *Coleodactylus brachystoma;* **(7)** *Phyllopezus pollicaris;* **(8)** *Hemidactylus brasilianus;* **(9)** *Copeoglossum nigropunctatum;* **(10)** *Colobosaura modesta;* **(11)** *Micrablepharus maximiliani;* **(12)** *Ameivula* cf. *mumbuca*

and in different seasons for a proper estimate of the local diversity of a Cerrado herpetofauna. It is worth noting that sites with higher species richness in the Cerrado are those that underwent intense sampling efforts in long-term studies conducted in association with large enterprises of great environmental impacts,

FIGURE 3: **(13-24)** Some reptile species sampled in the EEUU. **(13)** *Salvator merianae;* **(14)** *Tupinambis quadrilineatus;* **(15)** *Amphisbaena vermicularis;* **(16)** *Corallus hortulanus;* **(17)** *Chironius flavolineatus;* **(18)** *Tantilla melanocephala;* **(19)** *Apostolepis polylepis;* **(20)** *Erythrolamprus reginae;* **(21)** *Rodriguesophis iglesiasi;* **(22)** *Oxyrhopus trigeminus;* **(23)** *Typhlops brongersmianus;* **(24)** *Micrurus ibiboboca.*

such as hydroelectric power plants (Pavan & Dixo, 2004; Vaz-Silva *et al.,* 2007; Silva Junior *et al.,* 2009; Nogueira *et al.,* 2010; Silveira *et al.,* 2010).

Even with a high diversity observed for the snakes, this effort possibly represents a sub-sample of the real diversity of the region, as the methodology

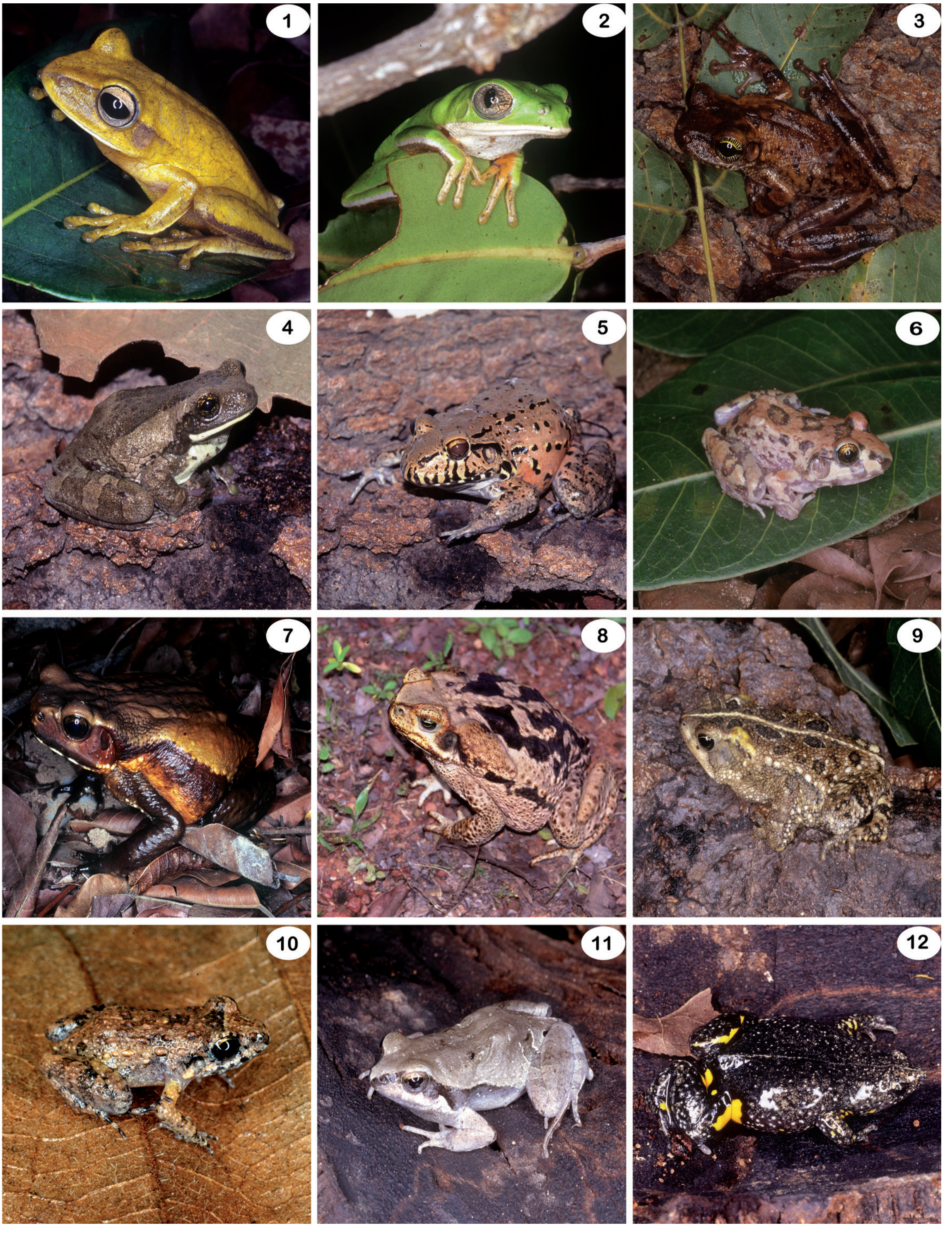

FIGURE 4: Some anurans species sampled in the EEUU. **(1)** *Hypsiboas multifasciatus;* **(2)** *Phyllomedusa azurea;* **(3)** *Osteocephalus taurinus;* **(4)** *Trachycephalus typhonius;* **(5)** *Leptodactylus vastus;* **(6)** *Leptodactylus troglodytes;* **(7)** *Rhaebo guttatus;* **(8)** *Rhinella jimi;* **(9)** *Rhinella ocellata;* **(10)** *Pseudopaludicola* cf. *mystacalis;* **(11)** *Physalaemus centralis;* **(12)** *Elachistocleis carvalhoi.*

based on pitfall traps presents low efficiency for the group (Cechin & Martins, 2000). Snakes of medium to large body size can easily escape from the buckets or even avoid falling inside them. Another important factor that often hampers a good sampling of snakes refers to their mode of life, as species of fossorial, arboreal or aquatic habits are usually difficult to observe in activity. Thus, the mostly occasional capture of snakes during herpetofaunal inventories results in suboptimal inventories for this group even with extended sampling efforts, hampering comparisons among different localities. Not surprisingly, the majority of the species in the snake community of the EEUU is represented by widespread species in comparison to lizards and amphibians.

The species observed prefer specific types of habitat, as shown by our co-occurrence and cluster analyses, resulting in a non-random distribution in the landscape that is in agreement with other studies for the Cerrado (Valdujo, 2003; Nogueira *et al.,* 2005, 2009; Pavan, 2007; Vitt *et al.,* 2007; Recoder *et al.,* 2011). In fact, the landscape mosaic present in the Cerrado with horizontal stratification of habitats allows for the coexistence of lineages with distinct ecological requirements, representing a major factor that explains the local diversity of the herpetofauna in the area (Colli *et al.,* 2002; Nogueira *et al.,* 2005, 2009).

There is a clear spatial structure in species composition, especially with regard to species that prefer wet environments ("wet fields" and "palm marshes"), such as *Osteocephalus taurinus, Hypsiboas multifaciatus, Eunectes murinus, Caiman crocodilus.* These habitats mainly harbor species that are shared with the Amazonian herpetofauna. The "dry forest" and "hillside forest" habitats are the ones with the greatest similarity in species composition (*e.g., Hoplocercus spinosus, Ameivula* cf. *mumbuca, Rhinella veredas, Corallus hortulanus*), and also present a similar vegetation structure.

Despite the structural similarity with other forested physiognomies, "gallery forest" has a low similarity in species composition with forest environments, sharing more species with open habitats. One possible explanation is the displacement of species from open habitats, dominant in extension in the landscape, to more humid areas during drier periods (Rodrigues, 2005). Despite their similar physiognomic

TABLE 3: Species richness of the herpetofauna sampled in different campaigns. In parentheses is represented the number of species sampled with pitfall traps.

Species	1st campaign	2nd campaign	3rd campaign
Lizards	18 (8)	12 (10)	11 (10)
Snakes	19 (6)	8 (2)	12 (2)
Amphisbaenians	1	1	2
Crocodiles	0	0	1
Anurans	22 (12)	12 (3)	23 (11)
Total	60 (26)	33 (15)	49 (23)

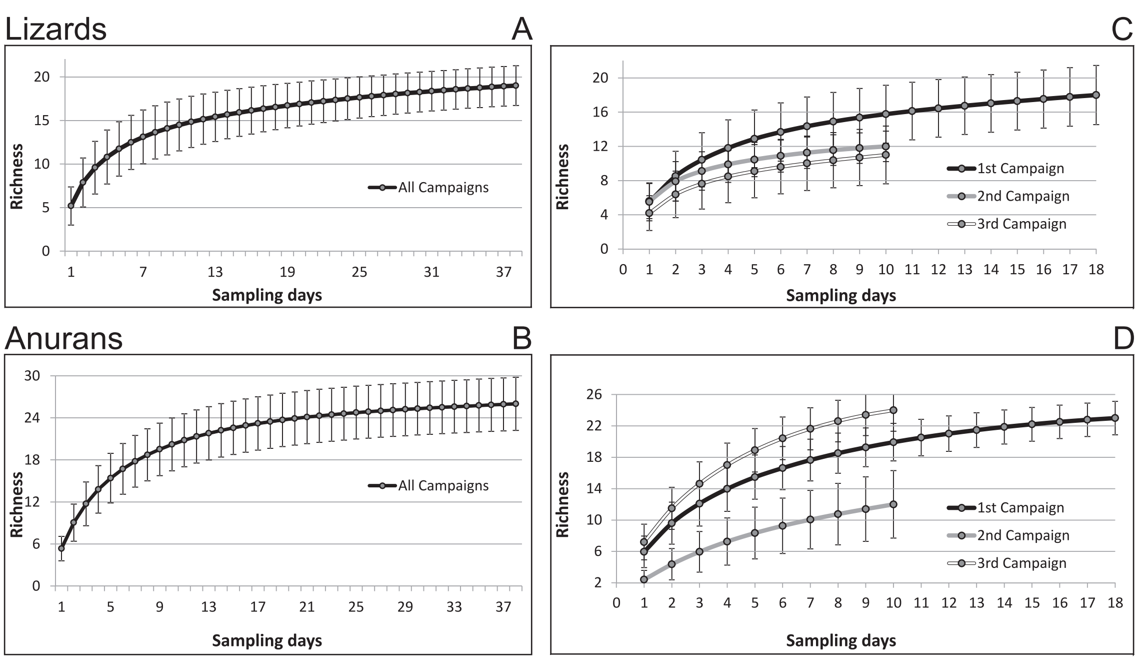

FIGURE 5: Species rarefaction curves with confidence interval for the species of **(A, B)** lizards and **(C, D)** amphibians, sampled in three campaigns carried out in the EEUU.

characteristics, both "cerrado near the station" and "cerrado of Ema Flor Farm" open habitats share only a low number of species, with some species dwelling in one of the two physiognomies (for example, *Hemidactylus brasilianus* was seen only in "cerrado near the station" while *Dendropsophus soaresi* was recorded only in "cerrado of Ema Flor Farm"). This faunal stratification in Cerrado physiognomies is probably related to geomorphological differences between lowland valleys ("cerrado near the station") and highland plateaus ("cerrado of Ema Flor Farm"). It is possible that these faunal differences reflect distinct evolutionary histories for species in valleys and plateaus (Pavan, 2007; Nogueira *et al.,* 2011; Valdujo, 2011).

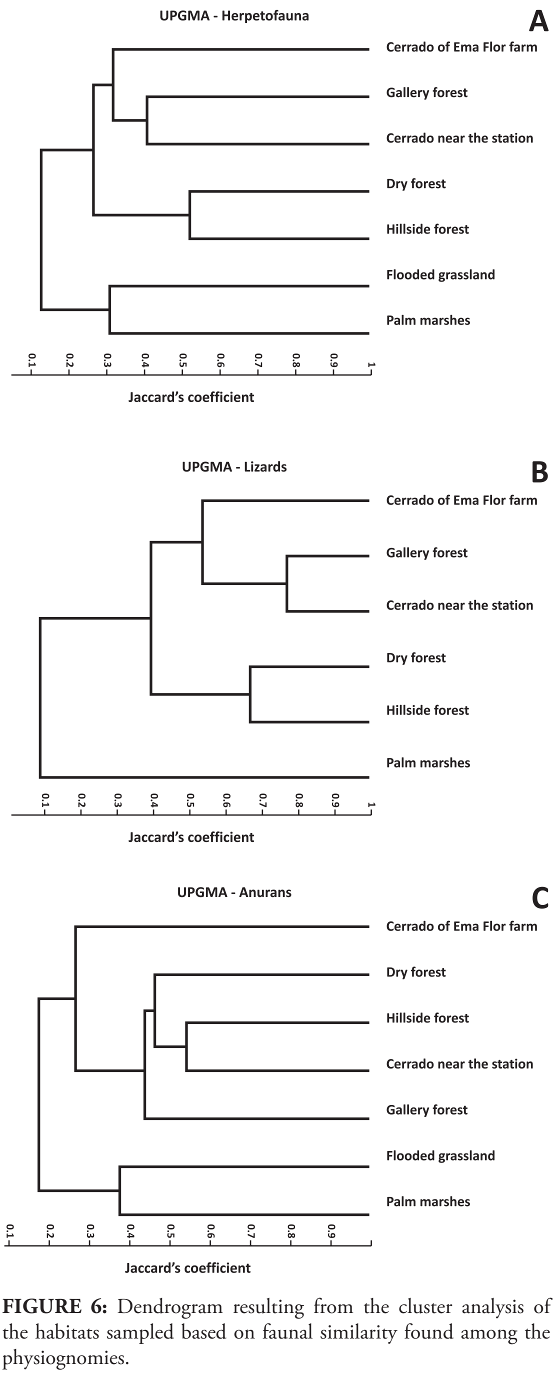

FIGURE 6: Dendrogram resulting from the cluster analysis of the habitats sampled based on faunal similarity found among the physiognomies.

The herpetofauna of the EEUU is characterized by having mostly widespread species, demonstrating the relevance of faunal exchange with adjacent biomes in regional species richness. The high similarity with the Caatinga is due, in large part, to the spatial proximity and dynamic history of inter-digitations between these morphoclimatic domains, favoring faunal exchanges (Vanzolini, 1976). A high proportion of the species also occurs in the Amazon, which may be explained by dispersion through the Cerrado forest formations (Rodrigues, 2005). This is especially evident in the Tocantins basin, where there is a typical Amazonian fauna in the forested habitats of the Cerrado landscapes (Pavan, 2007). About 22% of the species present in the EEUU are endemic to the Cerrado, revealing the presence of a typical fauna of the domain. A comparison of the fauna of our study site with herpetofaunal lists of different morphoclimatic domains reveals a clear association of the local fauna with the Cerrado.

Although our work is only based on ecological analyses for the species community currently present in the habitats, our cluster analysis of similarity indicates that the group "Cerrado" is divided into two sub-regions, according to the lists of lizards and amphibians, with a slight difference in faunal composition between the northern and southern Cerrado (Figs. 7A, B). This is most probably due to the presence of the "Planalto Central", an extensive plateau that influences the regional composition of the Cerrado fauna (Nogueira *et al.,* 2011). In the case of anurans, although EEUU is grouped with the Cerrado, there is a strong influence of the Caatinga, which is not so evident in the case of lizards that have deep sharing with the northern Cerrado fauna.

At least two species found in the EEUU might be new to science: a frog (*Adenomera* sp. nov.) and a snake (*Thamnodynastes* sp. nov.). *Adenomera* sp. nov. corresponds to a lineage whose populations are also distributed in the Caatinga (Fouquet *pers. com.*). *Thamnodynastes* sp. nov. is also a species shared with the Caatinga, which is referred as *Thamnodynastes* sp.2 in the work of Franco & Ferreira (2003).

In this study we also obtained a sample of five small and thin individuals of *Amphisbaena* that fits clearly with *A. miringoera* by folidosis and general morphology. *Amphisbaena miringoera* was described from Porto Velho, state of Mato Grosso, and recently

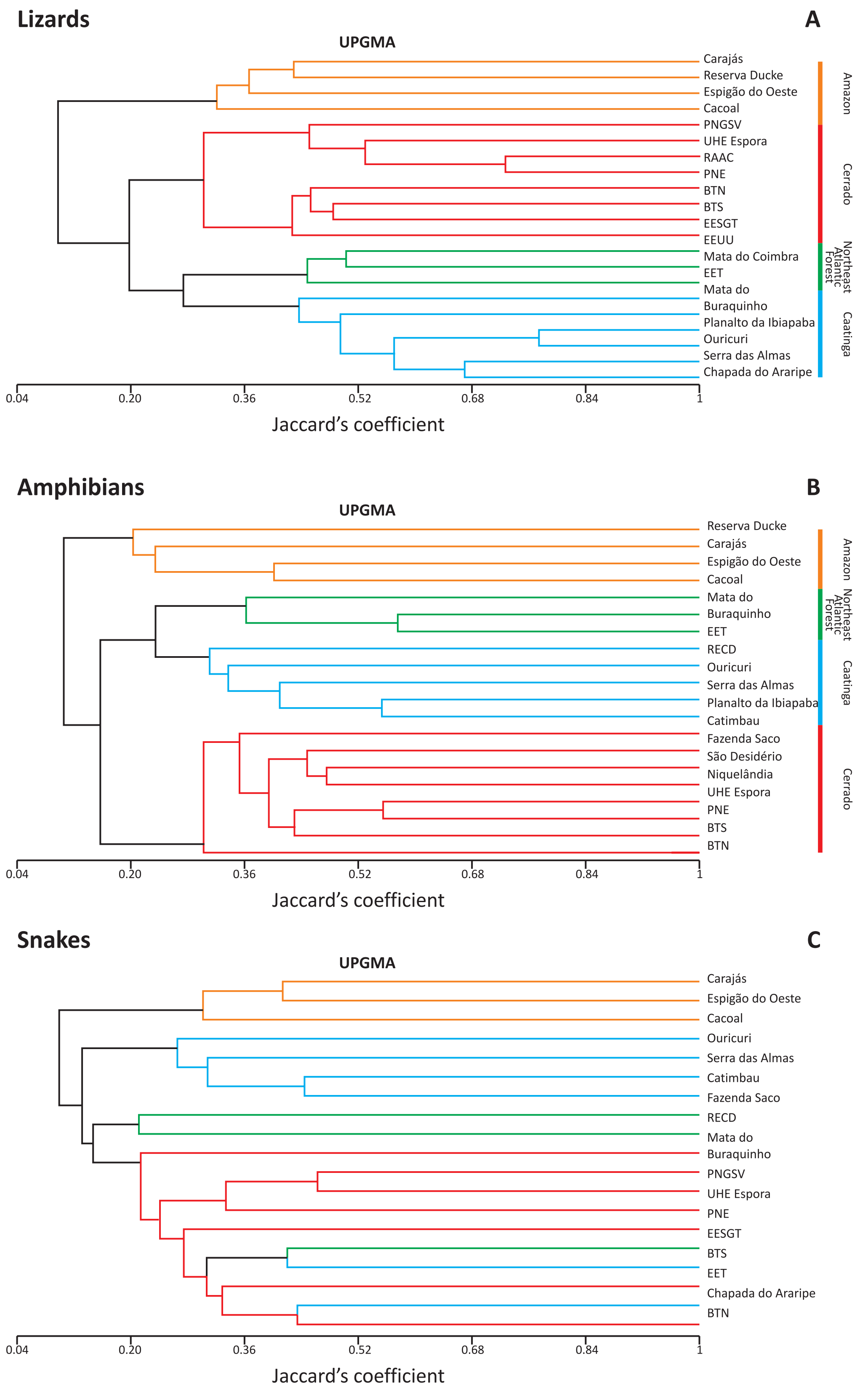

FIGURE 7: Dendogram resulting from cluster analysis of the lists of herpetofauna conducted in different localities of the Cerrado, Caatinga, Amazon and northeastern Atlantic Forest. **(A)** Lizards, **(B)** Anurans; **(C)** Snakes.

recorded in the state of Pará (Mott *et al.,* 2011). A large geographical distance separates EEUU from FLONA Carajás in Pará, the closest record of the species, including the Araguaia and Tocantins river basin. Nevertheless, with the current knowledge of the systematics of the group, these specimens thus represent a remarkable extension of distribution for *A. miringoera.*

The genus *Pseudopaludicola* is taxonomically very complex and confusing due to the small body size and cryptic coloration of the species. Although in the last decade four new species have been described (Giaretta & Kokubum, 2003; Toledo *et al.,* 2010; Toledo, 2010; Carvalho, 2012), little has been done to facilitate the identification of species of this group. The specimens collected in the Cerrado and Caatinga, are mostly identified as *Pseudopaludicola* cf. *mystacalis, Pseudopaludicola* aff. *falcipes, Pseudopaludicola* sp. (*falcipes* group) or *Pseudopaludicola* sp. (Kopp *et al.,* 2010; Moura *et al.,* 2011a; Loebmann & Mai, 2008; Loebmann & Haddad, 2010; Borges-Nojosa & Cascon, 2005. Similarly to *Adenomera, Pseudopaludicola* presents evidence of cryptic diversity. For this reason, we treat as *Psedopaludicola* cf. *mystacalis* the specimens obtained in the EEUU. The species of the *Scinax ruber* group represent another example of taxonomic confusion. We recognized at least two different forms in the EEUU sample, most likely to correspond to populations related to *Scinax fucovarius* and *Scinax x-signatus.* However, due to the difficulty of identification and taxonomic uncertainties for the Cerrado populations, we find it appropriate to assume a more conservative position and leave these two identities referred to as *Scinax* gr. *ruber.*

In the case of *Physalaemus,* clearly two species were sampled: *P. centralis* and *P. cuvieri.* In the field, these two species are easily identified due to the larger body size of *P. centralis* and differences in color pattern and advertisement call. But identification of the preserved material was difficult, as the majority of the collected specimens were sub-adults, having no information on calling or field identification. We thus recognized five specimens as *Physalaemus centralis,* used separately in the analyses, and several specimens of *Physalaemus cuvieri.* However, a large portion of the *Physalaemus* captured was juveniles or sub-adults that we treated as belonging to the "*cuvieri* group".

The genus *Ameivula* currently presents a low taxonomic resolution with respect to the Cerrado populations of the *Ameivula ocellifer* complex. A review of the group is in progress (Arias *et al.,* 2011a, b), and *Ameivula* cf. *mumbuca* of the EEUU is likely to be recognized as a new species (Arias, *pers. com.*). *Phrynops* is another genus that presents taxonomic confusion in regard to the classification of populations of *Phrynops geoffroanus* and *Phrynops tuberosus.* The diagnostic characters of these species are based on the formula of the plastron and carapace carinaes, but these characters vary intra-specifically, and in case of the keel, ontogenetically (Molina. *pers. com.*). It is likely that a deeper study on morphological variation in *P. geoffroanus* and *P. tuberosus* will reveal more than two species (Molina. *pers. com.*). With the current taxonomy and species distribution, we recognized the individuals of *Phrynops* from the EEUU as *P.* cf. *tuberosus.*

Finally, a closer inspection of the Cerrado landscapes bordering the EEUU suggests that the region is experiencing large-scale pressure from agricultural expansion, with the rapid transformation of natural cover. However, none of the species observed in the EEUU is considered under threat. This fact probably results from an incomplete knowledge of species diversity, coupled with the lack of robust information about the distribution and natural history of the species that would provide tools for understanding population dynamics and species vulnerability to anthropic activities. In fact, this knowledge gap limits our assessment of conservation status of the fauna in the Cerrado domain.

In this context, the herpetofauna of the EEUU being rich and characteristic of the Cerrado domain, and presenting populations of species shared with the adjacent biomes acquires a unique role in preserving a regional faunal pool, and providing basic material for the understanding of historical processes that lead to its composition. Also, this conservation unit provides raw material for studies aimed at understanding the basic population biology and distribution of species in ecotonal areas, thus contributing to the development of conservation strategies on a broad scale.

RESUMO

Este trabalho foi realizado com objetivo de analisar a herpetofauna amostrada numa área de Cerrado no estado do Piauí, Brasil, influenciada pelos biomas vizinhos e uma das regiões menos conhecidas dentro do domínio. A herpetofauna de diferentes fisionomias da Estação Ecológica de Uruçuí-Una (EEUU) foi amostrada intensivamente durante três campanhas (duas na estação chuvosa e uma na seca). Nós registramos 90 espécies da herpetofauna, 64 répteis e 26 anuros, uma alta riqueza quando comparada com outras localidades bem amostradas do Cerrado. As curvas de rarefação, tanto para lagartos como para

anuros, indicam que a riqueza observada se aproxima da real e os estimadores de riqueza apontam que novos registros podem ser adicionados a lista de espécies obtida. As análises de co-ocorrência mostram que as espécies não estão distribuídas aleatóriamente na paisagem, indicando que elas usam preferencialmente os diferentes tipos de habitats. Apesar se localizar em uma área transicional e ser influenciada pelos biomas vizinhos, as análise de agrupamento por similaridade sugerem que a herpetofauna da EEUU é típica do Cerrado. Desse modo, os resultados desse estudo indicam que a herpetofauna da EEUU desempenha um importante papel na conservação de uma riqueza faunística regional.

Palavras-Chave: Répteis; Anuros; Cerrado do Piauí; Conservação.

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