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RESEARCH ARTICLE



Herpetofauna from a Caatinga's Brejo de altitude in Northeast Brazil

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ABSTRACT

Inventories are essential because they can assist in decision-making about the protection of species, communities, and ecosystems. They also play a crucial role in engaging human populations, whether by involving them in citizen science initiatives or by providing a foundation for conservation actions. We provide an inventory of herpetofauna species from the Environmental Protection Area Serra de Maranguape and compare its diversity of herpetofauna with other Caatinga conservation units. The Serra de Maranguape is a pre-coastal residual massif considered a priority area for herpetofauna conservation. However, this residual massif has been subject to intense degradation and replacement of forests with crops. We found 33 species of amphibians and 52 Squamata species. The Serra de Maranguape herpetofauna consists of Caatinga's typical species, well-distributed species, and some restricted species to the altitudinal humid forests. In addition, this herpetofauna composition is more similar to other 'Brejos de Altitude' rather than Caatinga. Our study's data on richness and composition suggest that Serra de Maranguape is an area of extreme biological importance and unique because of some endemic and threatened species. This mountain range is one of the most critical areas for conserving herpetofauna in Northeastern Brazil.

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Amphibians; reptiles; conservation; "Brejos de altitude"; inventories

Introduction

Herpetology is the science that studies amphibians and reptiles (Vitt and Caldwell 2013; Pough et al. 2016). These animals are one of the most diverse groups of vertebrates, with 8753 amphibians (Frost 2024) and 12,162 reptile species worldwide (Uetz 2024). These animals inhabit a high diversity of microhabitats in Brazilian biomes, including aquatic, fossorial, terrestrial, and arboreal environments (Segalla et al. 2021; Guedes et al. 2023). They are essential components of different food networks (Valencia-Aguilar et al. 2013) and are considered environmental bioindicators (Moura et al. 2023).

Brazil has the highest diversity of amphibians in the world (Segalla et al. 2021) and is the third country in number of reptile species (Guedes et al. 2023). In recent years, Brazil has experienced an increase both in the number of inventories of amphibians and reptiles in different ecosystems as well as in basic ecology

studies (Lisboa et al. 2021; Oliveira et al. 2021; Santos-Azevedo et al. 2021; Freitas et al. 2023; Vicente-Ferreira et al. 2024). However, some areas and species remain understudied (Guerra et al. 2020; Marques et al. 2023).

Inventories are essential because they can increase knowledge about the diversity and distribution patterns of herpetofaunal species (Silveira et al. 2010). In addition, data from inventories can assist in decision-making about the protection of species, communities, and ecosystems (Urbina-Cardona 2008; Glorioso et al. 2022). In Brazil, herpetofaunal inventories are biased, and most studies focus on coastal regions, along large rivers, or close to large urban centers (Guerra et al. 2020), also having biomes historically undersampled, such as the Caatinga (Garda et al. 2018).

Caatinga is considered the largest, most isolated, and biodiverse nucleus of Seasonally Dry Tropical Forest in the Neotropical region (Pennington et al. 2000), being

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characterized by the presence of shallow soils, irregular rainfalls, high temperatures, and xerophytic vegetation with adaptations to the instability of the local climate (Ab'Sáber 2003; Moro et al. 2015). However, exceptional montane landscapes called 'Brejos de altitude' rise in the dry scenery. They are montane forest relicts that preserve a biological diversity strongly influenced by the humid paleoclimatic periods (Andrade-Lima 1982; Carnaval and Bates 2007). Due to the high humidity caused by the orographic rains (Araújo et al. 2007) and ecological history of the region, these humid enclaves have a different biological diversity from that found in surrounding Caatinga areas (Borges-Nojosa and Caramaschi 2003; Loebmann and Haddad 2010).

Particularly in Ceará State, these mountain regions are responsible for harboring a significant part of its herpetofauna, including threatened and endemic species (Roberto and Loebmann 2016). The Serra de Maranguape is considered a priority area for herpetofauna conservation (Tabarelli and Silva 2003) having a high species diversity, including some threatened and endemic species (Roberto and Loebmann 2016; Araújo et al. 2024). However, this mountain has been subject to intense degradation and replacement of forests by crops (Lima and Cascon 2008), and some areas are still under-sampled. In this sense, we provide an inventory of amphibian and reptile species from the Conservation Unit Environmental Protection Area of Serra of Maranguape and compare its herpetofauna diversity with other conservation units in the Caatinga biome.

Material and methods

Study area

The Serra de Maranguape (Figure 1) is a pre-coastal residual massif between Maranguape, Maracanaú, and Caucaia municipalities in Ceará State, Northeastern Brazil. It was recognized as a Conservation Unit Environmental Protection Area under municipal Law No. 1168, of 8 July 1993 (Ceará 2002). This mountain covers an approximate area of 22.5 km long and 13 km wide, reaching its culminating point at 920 m of altitude (Arruda 2001). The rainy season in the Serra de Maranguape occurs from December to May, with annual rainfall averaging 1300 mm and the annual mean temperature between 23°C and 26°C (Ceará 2002). Inserted in the Caatinga biome, three basic vegetation types occur in the Serra de Maranguape: Floresta Subperenifolia Tropical Plúvio-Nebular (Humid Forest), Floresta Subcaducifolia Tropical Pluvial (Dry Forest), and Floresta Caducifolia Espinhosa (Arboreal Caatinga) (Fernandes 1998).

Data collection and statistics analysis

We used the repository database of amphibians and reptiles sampled at different periods over the last 30 years with voucher specimens deposited in the Núcleo Regional de Ofiologia (NUROF) of the Universidade Federal do Ceará (UFC), Ceará State, Brazil. We evaluate amphibian and reptile species distribution and association with Brazilian biomes (Instituto Brasileiro de Geografia e Estatística 2019) from literature records (see Segalla et al. 2021; Guedes et al. 2023; Frost 2024; Uetz 2024). In addition, we obtained the amphibian and reptile conservation status regarding global, regional, and local scales following IUCN (2023), Ministério do Meio Ambiente (2022), and Secretaria do Meio Ambiente (2022), respectively. Nomenclature for amphibians follows Frost (2024) and reptiles Guedes et al. (2023).

We generate a heatmap using the Jaccard Similarity Measure, with the software R, and packages Vegan and Corrplot (R Core Team 2024; Oksanen 2024; Wei and Simko 2024), to compare the amphibian and reptile assemblages of Maranguape with five areas of 'Brejos-de-altitude' located in the state of Ceará: 1 – National Forest of Araripe (ARA-CE, Ribeiro et al. 2012); 2 – Serra da Aratanha Environmental Protection Area (ART-CE, Roberto and Loebmann 2016); 3 – Serra de Baturité Environmental Protection Area (BAT-CE, Borges-Nojosa 2007); 4 – Serra da Meruoca Environmental Protection Area (MER-CE, Roberto and Loebmann 2016); and 5 – Serra da Ibiapaba Environmental Protection Area and Ubajara National Park (IBI-CE, Loebmann and Haddad 2010; Roberto and Loebmann 2016; Castro et al. 2019); and six other areas of Caatinga protected by strict protection Conservation Units: 1 – Catimbau National Park (CAT-PE, Pedrosa et al. 2014); 2 – Serra das Confusões National Park (CON-PI, Marques et al. 2023); 3 – Aiuaba Ecological Station (AIU-CE, Costa et al. 2018); 4 – Seridó Ecological Station (SER-RN, Caldas et al. 2016); 5 – Serra da Capivara National Park (CAP-PI, Cavalcanti et al. 2014); and 6 – Raso da Catarina Ecological Station (CAT-BA, Garda et al. 2013). We consider only the presence and absence of species for this analysis.

Results

Amphibian species composition

We found 33 species of amphibians in the Serra de Maranguape belonging to the orders Anura and Gymnophiona. The first one comprises 31 anuran species

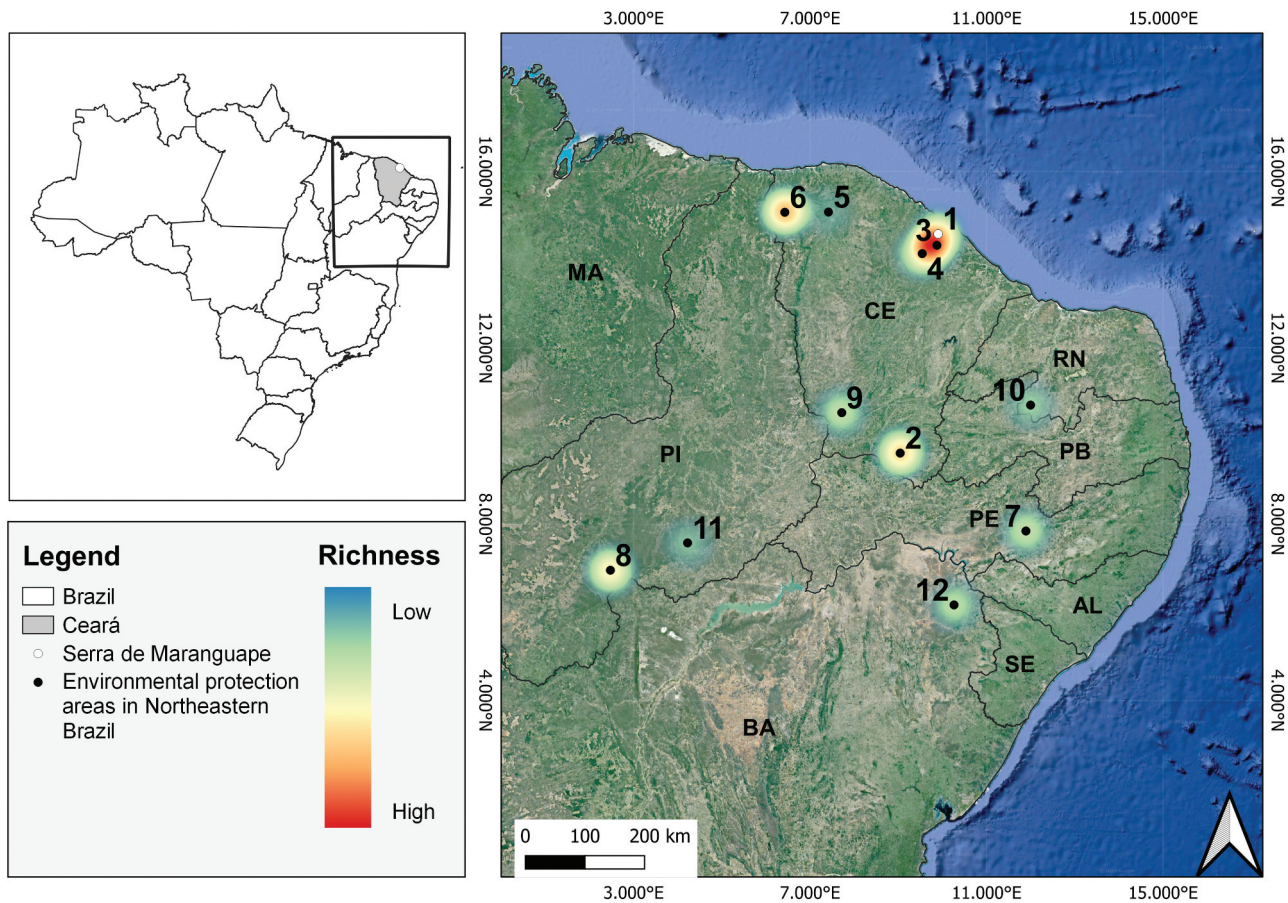


Figure 1. Schematic map showing the Environmental Protection area Serra de Maranguape, Ceará State, and different environmental protection areas in northeastern Brazil. **1** – Serra de Maranguape (MGP-CE) **2** - National Forest of Araripe (ARA-CE) **3** – Serra da Aratanha (ART-CE), **4** – Serra de Baturité (BAT-CE), **5** – Serra da Meruoca (MER-CE), **6** – Serra da Ibiapaba (IBI-CE), **7** – Catimbau National Park (CAT-PE), **8** – Serra das Confusões National Park (CON-PI), **9** – Aiuaba ecological station (AIU-CE), **10** - seridó ecological station (SER-RN), **11** - Serra da Capivara National Park (CAP-PI), **12** - Raso da Catarina ecological station (CAT-BA).

included in the following families: Bufonidae ($N = 2$ spp.), Craugastoridae ($N = 1$ sp.), Eleutherodactylidae ($N = 2$ spp.), Hylidae ($N = 11$ spp.), Leptodactylidae ($N = 11$ spp.), Microhylidae ($N = 2$ spp.), and Odontophrynidae ($N = 2$ spp.). Regarding caecilians, we found one species from each of the families Caeciliidae and Siphonopidae (Table 1, Figures 2–5).

Most species are widely distributed in the Brazilian biomes ($N = 19$ spp.) or occur at least in three biomes ($N = 8$ spp.). *Dendropsophus tapacurensis* and *Proceratophrys renalis* occur only in the Atlantic Forest and the ‘Brejos de altitude’ of the Caatinga biome. *Leptodactylus pustulatus* and *Elachistocleis piauiensis* are common to the Caatinga and Cerrado biomes. *Caecilia tentaculata* is typical of the Amazon Forest and occurs in the ‘Brejos de altitude’ of the Caatinga biome. In addition, *Pristimantis relictus*; *Adelophryne baturitensis*

and *Adelophryne maranguapensis* are endemic to the ‘Brejos de altitude’ of the Ceará, with the last one occurring only at high altitudes of the Serra de Maranguape. Considering global, regional, and local scales, the amphibian community was not threatened with imminent extinction except for *Adelophryne maranguapensis*, which is critically endangered (CR). Species recently described or without specific identification have not had their conservation status evaluated (Table 1).

The diversity of amphibians in the Serra de Maranguape was more similar to those registered for the Serra de Aratanha ($J = 0.82$) and Serra de Baturité ($J = 0.82$), both pre-coastal residual massifs with humid forests located in Ceará State, and was more dissimilar to those found in the Serra da Capivara, Piauí State ($J = 0.21$) and Raso da Catarina, Pernambuco State ($J = 0.18$) (Figure 6).

Table 1. Amphibians registered in the Environmental Protection Area Serra de Maranguape, Ceará State, Northeastern Brazil. Distribution across Brazilian biomes: Amazon Rainforest (AM), Atlantic Forest (AT), Brejos de Altitude (BR), Caatinga (CA), Cerrado (CE), and widely distributed (WD). Conservation status at the global (IUCN), national (MMA), and state (CE) levels: Least Concern (LC), Endangered (EN), Critically Endangered (CR), Data Deficient (DD), and Not Evaluated (NE).

Taxa	Voucher	Distribution	Conservation status			Records
			IUCN	MMA	CE	
Order Anura						
Bufonidae						
<i>Rhinella diptycha</i> (Cope, 1862)	CHUFCA9095	WD	LC	LC	LC	Roberto and Loebmann (2016); Oliveira et al. (2022)
<i>Rhinella granulosa</i> (Spix, 1824)	CHUFCA6694	WD	LC	LC	LC	Roberto and Loebmann (2016); Oliveira et al. (2022)
Craugastoridae						
<i>Pristimantis relictus</i> Roberto et al. (2022)	CHUFCA6726	BR	NE	NE	LC	Oliveira et al. (2022)
Eleutherodactylidae						
<i>Adelophryne maranguapensis</i> Hoogmoed et al. (1994)	CHUFCA8542	BR	CR	CR	CR	Cassiano-Lima et al. (2011, 2020); Roberto and Loebmann (2016); Oliveira et al. (2022); Araújo et al. (2023)
<i>Adelophryne baturitensis</i> Hoogmoed et al. (1994)	CHUFCA6639	BR	LC	LC	LC	Roberto and Loebmann (2016)
Hylidae						
<i>Boana raniceps</i> (Cope, 1862)	CHUFCA6605	WD	LC	LC	LC	Roberto and Loebmann (2016); Oliveira et al. (2022); Rodrigues et al. (2023)
<i>Corythomantis greeningi</i> (Boulenger, 1896)	CHUFCA2613	AT, CA, CE	LC	LC	LC	Roberto and Loebmann (2016); Oliveira et al. (2022)
<i>Dendropsophus tapacurensis</i> (Oliveira et al. 2021)	CHUFCA6702	AT, BR	DD	NE	LC	Oliveira et al. (2022)
<i>Dendropsophus minusculus</i> (Rivero, 1971)	CHUFCA6613	WD	LC	LC	LC	Oliveira et al. (2022)
<i>Dendropsophus minutus</i> (Peters, 1872)	CHUFCA6614	WD	LC	LC	LC	Oliveira et al. (2022)
<i>Dendropsophus nanus</i> (Boulenger, 1889)	CHUFCA3565	WD	LC	LC	LC	Oliveira et al. (2022)
<i>Dendropsophus soaresi</i> (Caramaschi and Jim, 1983a)	CHUFCA8908	AT, CA, CE	LC	LC	LC	This study
<i>Scinax nebulosus</i> (Spix, 1824)	CHUFCA9098	WD	LC	LC	LC	This study
<i>Scinax x-signatus</i> (Spix, 1824)	CHUFCA6615	WD	LC	LC	LC	Roberto and Loebmann (2016); Oliveira et al. (2022)
<i>Pithecopus gonzagai</i> (Andrade et al. 2020)	CHUFCA8338	AT, CA, CE	LC	LC	LC	Roberto and Loebmann (2016); Oliveira et al. (2022)
<i>Trachycephalus typhonius</i> (Linnaeus, 1758)	CHUFCA6601	WD	LC	LC	LC	Roberto and Loebmann (2016); Oliveira et al. (2022); Araújo-Silva et al. (2024)
Leptodactylidae						
<i>Adenomera juikitam</i> (Carvalho and Giarretta, 2013)	CHUFCA7030	AM, CA, CE	LC	LC	LC	Roberto and Loebmann (2016); Oliveira et al. (2022)
<i>Leptodactylus fuscus</i> (Schneider, 1799)	CHUFCA9816	WD	LC	LC	LC	Oliveira et al. (2022)
<i>Leptodactylus macrosternum</i> (Miranda-Ribeiro, 1926)	CHUFCA0783	WD	LC	LC	LC	Roberto and Loebmann (2016); Oliveira et al. (2022)
<i>Leptodactylus cf. mystaceus</i>	CHUFCA6924	WD	LC	LC	LC	Oliveira et al. (2022)
<i>Leptodactylus natalensis</i> (Lutz, 1930)	CHUFCA8591	WD	LC	LC	LC	This study
<i>Leptodactylus pustulatus</i> (Peters, 1870)	CHUFCA9822	CA, CE	LC	LC	LC	Oliveira et al. (2022)
<i>Leptodactylus syphax</i> (Bokermann, 1969)	CHUFCA5605	WD	LC	LC	LC	Oliveira et al. (2022)
<i>Leptodactylus troglodytes</i> Lutz, 1926	CHUFCA7051	WD	LC	LC	LC	Roberto and Loebmann (2016)
<i>Leptodactylus vastus</i> (Lutz, 1930)	CHUFCA9931	WD	LC	LC	LC	Roberto and Loebmann (2016)
<i>Physalaemus albifrons</i> (Spix, 1824)	CHUFCA8519	AT, CA, CE	LC	LC	LC	This study
<i>Physalaemus cuvieri</i> (Fitzinger, 1826)	CHUFCA8535	WD	LC	LC	LC	Roberto and Loebmann (2016)
Microhylidae						
<i>Dermatonotus muelleri</i> (Boettger, 1885)	CHUFCA7080	WD	LC	LC	LC	This study
<i>Elachistocleis piauiensis</i> (Caramaschi and Jim, 1983b)	CHUFCA8328	CA, CE	LC	LC	LC	Oliveira et al. (2022)
Odontophrynidae						
<i>Proceratophrys cristiceps</i> (Müller, 1883)	CHUFCA7045	AT, CA, CE	LC	LC	LC	Oliveira et al. (2022)
<i>Proceratophrys renalis</i> (Miranda-Ribeiro, 1920)	CHUFCA7029	AT, BR	LC	LC	LC	Roberto and Loebmann (2016); Oliveira et al. (2022)
Order Gymnophiona						
Caeciliidae						
<i>Caecilia tentaculata</i> (Linnaeus, 1758)	CHUFCA6773	AM, BR	LC	LC	LC	Borges-Nojosa et al. (2017)
Siphonopidae						
<i>Siphonops cf. paulensis</i> Boettger, 1892	CHUFCA6720	WD	LC	LC	LC	Roberto and Loebmann (2016)

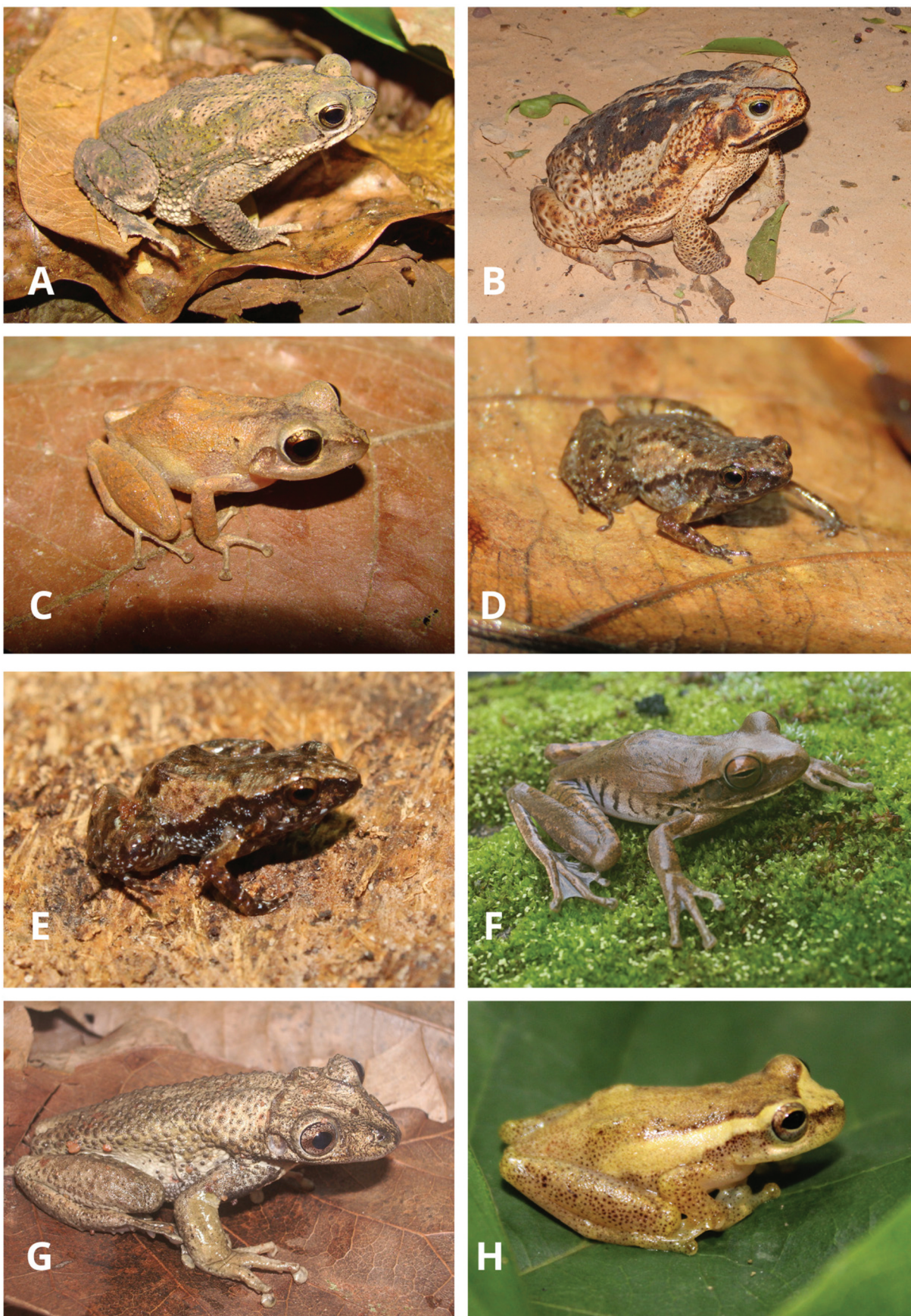


Figure 2. Amphibians from the Environmental Protection area Serra de Maranguape, Ceará State, Northeastern Brazil: (A) *Rhinella granulosa*, (B) *Rhinella diptycha*, (C) *Pristimantis relictus*, (D) *Adelophryne maranguapensis*, (E) *Adelophryne baturitensis*, (F) *Boana raniceps*, (G) *Corythomantis greeningi*, (H) *Dendropsophus tapacurensis*.

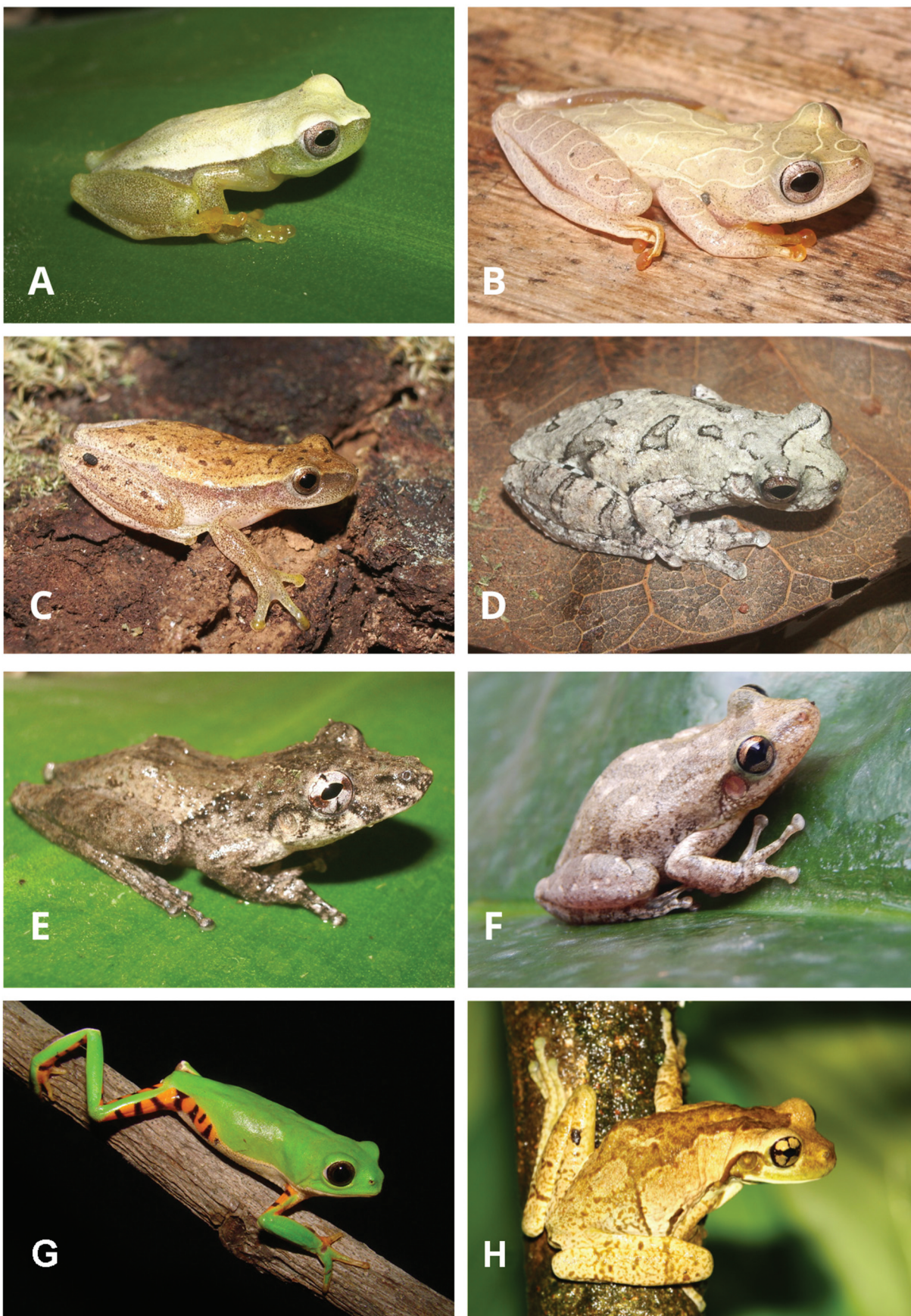


Figure 3. Amphibians from the Environmental Protection area Serra de Maranguape, Ceará State, Northeastern Brazil: (A) *Dendropsophus minusculus*, (B) *Dendropsophus minutus*, (C) *Dendropsophus nanus*, (D) *Dendropsophus soaresi*, (E) *Scinax nebulosus*, (F) *Scinax x-signatus*, (G) *Pithecopus gonzagai*, (H) *Trachycephalus typhonius*.

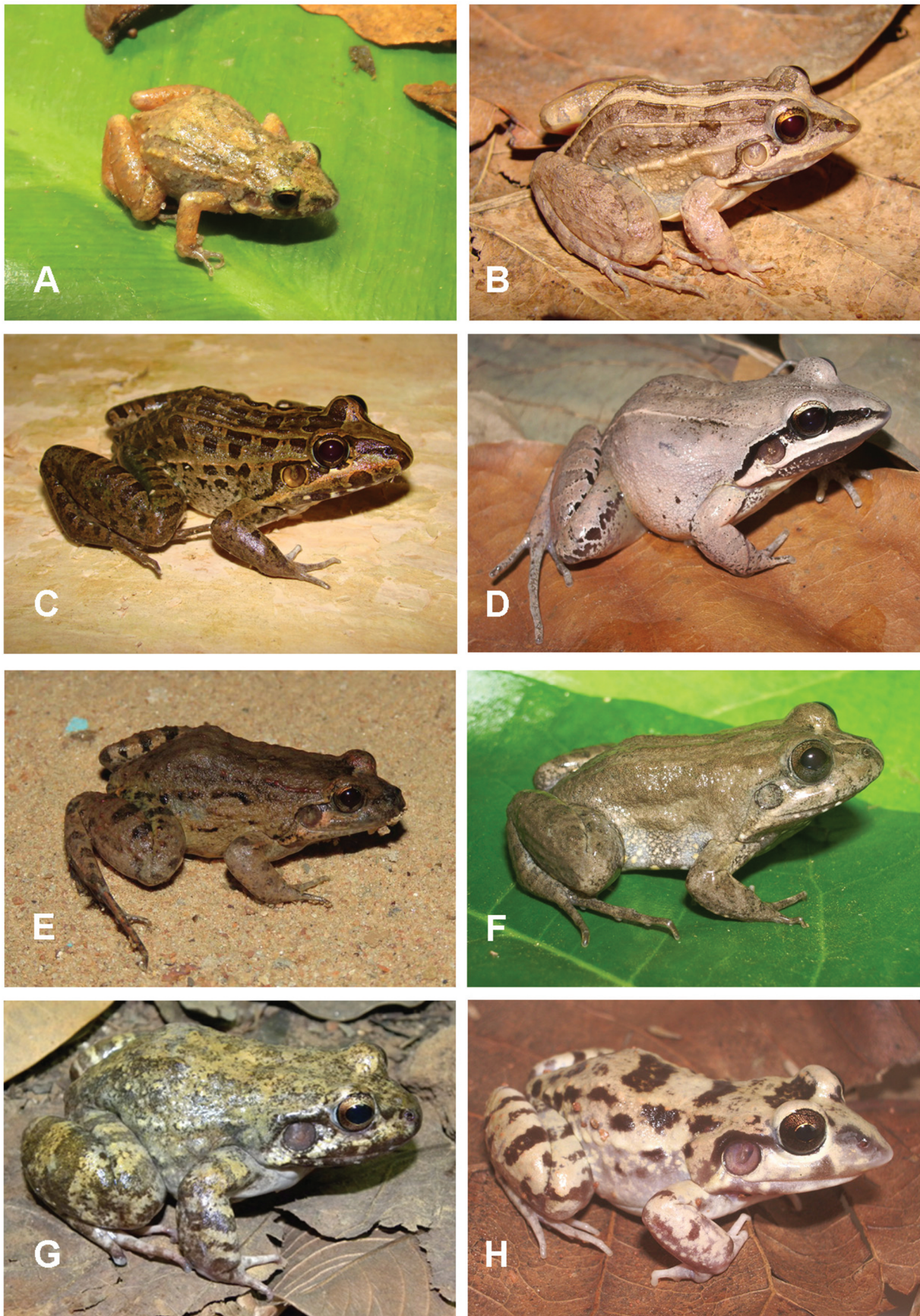


Figure 4. Amphibians from the Environmental Protection Area Serra de Maranguape, Ceará State, Northeastern Brazil: (A) *Adenomera juikitam*, (B) *Leptodactylus fuscus*, (C) *Leptodactylus macrosternum*, (D) *Leptodactylus* cf. *mystaceus*, (E) *Leptodactylus natalensis*, (F) *Leptodactylus pustulatus*, (G) *Leptodactylus syphax*, (H) *Leptodactylus troglodytes*.

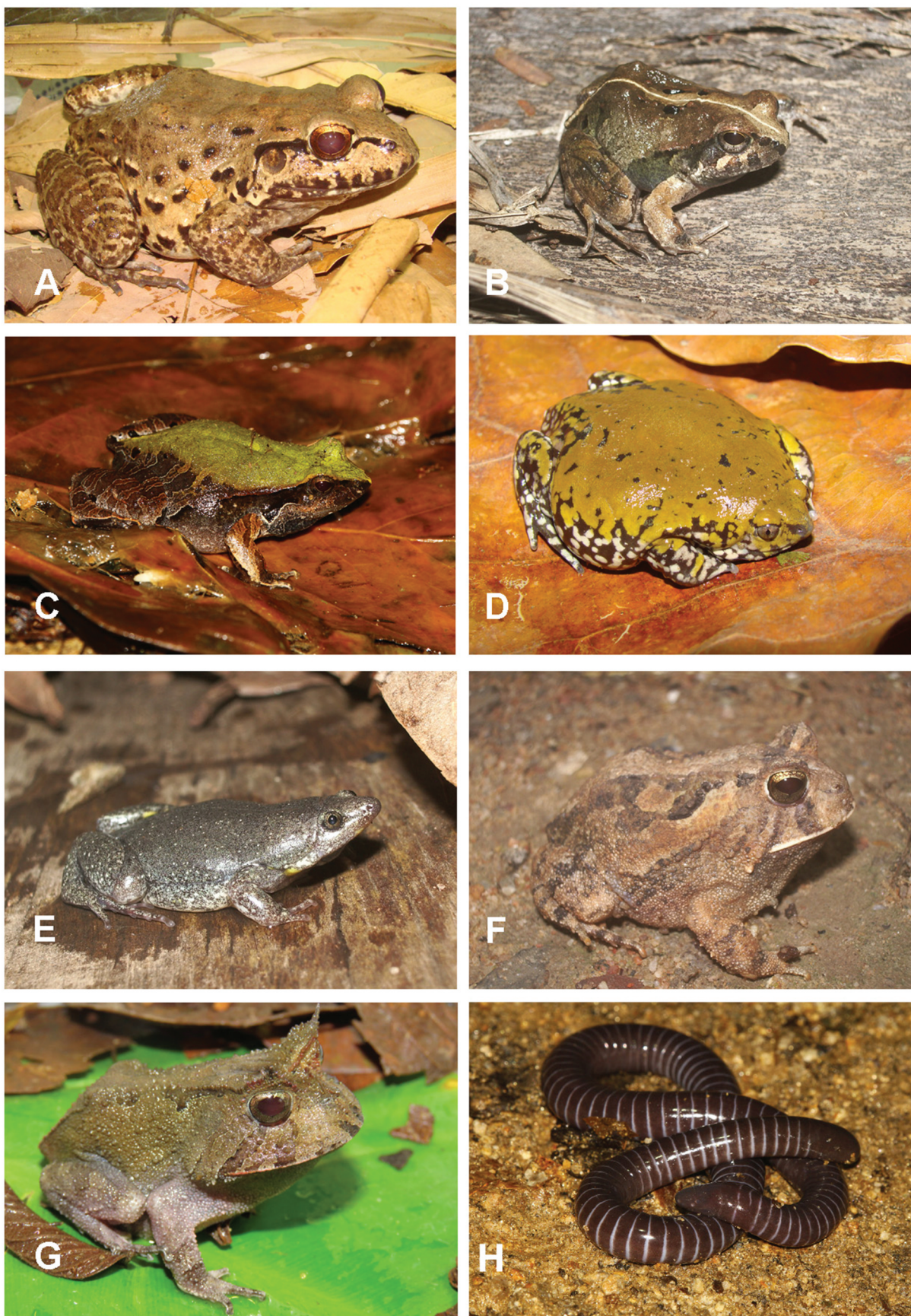


Figure 5. Amphibians from the Environmental Protection Area Serra de Maranguape, Ceará State, Northeastern Brazil: (A) *Leptodactylus vastus*, (B) *Physalaemus albifrons*, (C) *Physalaemus cuvieri* (D) *Dermatoneotus muelleri*, (E) *Elachistocleis piauiensis*, (F) *Proceratophrys cristiceps*, (G) *Proceratophrys renalis*, (H) *Siphonops* cf. *paulensis*.

Reptilian species composition

We found 52 reptile species of the Squamata order in the Serra de Maranguape included in the following families: ‘amphisbaenians’ Amphisbaenidae ($N=4$ spp.); ‘lizards’ Dactyloidae ($N=1$ sp.), Diploglossidae ($N=1$ sp.), Gekkonidae ($N=3$ spp.), Gymnophthalmidae ($N=6$ spp.), Phyllodactylidae ($N=1$ sp.), Polychrotidae ($N=1$ sp.), Scincidae ($N=1$ sp.), Sphaerodactylidae ($N=1$ sp.), Teiidae ($N=3$ spp.), and Tropiduridae ($N=3$ spp.); ‘snakes’ Boidae ($N=3$ spp.), Colubridae ($N=12$ spp.), Dipsadidae ($N=9$ spp.), Elapidae ($N=2$ spp.), and Leptotyphlopidae ($N=1$ sp.) (Table 2, Figures 7–12).

Likewise, most reptile species are widely distributed in the Brazilian biomes (61,53%) or occur at least in three biomes (23.98%). However, we found six endemisms in the Caatinga biome. *Placosoma limaverdorum* and *Apostolepis thalesdelemai* are endemic to the ‘Brejos de Altitude’ of Ceará State, Northeastern Brazil. *Stenolepis ridleyi* is endemic to the ‘Brejos de Altitude,’ occurring from Ceará to Pernambuco State and *Leposoma baturitensis*, occurring from Ceará to Alagoas State. *Diploglossus lessonae*, *Colobosauroides cearensis* and *Epictia borapeliotes* are found in the Atlantic Forest and Caatinga areas. *Strobilurus torquatus* occurs only in the Atlantic Forest and the ‘Brejos de Altitude’ of the Caatinga biome. *Hemidactylus agrius*, *Lygodactylus klugei*, *Ameivula pyrrhogularis*, and *Leptodeira tarairiu* are recorded in the Caatinga and Cerrado biomes. Except for the snakes and lizards considered endangered species (EN) and those without specific identification, all reptiles are classified as least concern (LC) (Table 2).

The diversity of reptiles in the Serra de Maranguape was also more similar to those registered in the Serra da Aratanha ($J=0.59$) and Serra de Baturité ($J=0.57$), whereas it was more dissimilar to those found in the Serra da Meruoca ($J=0.16$), all in Ceará State, Serra da Capivara, Piauí State ($J=0.24$) and Raso da Catarina, Pernambuco State ($J=0.25$) (Figure 13).

Discussion

In Ceará State, mountain regions are responsible for harboring a significant part of its herpetofauna, including threatened and endemic species (Roberto and Loebmann 2016). Although herpetofaunal studies have increased in these mountains, some remain undersampled. For instance, the Serra de Maranguape is considered a priority area for herpetofauna conservation (Tabarelli and Silva 2003), where some ecological studies dealing with amphibians (e.g. Borges-Nojosa et al. 2017; Oliveira et al. 2022, 2023; Rodrigues et al.

2023) and reptiles (Borges-Nojosa and Caramaschi 2003; Roberto and Albano 2012; Borges-Nojosa et al. 2016, 2016) were performed, including threatened species (Cassiano-Lima et al. 2011, 2014, 2020; Araújo et al. 2023). However, this mountain has been subject to intense degradation and replacement of forests by crops (Lima and Cascon 2008), and some areas are still undersampled.

In the Serra de Maranguape, we found one of the most diverse fauna of amphibians and reptiles amongst the conservation units in the Caatinga biome. This biome has areas with a rich herpetofaunal diversity such as Delta do Parnaíba ($N=86$ species; Araújo et al. 2020), Boqueirão da Onça ($N=76$ species; Cavalheri et al. 2015), and Serra das Confusões ($N=73$ species; Marques et al. 2023). The Serra de Maranguape has a high herpetofauna diversity ($N=85$ species) and is considered unique by the presence of some endemism and threatened species such as *Pristimantis relictus*, *Adelophryne baturitensis* and *Adelophryne maranguapensis*, *Leposoma baturitensis*, *Placosoma limaverdorum* and *Apostolepis thalesdelemai* (Roberto and Loebmann 2016). Therefore, it might be considered one of the most important herpetofaunal hotspots in this biome (Camardelli and Napoli 2012; Garda et al. 2017).

Specifically, regarding amphibians, we found a predominance of species from the Leptodactylidae and Hylidae families, which is the common pattern for neotropical frogs (Duellman 1994), including in the Caatinga biome (Garda et al. 2017). The amphibian species composition is a miscellany of those occurring in open and forested environments, together with species that are restricted to the altitudinal humid forests of the State of Ceará (Roberto and Loebmann 2016). Most amphibian species that occur in the Serra de Maranguape have a wide geographical distribution in the Brazilian biomes. However, there are three endemic species in the ‘Brejos de altitude:’ *Adelophryne baturitensis*, *Adelophryne maranguapensis*, and *Pristimantis relictus* (Araújo et al. 2024). *Dendropsophus tapacurensis* and *Proceratophrys renalis* that occur only in the ‘Brejos de altitude’ and Atlantic Forest (Oliveira et al. 2021; Araújo et al. 2024), and *Caecilia tentaculata* that occurs only in the ‘Brejos de altitude’ and Amazon Forest (Borges-Nojosa et al. 2017). Overall, the species tend to be well distributed in the Serra de Maranguape, with exception of the species adapted to high-altitudes (humid forests) such as: *Adelophryne maranguapensis*, *Dendropsophus tapacurensis* and *Proceratophrys renalis* (Roberto and Loebmann 2016; Araújo et al. 2024).

The number of amphibian species we found is similar to that recorded in three other areas of altitudinal humid forests in the State of Ceará: Ibiapaba plateau

Heatmap of similarity in amphibian composition

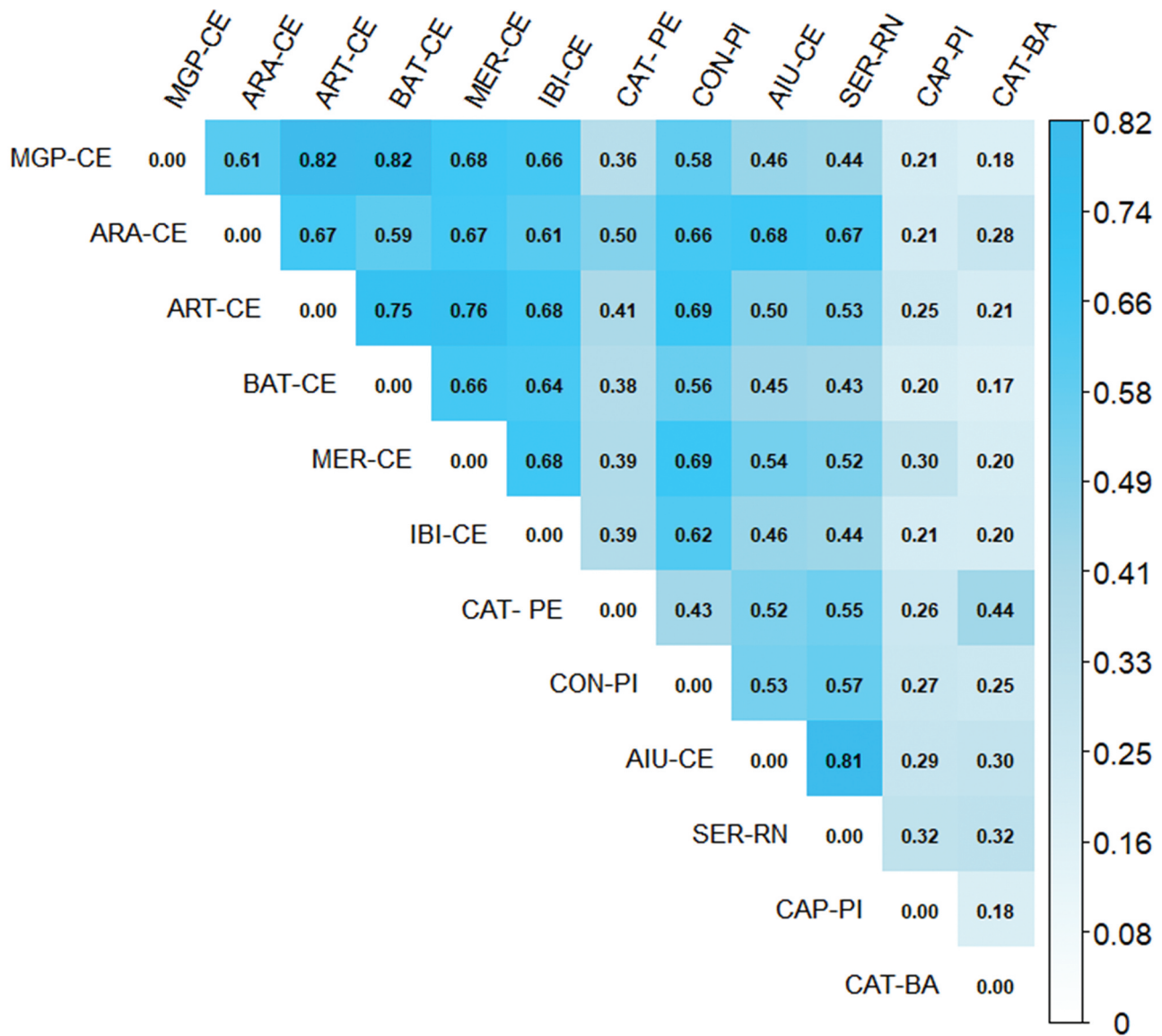


Figure 6. Heatmap of Jaccard similarity index for amphibian composition in pairwise comparisons between Environmental Protection Area Serra de Maranguape and different environmental protection areas in Northeastern Brazil. Serra de Maranguape Environmental protection area, Ceará (MGP-CE) (this study); National Forest of Araripe (ARA-CE) (Ribeiro et al. 2012; Roberto and Loebmann 2016); Serra da Aratanha Environmental protection area (ART-CE) (Roberto and Loebmann 2016); Serra de Baturité Environmental Protection Area, Ceará (BAT-CE) (Borges-Nojosa, 2007; Roberto and Loebmann 2016); Serra da Meruoca Environmental protection area, Ceará (MER-CE) (Roberto and Loebmann 2016); Serra da Ibiapaba Environmental protection area and Ubajara National Park, Ceará (IBI-CE) (Loebmann and Haddad 2010; Roberto and Loebmann 2016; Castro et al. 2019); Catimbau National Park, Pernambuco (CAT-PE) (Pedrosa et al. 2014); Serra das Confusões National Park, Piauí (CON-PI) (Marques et al. 2023); Aiuaba Ecological station, Ceará (AIU-CE) (Costa et al. 2018); seridó Ecological station, Rio Grande do norte (SER-RN) (Caldas et al. 2016); Serra da Capivara National Park, Piauí (CAP-PI) (Cavalcanti et al. 2014); Raso da Catarina Ecological station, Bahia (CAT-BA) (Garda et al. 2013).

Table 2. Reptilians registered in the Environmental Protection Area Serra de Maranguape, Ceará State, Northeastern Brazil. Distribution across Brazilian biomes: Amazon Rainforest (AM), Atlantic Forest (AT), Brejos de Altitude (BR), Caatinga (CA), Cerrado (CE), and widely distributed (WD). Conservation status at the global (IUCN), national (MMA), and state (CE) levels: Least Concern (LC), Endangered (EN), Critically Endangered (CR), Data Deficient (DD), and Not Evaluated (NE).

Species	Voucher	Distribution	Conservation status			Records
			IUCN	MMA	CE	
Order Squamata						
'Amphisbaenians'						
Amphisbaenidae						
<i>Amphisbaena alba</i> Linnaeus (1758)	CHUFCL2247	WD	LC	LC	LC	Borges-Nojosa and Caramaschi (2003); Roberto and Loebmann (2016)
<i>Amphisbaena</i> sp.	CHUFCL2243	NE	NE	NE	NE	Borges-Nojosa and Caramaschi (2003); Roberto and Loebmann (2016)
<i>Amphisbaena vermicularis</i> Wagler in Spix (1824)	CHUFCL2270	WD	LC	LC	LC	Borges-Nojosa and Caramaschi (2003); Roberto and Loebmann (2016)
<i>Leposternon polystegum</i> (Duméril in Duméril and Duméril 1851)	CHUFCL1959	WD	LC	LC	LC	Borges-Nojosa and Caramaschi (2003);
'Lizards'						
Dactyloidae						
<i>Norops fuscoauratus</i> (Duméril and Bibron 1837 in Duméril and Bibron 1837)	CHUFCL5687	WD	LC	LC	LC	Borges-Nojosa and Caramaschi (2003); Roberto and Loebmann (2016)
Diploglossidae						
<i>Diploglossus lessonae</i> Peracca (1890)	CHUFCL2949	AT, CA	LC	LC	LC	Borges-Nojosa and Caramaschi (2003); Roberto and Loebmann (2016)
Gekkonidae						
<i>Hemidactylus agrius</i> Vanzolini (1978)	CHUFCL5646	CA, CE	LC	LC	LC	Borges-Nojosa and Caramaschi (2003); Roberto and Loebmann (2016)
<i>Hemidactylus mabouia</i> (Moreau de Jonnés 1818)	CHUFCL2320	WD	LC	LC	NE	Borges-Nojosa and Caramaschi (2003); Roberto and Loebmann (2016)
<i>Lygodactylus klugei</i> (Smith et al. 1977)	CHUFCL2289	CA, CE	LC	LC	LC	Borges-Nojosa and Caramaschi (2003); Roberto and Loebmann (2016)
Gymnophthalmidae						
<i>Colobosauroides cearensis</i> Cunha et al. (1991)	CHUFCL6655	AT, CA	LC	LC	LC	Borges-Nojosa and Caramaschi (2003); Roberto and Loebmann (2016)
<i>Leposoma baturitensis</i> Rodrigues & Borges, 1997	CHUFCL6098	BR	EN	EN	EN	Borges-Nojosa and Caramaschi (2003); Roberto and Loebmann (2016)
<i>Micrablepharus maximiliani</i> (Reinhardt and Lütken 1862)	CHUFCL6662	WD	LC	LC	LC	This study
<i>Placosoma limaverdorum</i> Borges-Nojosa, Caramaschi & Rodrigues, 2016	CHUFCL5783	BR	NE	LC	EN	Borges-Nojosa and Caramaschi (2003); Borges-Nojosa, Caramaschi, et al. (2016); Roberto and Loebmann (2016)
<i>Stenolepis ridleyi</i> Boulenger, 1887	CHUFCL6652	BR	LC	LC	LC	This study
<i>Vanzosaura multiscutata</i> (Amaral 1933)	CHUFCL2298	CA	LC	LC	LC	This study
Phyllodactylidae						
<i>Phyllopezus pollicaris</i> (Spix 1825)	CHUFCL2084	WD	LC	LC	LC	Roberto and Loebmann (2016)
Polychrotidae						
<i>Polychrus acutirostris</i> Spix, 1825	CHUFCL5636	WD	LC	LC	LC	Borges-Nojosa and Caramaschi (2003); Roberto and Loebmann (2016)
Scincidae						
<i>Brasiliscincus heathi</i> (Schmidt and Inger 1951)	CHUFCL5641	WD	LC	LC	LC	This study
Sphaerodactylidae						
<i>Coleodactylus meridionalis</i> (Boulenger 1888)	CHUFCL6583	AT, CA, CE	LC	LC	LC	Borges-Nojosa and Caramaschi (2003); Roberto and Loebmann (2016)
Teiidae						
<i>Ameiva ameiva</i> (Linnaeus 1758)	CHUFCL5635	WD	LC	LC	LC	Borges-Nojosa and Caramaschi (2003); Roberto and Loebmann (2016)
<i>Ameivula pyrrhogularis</i> (Basto and Ávila-Pires 2013)	CHUFCL7560	CA, CE	LC	LC	LC	This study
<i>Salvator merianae</i> Duméril & Bibron, 1839	CHUFCL2964	WD	LC	LC	LC	This study
Tropiduridae						
<i>Strobilurus torquatus</i> (Wiegmann 1834)	CHUFCL4227	AT, BR	LC	LC	DD	Borges-Nojosa and Caramaschi (2003); Roberto and Loebmann (2016)
<i>Tropidurus hispidus</i> (Spix, 1825)	CHUFCL5647	WD	LC	LC	LC	Borges-Nojosa and Caramaschi (2003); Roberto and Loebmann (2016)
<i>Tropidurus semitaeniatus</i> (Spix, 1825)	CHUFCL2422	WD	LC	LC	LC	Borges-Nojosa and Caramaschi (2003); Roberto and Loebmann (2016)
'Snakes'						
Boidae						
<i>Boa constrictor</i> Linnaeus (1758)	CHUFCS731	WD	LC	LC	LC	Roberto and Loebmann (2016)
<i>Epicrates assisi</i> Machado, 1945	CHUFCS4528	AT, CA, CE	LC	LC	LC	Roberto and Loebmann (2016)
<i>Corallus hortulana</i> (Linnaeus 1758)	CHUFCS3816	WD	LC	LC	LC	This study
Colubridae						
<i>Drymoluber dichrous</i> (Peters, 1863)	CHUFCS2104	WD	LC	LC	DD	Roberto and Loebmann (2016)

(Continued)

Table 2. (Continued).

Species	Voucher	Distribution	Conservation status			Records
			IUCN	MMA	CE	
<i>Leptophis dibernardoi</i> Albuquerque et al. (2022)	CHUFCS2202	CA	NE	LC	LC	Albuquerque et al. (2022)
<i>Oxybelis aeneus</i> (Wagler in Spix 1824)	CHUFCS2070	WD	LC	LC	LC	Roberto and Loebmann (2016)
<i>Palusophis bifossatus</i> (Raddi 1820)	CHUFCS1173	WD	LC	LC	NE	Roberto and Loebmann (2016)
<i>Pseudoboa nigra</i> (Duméril et al. 1854)	CHUFCS2215	WD	LC	LC	LC	Roberto and Loebmann (2016)
<i>Spilotes pullatus</i> (Linnaeus 1758)	CHUFCS2274	WD	LC	LC	LC	Roberto and Loebmann (2016)
Dipsadidae						
<i>Apostolepis cearensis</i> (Gomes, 1915)	CHUFCS1524	WD	LC	LC	LC	Roberto and Loebmann (2016)
<i>Apostolepis thalesdelemai</i> Borges-Nojosa, Lima, Bezerra & Harris, 2016	CHUFCS2085	BR	LC	LC	EN	Borges-Nojosa, Lima, et al. (2016); Entiauspe-Neto et al. (2020)
<i>Erythrolamprus poecilogyrus</i> (Wied-Neuwied 1824)	CHUFCS780	WD	LC	LC	LC	Roberto and Loebmann (2016)
<i>Erythrolamprus reginae</i> Linnaeus (1758)	CHUFCS3756	WD	LC	LC	LC	Roberto and Loebmann (2016)
<i>Erythrolamprus viridis</i> (Günther 1862)	CHUFCS2078	AT, CA, CE	LC	LC	LC	Roberto and Loebmann (2016)
<i>Imantodes cenchoa</i> (Linnaeus 1758)	CHUFCS2713	WD	LC	LC	LC	Roberto and Loebmann (2016)
<i>Leptodeira tarairiu</i> Costa et al. (2022)	CHUFCS2299	CA, CE	NE	LC	LC	Costa et al. (2022)
<i>Lygophis dilepis</i> Cope (1862)	CHUFCS1963	WD	LC	LC	LC	Roberto and Loebmann (2016)
<i>Oxyrhopus trigeminus</i> Duméril et al. (1854)	CHUFCS3755	WD	LC	LC	LC	Roberto and Loebmann (2016)
<i>Oxyrhopus melanogenys</i> (Tschudi 1845)	CHUFCS894	WD	LC	LC	LC	This study
<i>Philodryas nattereri</i> (Steindachner, 1870)	CHUFCS1229	WD	LC	LC	LC	Roberto and Loebmann (2016)
<i>Philodryas olfersii</i> (Lichtenstein 1823)	CHUFCS2103	WD	LC	LC	LC	Roberto and Loebmann (2016)
<i>Sibon nebulatus</i> (Linnaeus 1758)	CHUFCS2800	AT, AM, CA	LC	LC	LC	Roberto and Loebmann (2016)
<i>Adelphostigma occipitalis</i> (Jan 1863)	CHUFCS3759	WD	LC	LC	NE	This study
<i>Xenodon merremii</i> (Wagler in Spix 1824)	CHUFCS1596	WD	LC	LC	LC	Roberto and Loebmann (2016)
Elapidae						
<i>Micrurus bonita</i> Nascimento, Graboski, Silva & Prudente, 2024	CHUFCS755	AT, CA, CE	NE	NE	NE	Nascimento et al. (2024)
<i>Micrurus lemniscatus</i> (Linnaeus 1758)	CHUFCS751	WD	LC	LC	LC	This study
Leptotyphlopidae						
<i>Epictia borapeliotes</i> (Vanzolini 1996)	CHUFCS3757	AT, CA	LC	LC	LC	Roberto and Loebmann (2016)

($N = 38$ species; Loebmann and Haddad 2010), Araripe bioregion ($N = 31$ species; Ribeiro et al. 2012), Baturité ($N = 30$ species; Borges-Nojosa 2007), and Ubajara (29 species; Castro Mângia, et al. 2019). In addition, the richness observed in the present study was higher than in other coastal and Caatinga *stricto sensu* areas in the State of Ceará: São Gonçalo do Amarante ($N = 23$ species; Borges-Leite et al. 2014), Salgado River Region ($N = 23$ species; Silva-Neta et al. 2018), Farias Brito ($N = 23$ species; Oliveira et al. 2021), Serra das Almas ($N = 22$ species; Borges-Nojosa and Cascon 2005), Lower Jaguaribe river ($N = 16$ species; Arruda et al. 2024), Caucaia ($N = 20$ species; Borges-Nojosa et al. 2010), Aiuaba (20 species; Costa et al. 2018), Itapipoca ($N = 19$ species; Castro et al. 2018), and Jaguaribe River Region ($N = 19$ species; Santana et al. 2015).

Regarding the amphibian species composition, we observed that the Serra de Maranguape shares more species with other nearest pre-coastal residual massifs with humid forests, such as the Serra de Aratanha and Baturité, probably because of the geographical proximity to these mountains. The 'Brejos de altitude' in Ceará State has a similar plant physiognomy (Moro et al. 2015) and present a unique composition of endemic and threatened species. The amphibian fauna of

the Serra de Maranguape presents species shared with other areas of Caatinga and with forested phytogeographic domains, such as the Amazon and the Atlantic Forest (Araújo et al. 2024). In terms of reptile species composition, we found a predominance of the Gymnophthalmidae family for lizards ($N = 6$ species) and the Dipsadidae family for snakes ($N = 15$ species). These results are similar to those found in other areas of Caatinga (Castro et al. 2019). Furthermore, the area also has a high number of amphisbaenid species, containing four of the seven species present in the state of Ceará (Borges-Nojosa et al. 2021). Most of the reptile species found in Serra de Maranguape have a wide geographic distribution in Brazilian biomes, and at least three species are endemic to the 'Brejos-de-altitude': *Leposoma baturitensis*, *Placosoma limaverdorum* and *Apostolepis thalesdelemai*. Furthermore, *Strobilurus torquatus* and *Stenolepis ridleyi* occur only in the 'Brejos-de-altitude' and Atlantic Forest, and species such as *Sibon nebulatus* are shared with the Amazon, Atlantic Forest and Caatinga areas located in coastal regions (Roberto and Loebmann 2016).

Regarding reptiles, the species composition follows the same pattern found for amphibians, with species sharing with forested and open Brazilian phytogeographic



Figure 7. Reptiles from the Environmental Protection Area Serra de Maranguape, Ceará State, Northeastern Brazil: (A) *Amphisbaena alba*, (B) *Amphisbaena vermicularis*, (C) *Leposternon polystegum*, (D) *Norops fuscoauratus*, (E) *Diploglossus lessonae*, (F) *Hemidactylus agrius*, (G) *Hemidactylus mabouia*, (H) *Lygodactylus klugei*.

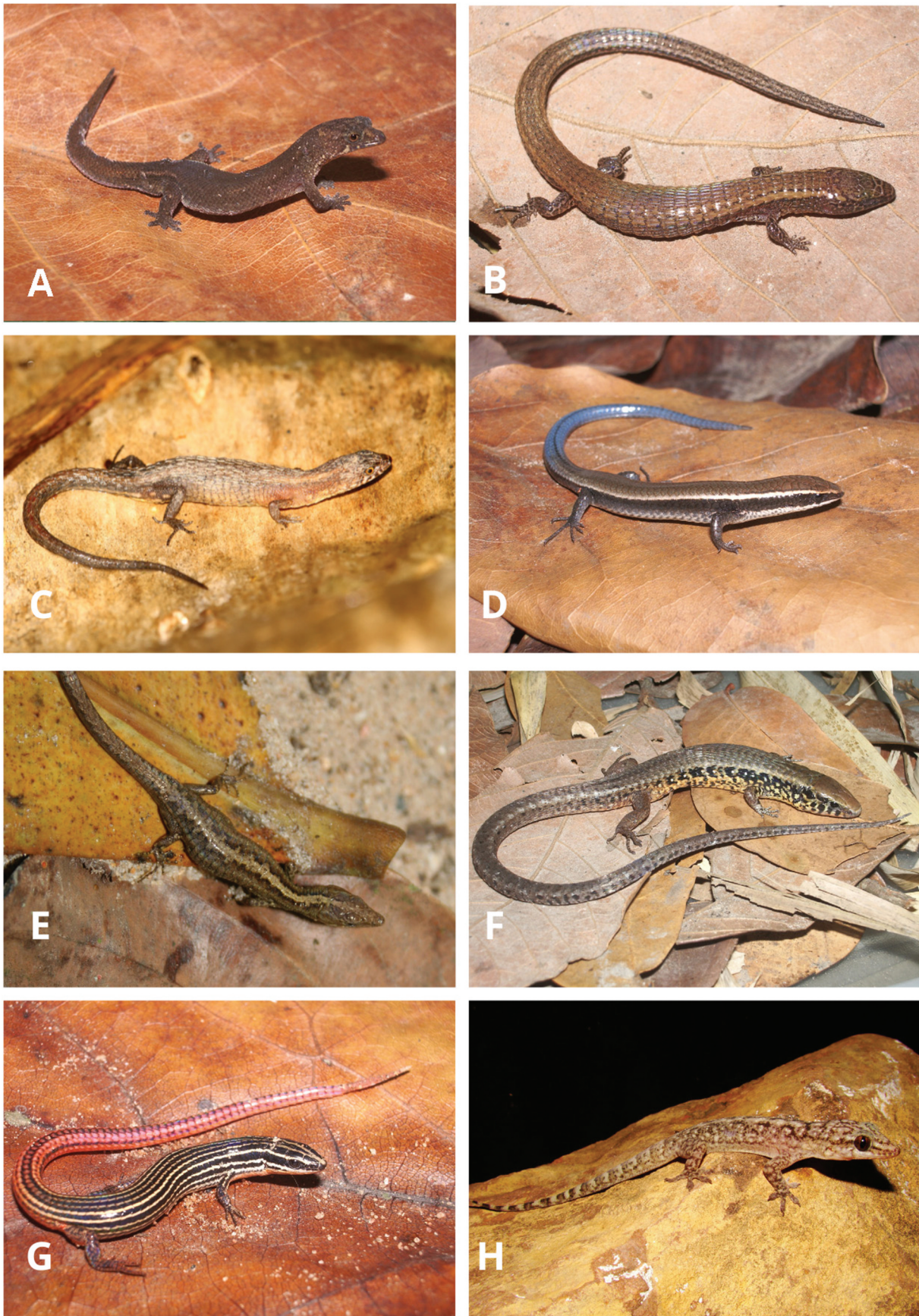


Figure 8. Reptiles from the Environmental Protection Area Serra de Maranguape, Ceará State, Northeastern Brazil: (A) *Coleodactylus meridionalis*, (B) *Colobosauroides cearensis*, (C) *Leposoma baturitensis*, (D) *Micrablepharus maximiliani*, (E) *Placosoma limaverdorum*, (F) *Stenolepis ridleyi*, (G) *Vanzosaura multiscutata*, (H) *Phyllopezus pollicaris*.



Figure 9. Reptiles from the Environmental Protection Area Serra de Maranguape, Ceará State, Northeastern Brazil: (A) *Polychrus acutirostris*, (B) *Brasiliscincus heathi*, (C) *Ameiva ameiva*, (D) *Ameivula pyrrhogularis*, (E) *Salvator merianae*, (F) *Strobilurus torquatus*, (G) *Tropicurus hispidus*, (H) *Tropicurus semitaeniatus*.



Figure 10. Reptiles from the Environmental Protection Area Serra de Maranguape, Ceará State, Northeastern Brazil: (A) *Boa constrictor*, (B) *Epicrates assisi*, (C) *Corallus hortulana*, (D) *Drymoluber dichrous*, (E) *Leptophis dibernardoi*, (F) *Oxybelis aeneus*, (G) *Spilotes pullatus*, (H) *Apostolepis cearensis*.



Figure 11. Reptiles from the Environmental Protection Area Serra de Maranguape, Ceará State, Northeastern Brazil: (A) *Apostolepis thalesdelemai*, (B) *Erythrolamprus poecilogyrus*, (C) *Erythrolamprus reginae*, (D) *Erythrolamprus viridis*, (E) *Imantodes cenchoa*, (F) *Leptodeira tarairiu*, (G) *Lygophis dilepis*, (H) *Oxyrhopus trigeminus*.



Figure 12. Reptiles from the Environmental Protection Area Serra de Maranguape, Ceará State, Northeastern Brazil: (A) *Philodryas nattereri*, (B) *Philodryas olfersii*, (C) *Pseudoboa nigra*, (D) *Sibon nebulatus*, (E) *Adelphostigma occipitalis*, (F) *Xenodon merremii*, (G) *Micrurus bonita*, (H) *Micrurus lemniscatus*.

Heatmap of similarity in reptiles composition

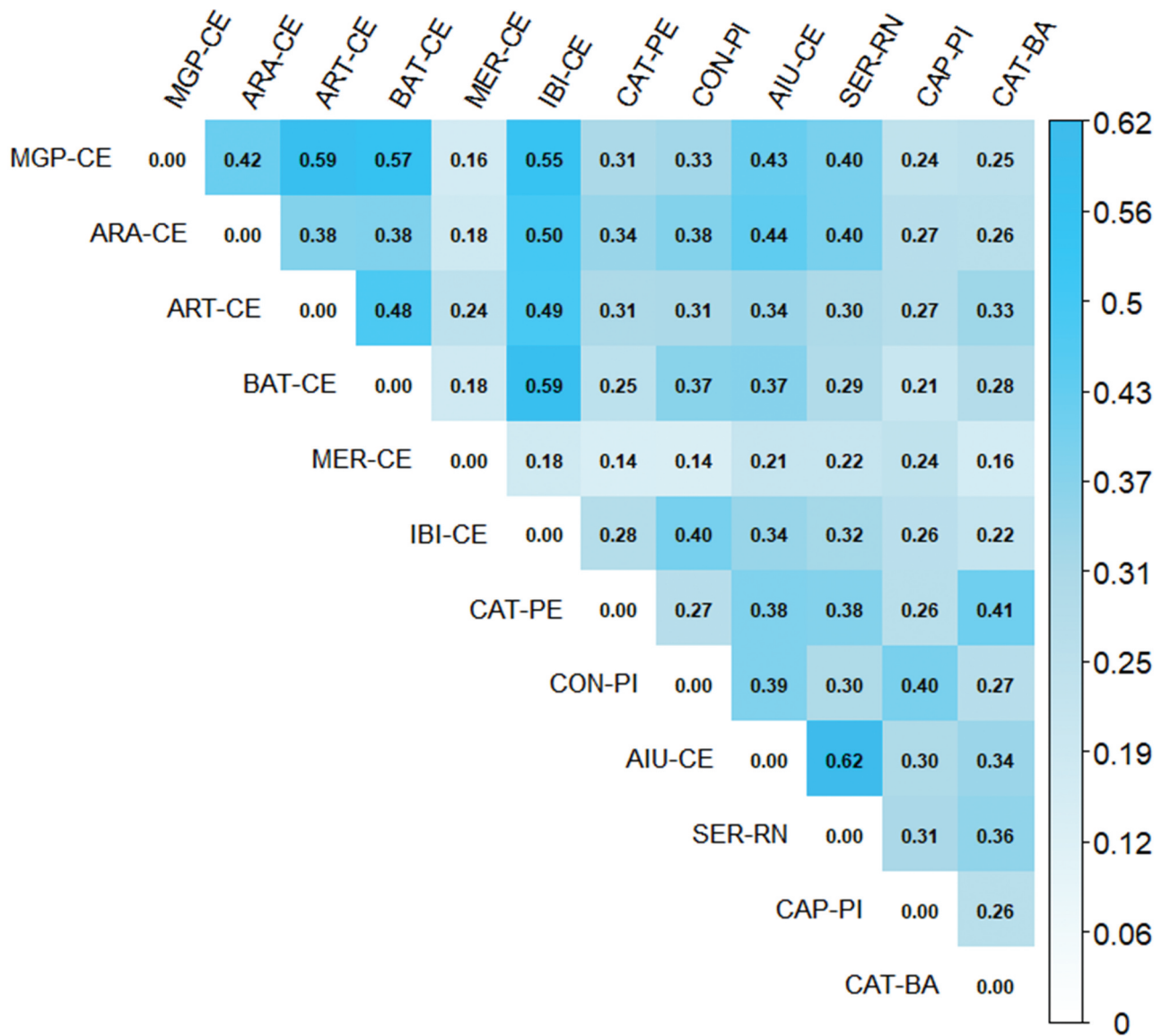


Figure 13. Heatmap of Jaccard Similarity Index for reptiles composition in pairwise comparisons between Environmental Protection Area Serra de Maranguape and different environmental protection areas in Northeastern Brazil. Serra de Maranguape Environmental protection area, Ceará (MGP-CE) (this study); National Forest of Araripe (ARA-CE) (Ribeiro et al. 2012); Serra da Aratanha Environmental protection area (ART-CE) (Roberto and Loebmann 2016); Serra de Baturité Environmental protection area, Ceará (BAT-CE) (Borges-Nojosa 2007; Roberto and Loebmann 2016); Serra da Meruoca Environmental protection area, Ceará (MER-CE) (Roberto and Loebmann 2016); Serra da Ibiapaba Environmental protection area and Ubajara National Park, Ceará (IBI-CE) (Loebmann and Haddad 2010; Roberto and Loebmann 2016; Castro et al. 2019); Catimbau National Park, Pernambuco (CAT-PE) (Pedrosa et al. 2014); Serra das Confusões National Park, Piauí (CON-PI) (Marques et al. 2023); Aiuaba Ecological station, Ceará (AIU-CE) (Costa et al. 2018); seridó Ecological station, Rio Grande do norte (SER-RN) (Caldas et al. 2016); Serra da Capivara National Park, Piauí (CAP-PI) (Cavalcanti et al. 2014); Raso da Catarina Ecological station, Bahia (CAT-BA) (Garda et al. 2013).

domains and greater influence from residual coastal mas-sifs and nearby sedimentary areas. The number of recorded reptile species is comparable to that of other relictual environments of Ceará State, including the Ibiapaba Plateau ($N=84$ species; Loebmann and

Haddad 2010; Castro, Mângia, et al. 2019), Baturité ($N=58$ species; Borges-Nojosa 2007), and Araripe Plateau ($N=78$ species; Ribeiro et al. 2012). However, it presents a higher species richness than that found in areas of Caatinga Stricto Sensu: Serra das Almas in Cratéus ($N=$

27 species; Borges-Nojosa and Cascon 2005), Farias Brito ($N = 40$ species; Oliveira et al. 2021), Aiuaba Experimental Station ($N = 37$ species; Costa et al. 2018), Salgado River region ($N = 34$ species; Silva-Neta et al. 2018) and Lower Jaguaribe river region ($N = 48$ species; Arruda et al. 2024). When compared to the coastal regions of the state of Ceará, the species richness is also higher: Caucaia ($N = 30$ species, Borges-Nojosa et al. 2010) and São Gonçalo do Amarante ($N = 37$ species, Borges-Leite et al. 2014).

Previous works, such as Vanzolini (1981), Rodrigues (1990), and Borges-Nojosa and Caramaschi (2003), found that the Northeastern Altitudinal Humid Forests have different fauna compositions, with combinations, quantities, and richness of differentiated species, each of them considered unique elements (Vanzolini 1981). Our study's data on richness and composition suggest that despite the apparent similarity with other 'Brejos-de-altitude,' Serra de Maranguape is an area of extreme biological importance and highlights the conclusion of Camardelli and Napoli (2012), who stated that this mountain range is one of the most critical areas for the conservation of herpetofauna in Northeastern Brazil.

Given this, conserving local biodiversity is challenging due to real estate speculation, disordered tourism, and agricultural activities, especially banana production. These practices compromise local flora and fauna, particularly species that classified as Endangered, such as *Leposoma baturitensis* (IUCN 2021; MMA 2022; SEMA 2022), *Placosoma limaverdorum* (SEMA 2022), *Apostolepis thalesdelemai* (IUCN 2021; SEMA 2022), and *Adelophryne maranguapensis* classified such as Critically Endangered (MMA 2022; SEMA 2022; IUCN 2023). For this latter species, one of the main harmful effects on its habitat is the extraction of bromeliads, which are the reproductive sites for these animals (Cassiano-Lima et al. 2020).

Disclosure statement

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