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Inventory

Herpetofauna of protected areas in the Caatinga VIII: An updated checklist for the Serra das Confusões region with new data from Serra Vermelha, Piauí, Brazil

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Abstract: It is repeatedly stressed the need to characterize the extant biodiversity in tropical ecosystems. However, inventory studies are still progressing slowly in dry ecosystems, leading to the underestimation of their true biodiversity and hindering conservation efforts. In this study, we present primary and secondary data, along with an updated list of amphibians and reptiles from two localities in the São Francisco-Gurguéia region in Piauí. Additionally, we compare the species composition between nine areas within the Caatinga, which were sampled

using standardized methods over the past ten years, to examine broader spatial patterns of community composition. To survey reptiles and amphibians, we employed similar methods and sampling efforts in two areas within the Serra das Confusões National Park (SCNP) region. Our surveys recorded a total of 73 species of amphibians and reptiles, of which 24 are new distribution records for the SCNP region. Consequently, our findings increase the known herpetofauna in the region to 94 species. Despite their proximity, the two sites in the SCNP region exhibited only 42% similarity in species composition, and they differed significantly from other areas within the Caatinga. Furthermore, even the closer Caatinga areas presented differences in species composition, highlighting the necessity to evaluate biodiversity across the landscape and contribute to understanding biogeographic patterns.
Keywords: *Wallacean shortfall; semi-arid; São Francisco-Gurguéia region; biogeography.*

Herpetofauna das áreas protegidas da Caatinga VIII: Um inventário atualizado para a região da Serra das Confusões com novos dados da Serra Vermelha, Piauí, Brazil

Resumo: É repetidamente enfatizada a necessidade de caracterizar a biodiversidade vivente em ecossistemas tropicais. No entanto, os estudos de inventário ainda estão progredindo lentamente em ecossistemas secos, levando à subestimação de sua verdadeira biodiversidade e dificultando os esforços de conservação. Neste estudo, apresentamos dados primários e secundários, juntamente com uma lista atualizada de anfíbios e répteis de duas localidades na região de São Francisco-Gurguéia, do Piauí. Além disso, comparamos a composição de espécies entre nove áreas dentro da Caatinga, que foram amostradas usando métodos padronizados nos últimos dez anos, para examinar padrões espaciais mais amplos de composição da comunidade. Para estudar répteis e anfíbios, utilizamos métodos e esforços de amostragem semelhantes em duas áreas na região do Parque Nacional da Serra das Confusões (PNSC). Nossos levantamentos registraram um total de 73 espécies de anfíbios e répteis, das quais 24 são novos registros de distribuição para a região do PNSC. Consequentemente, nossos resultados aumentam a herpetofauna conhecida na região para 94 espécies. Apesar da proximidade, os dois locais na região do PNSC exibiram apenas 42% de similaridade na composição de espécies e diferiram significativamente de outras áreas dentro da Caatinga. Mesmo áreas mais próximas da Caatinga apresentaram diferenças na composição de espécies, destacando a necessidade de avaliar a biodiversidade em toda a paisagem e contribuir para a compreensão de padrões biogeográficos.
Palavras-chave: *Déficit Wallaceano; semi-árido; região de São Francisco-Gurguéia; biogeografia.*

Introduction

Characterizing extant biodiversity is increasingly important as anthropogenic activities alter natural habitats, often eroding species richness (Sala et al. 2000, Bellard et al. 2014). Tropical ecosystems have high biodiversity and contribute disproportionately to global ecosystem services. Within Neotropics, seasonally dry ecosystems like Cerrado and Caatinga comprise more than a quarter of Brazil and 4% of the global tropical land area (Coutinho 1978, Ab'Sáber 1983). Neotropical seasonally dry ecosystems span multiple unexplored and hard-to-access areas, making a complete faunal survey challenging; consequently, its biodiversity remains relatively understudied. This deficiency of local inventories contributes to the Wallacean shortfall (*i.e.*, species geographic ranges are poorly known), leading to underestimation of the true biodiversity (Bini et al. 2006, Antonelli et al. 2018) and undermining conservation efforts that require reliable information (Garda et al. 2017).

Until recently, the Caatinga was considered depleted of biodiversity (Vanzolini 1963, Vanzolini et al. 1980, Rodrigues 2003), a likely consequence of poor inventories. As of 2004, 41% of the region remained unsurveyed, and many previous surveys have been criticized for lacking rigor and thoroughness (Leal et al. 2005). Increased biodiversity studies have revealed a substantial number of plants and vertebrates with a richness similar to other tropical dry forests (Leal et al. 2003, 2005, Garda et al. 2018). The Caatinga is an exclusively Brazilian biome, mainly composed of flatlands with isolated high-altitude plateaus (>1,000 m), many vegetation physiognomies (e.g., open shrublands, savannas, wetlands, dry tropical forests, rain forests), and irregular precipitation with long dry seasons (Sampaio 1995, Prado 2003). Although the Caatinga covers roughly 735,000 km², much of the original vegetation has changed due to deforestation, wood extraction, livestock grazing, and human-induced fire (Antongiovanni et al. 2018). These and other emerging threats caused by global climate change are predicted to significantly impact existing biodiversity (Sala et al. 2000, Bellard et al. 2014, Torres et al. 2017, Silva et al. 2019). Although less than 2% of the Caatinga is under strict protection, existing protected areas provide opportunities to understand biodiversity patterns (Leal et al. 2005, MMA 2011, Brasil 2018) and monitor future changes.

The Caatinga is part of the South American dry (or open) diagonal, along with the Chaco and the Cerrado (Silva et al. 2017b). Transitional regions between these open biomes exhibit heterogeneity in soil characteristics, humidity, fire frequency, and habitat structure, which may support increased biodiversity (Pellegrini 2016). These ecotones are thus of particular conservation interest (Smith et al. 1997), especially considering that species richness in the Caatinga is likely underestimated and that the Cerrado is one of the global hotspots of biodiversity (Myers et al. 2000).

Amphibians and reptiles are prominent members of the vertebrate fauna in tropical ecosystems, showing high levels of diversity and

endemism (Murali et al. 2021). Additionally, they are often locally adapted and have narrow physiological tolerances, being model organisms for understanding biodiversity patterns (Huey et al. 2009, Díaz-Ricaurte et al. 2020). The most recent compilation for the Caatinga herpetofauna reported 224 reptile and 98 amphibian species (Garda et al. 2018), and these numbers have increased since then. Detailed inventories of the herpetofauna from Caatinga protected areas are known for Uruçuí-Una Ecological Reserve (Dal Vechio et al. 2013), Serra da Capivara National Park (Cavalcanti et al. 2014), and Serra das Confusões National Park (Dal Vechio et al. 2016). Studies on the herpetofauna have been conducted throughout Piauí state (e.g., Loebmann & Mai 2008, Roberto et al. 2013, Benício et al. 2015, Madella-Auricchio et al. 2017, Miranda et al. 2017, Santos et al. 2017, Araújo, Andrade, et al. 2020, Pantoja et al. 2022), but there is a notable sampling gap for the São Francisco-Gurguéia ecoregion, near the Serra das Confusões National Park. Here we present data for reptiles and amphibians from two localities in a Caatinga-Cerrado ecotone in the São Francisco-Gurguéia region in Piauí. We also compiled literature data for this region to provide an updated list of reptiles and amphibians. Finally, we compare species composition between nine areas within Caatinga sampled with standardized methods over the last ten years to examine broader spatial patterns of community composition.

Materials and Methods

1. Study area

The Serra das Confusões National Park (SCNP) is located in southeastern Piauí state, near the Bahia state border. The SCNP was created in October 1998 with an original area of 500,000 ha (Brasil 1998). In December 2010, it was expanded to 824,000 ha by aggregating parts of the Serra Vermelha region (Brasil 2010). The SCNP is located in a transition zone between Caatinga and Cerrado, a region of semi-arid inter-plateau depressions within the Piauí-Maranhão sedimentary basin (Ab'Sáber 1982). The area has a mean annual temperature of 27 ºC (range 18.6 to 36 ºC), with a marked dry season from May to October and an annual rainfall not exceeding 900 mm (Castro et al. 2009, Alves et al. 2020, Lima et al. 2020).

We collected data from two areas in the SCNP region (Figure 1). The first sampled site, Instituto Chico Mendes de Conservação da Biodiversidade (ICMB), is located within the boundaries of SCNP, at the central-east portion of the Confusões plateau, around the ICMBio field base in the municipality of Guaribas (3,118,227 km², –9.1678, –43.5658, 451 m above sea level [a.s.l.]). This site is in the Gurguéia River basin, in a transitional zone comprising tropical dry forest,

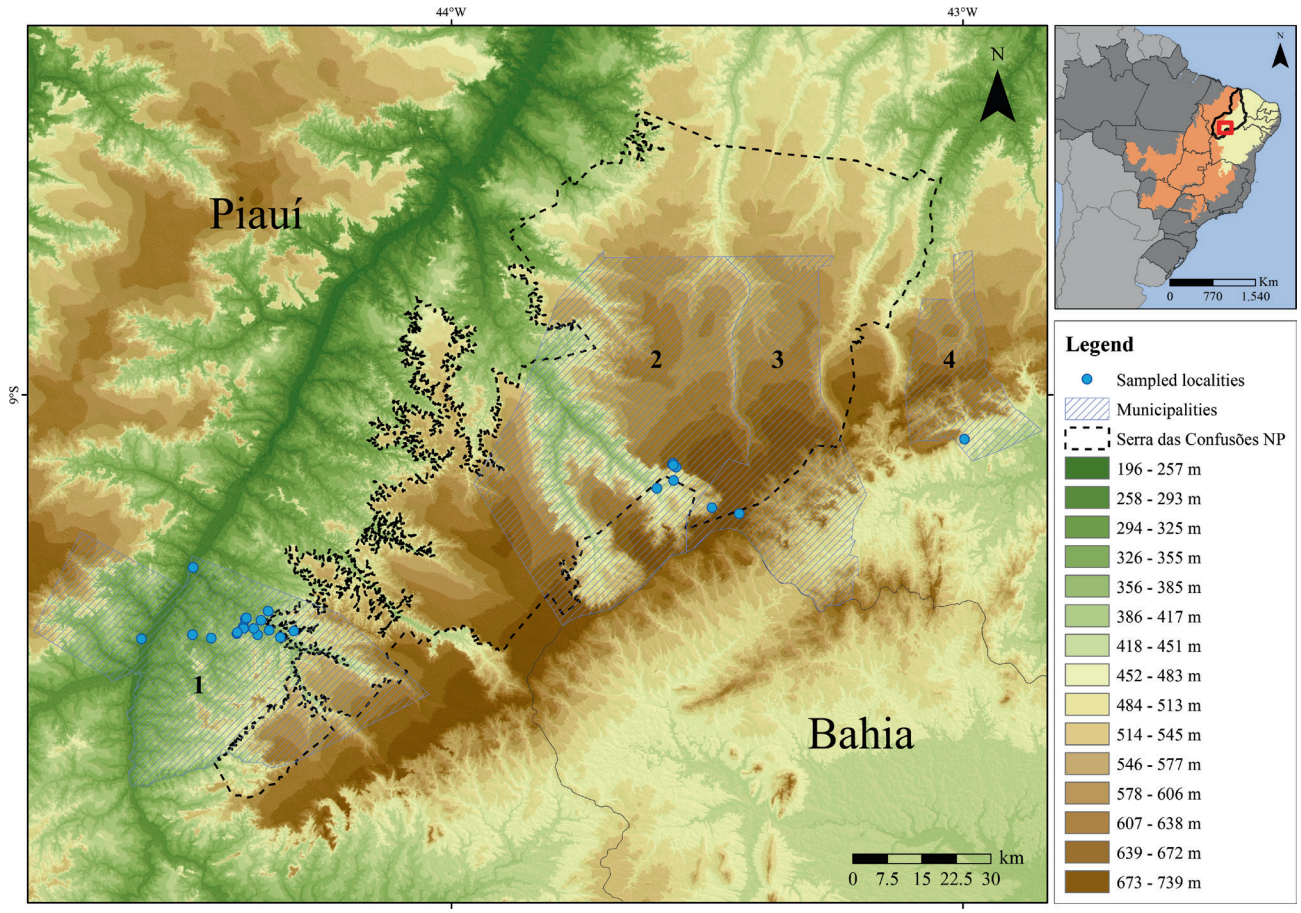

Figure 1. Map of the Serra das Confusões National Park region with its limits in dashed lines. Hatched polygons highlight the sampled municipalities of Redenção do Gurguéia (1) and proximities to the ICMBio field base in the municipalities of Guaribas (2), Caracol (3), and São Braz do Piauí (4). Blue dots show all sampled localities, detailed in Table 1.

caatinga bush vegetation, and cerrado vegetation (Silva et al. 2004). We also performed haphazard sampling in neighboring locations near SCNP, in the municipalities of Caracol and São Braz do Piauí, in the São Francisco River basin (see Table 1).

The second sampling site is near the village of São José, in the Redenção do Gurguéia (RdG) municipality (2,468,000 km², –9.4536, –44.4073, 366 m a.s.l.), at the southwestern portion of SCNP in the Serra Vermelha region. Situated about 100 km southwest of the ICMB, this site is in the Gurguéia River basin and is characterized as a Caatinga-Cerrado ecotone with many plateaus and valleys. This ecotone has dense and tall vegetation in some places (Caatinga) and open, stunt vegetation in others (Cerrado) (Silva et al. 2004). Seasonal semideciduous forests also exist at lower elevation areas (canyons), locally known as "baixões" (Castro et al. 2009). Recurrent fires occur at this site, mainly in the "baixões," where the vegetation is mostly in secondary succession with signs of past fire events (e.g., scorched tree trunks).

2. Sampling

We sampled the herpetofauna using a combination of glue traps, pitfall traps with drift fences, and active surveys (Foster 2012; Table 1). For ICMB, we conducted a 34-day survey in October-November 2014, at the beginning of the wet season. Each pitfall trap array consisted of four 30 l buckets positioned in a "Y" shape, with a central bucket connected to three buckets at the extremities by 5.0 × 0.5 m black tarp fences. We placed 35 pitfall trap arrays divided among four transects in different habitats (T1–4, Table 1). Each transect contained 8–9 arrays 35 m apart.

Table 1. Localities sampled at the Serra das Confusões National Park region, sampling method (PT: pitfall traps, AS: active surveys, GL: Glue traps), geographical coordinates, and municipality.

Locality	Sampling	Latitude	Longitude	Municipality
ICMBio field base (ICMB)				
1. Base ICMBIO (T1)	AS, PT, GL	–9.1678	–43.5658	Guaribas
2. Andorinha (T2-3)	AS, PT, GL	–9.1362	–43.5668	Guaribas
3. Museu (T4)	AS, PT, GL	–9.1408	–43.5618	Guaribas
4. Lagoa do Carlinho	AS	–9.2807	–43.3369	Guaribas
5. Barreiro	AS	–9.1831	–43.5982	Guaribas
6. Muquém	AS	–9.1390	–43.5981	Guaribas
7. Lagoa da Velha	AS	–9.1731	–43.5707	Guaribas
8. Olho d'Água da Santa	AS	–9.2191	–43.4902	Caracol
9. Gruta do Mirante	AS	–9.2203	–43.4917	Caracol
10. Entrada SCNP	AS	–9.2325	–43.4375	Caracol
11. Povoado de Tamanduá	AS	–9.0869	–42.9964	São Braz do Piauí
Redenção do Gurguéia (RdG)				
12. Povoado de São José	AS	–9.4537	–44.4071	Redenção do Gurguéia
13. Fazenda da Serra da Caatinga Grande	PT	–9.4673	–44.4195	Redenção do Gurguéia
14. Fazenda São Pedro	PT	–9.4235	–44.359	Redenção do Gurguéia
15. Baixão do Paraguai	AS, PT	–9.4745	–44.3349	Redenção do Gurguéia
16. Baixão dos Porcos	AS, PT	–9.4623	–44.3083	Redenção do Gurguéia
17. Riacho São José	AS	–9.4568	–44.4066	Redenção do Gurguéia
18. Riacho na estrada	AS	–9.4693	–44.5063	Redenção do Gurguéia
19. Poço Bonito	AS	–9.4758	–44.4697	Redenção do Gurguéia
20. Rio Gurguéia	AS	–9.4773	–44.6063	Redenção do Gurguéia
21. Cupins	AS	–9.338	–44.5054	Redenção do Gurguéia
22. Açude 1	AS	–9.4389	–44.4033	Redenção do Gurguéia
23. Açude 2	AS	–9.4368	–44.4011	Redenção do Gurguéia
24. Açude 3	AS	–9.4649	–44.4184	Redenção do Gurguéia
25. Açude 4	AS	–9.4693	–44.3791	Redenção do Gurguéia
26. Baixão do Pau D'Arco	AS	–9.4412	–44.3727	Redenção do Gurguéia
27. Buritizeiro	AS	–9.45707	–44.3867	Redenção do Gurguéia
28. Toca da Terra Preta	AS	–9.4607	–44.3567	Redenção do Gurguéia
29. Redenção do Gurguéia (city)	AS	–9.4885	–44.5789	Redenção do Gurguéia

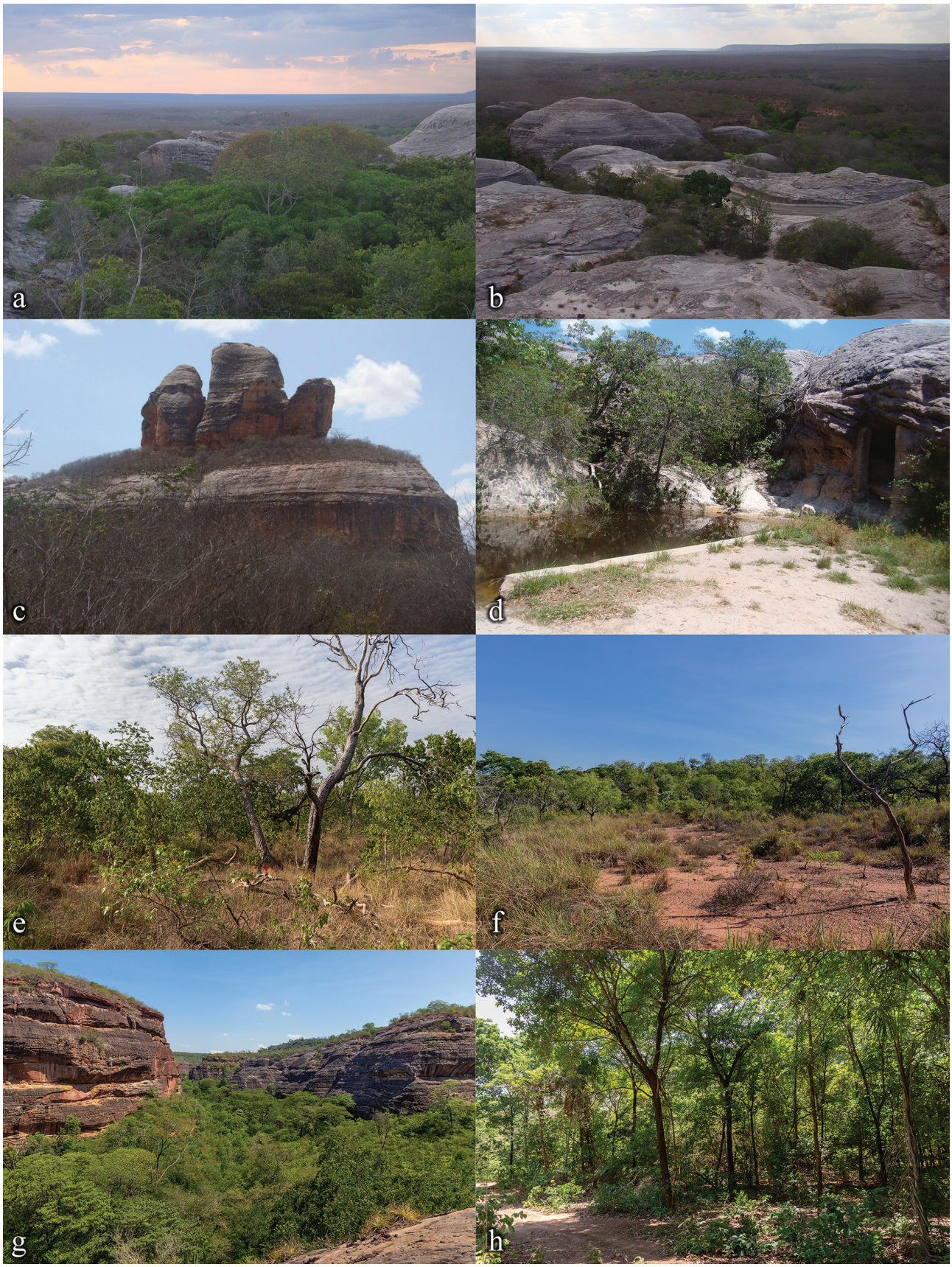

Figure 2. Vegetation physiognomies from Serra das Confusões National Park region. ICMBio field base: (a) arboreal strata, (b) rocky outcrops, (c) bush vegetation near transect, (d) pond; Redenção do Gurguéia municipality: (e) Cerrado, (f) Fazenda São Pedro, (g) Baixão dos Porcos, and (h) Baixão do Paraguai.

Pitfall traps remained open for 34 days and we did daily reviews in the morning, totaling 114,240 hours of sampling effort. At each pitfall trap array, we placed four glue traps (10 × 5 cm), two on the ground and two on the surrounding vegetation at one meter above the ground. For the 34–days survey we actively searched for amphibians and reptiles during daily pitfall checks and at night near lakes and ponds. We also included records from opportunistic encounters while in transit on roads and associated these records to the nearest sampling locality (Figure 1).

In RdG, we conducted surveys in November–December 2019 and January–February 2020. Although November–December survey occurred during the rainy season, we only observed light rainfall, with heavier rains occurring only during January–February survey. We placed transects in four areas with different vegetation types to cover most of the available habitats in the region: two areas with typical cerrado vegetation (Fazenda da Serra da Caatinga Grande and Fazenda São Pedro; Table 1; Figure 2E–F) and two areas with forest vegetation (Baixão dos Porcos and Baixão do Paraguai; Figure 2G–H). We placed 25 pitfall trap arrays in the open areas (Fazenda São Pedro: 13, Fazenda da Serra da Caatinga Grande: 12) and 25 arrays in forest areas (Baixão do Paraguai: 13, Baixão dos Porcos: 12). Pitfall traps remained open for 28 days in each survey period and we did morning reviews every day, comprising 268,800 hours. We also conducted haphazard night surveys near ponds, streams, and rivers (Table 1).

We euthanized all collected animals via intraperitoneal injection of sodium pentobarbital or topical application of benzocaine gel (for small amphibians only) (AVMA 2020). Then, we fixed specimens in formalin (10%) for at least 24 hours and stored them in 70% ethanol. Tissue samples and vouchers are housed in Coleção Herpetológica da Universidade Federal da Paraíba (CHUFPB) and Coleção Herpetológica da Universidade de Brasília (CHUNB). For taxonomy, we followed Burbrink et al. (2020) for Squamata and Frost (2023) for Amphibia, except for *Rhinella jimi* (see Rivera et al. 2022).

3. *Secondary data for species composition*

We combined our data with previously published records to generate an updated and comprehensive species list for the SCNP region. Two studies are worth mentioning: Dal Vechio et al. (2016), a list of the herpetofauna from the SCNP and nearby protected areas, and Madella-Auricchio et al. (2017), a compilation of reptile records from the Middle Gurguéia region. Most of our sampling areas did not overlap with Dal Vechio et al. (2016), except Olho d'Água da Santa (Table 1). Together, these two studies and ours comprise nine sampling sites in the SCNP region.

4. *Statistical analyses*

We used abundance data from ICMB and RdG to calculate Chao richness estimates for rarefied and extrapolated samples and the associated 95% confidence intervals with package iNEXT 2.0.2 (Chao et al. 2014, Hsieh et al. 2016) in R 3.6.3 (R Core Team 2022). Among the different herpetofaunal groups, we only obtained representative records for lizards, hence we calculated estimates for the whole herpetofauna assemblage and for amphibians, reptiles, and lizards separately, to test if our samples were good enough to reach the asymptote in the rarefaction curves.

We compared the Redenção do Gurguéia and SCNP herpetofauna with other Caatinga sites based on studies using similar sampling methods: (1) Raso da Catarina Ecological Station, Bahia state (Garda et al. 2013), (2) Chapada Diamantina National Park, Bahia state (Magalhães et al. 2015), (3) Serra da Capivara National Park, Piauí state (Cavalcanti et al. 2014), (4) Catimbau National Park, Pernambuco state (Pedrosa et al. 2014), (5) Seridó Ecological Station, Rio Grande do Norte state (Caldas et al. 2016), (6) Ubajara National Park, Ceará state (Castro et al. 2019), and (7) Aiuaba Ecological Station Ceará state (Costa et al. 2018) (Figure 11). To examine patterns of beta diversity and community composition, we used a species presence/absence matrix for the nine sites, estimated Jaccard dissimilarity index, and built a dissimilarity dendrogram with hierarchical clustering using package Vegan 2.5–7 (Oksanen et al. 2017) in R 3.6.3 (R Core Team 2022). The Jaccard index (S) considers only presence/absence and follows the formula $S = A/(B + C)$, where A is the shared species between areas, B is the total richness of the first area, and C is the total richness of the second area. The index ranges from 0 to 1, with 1 indicating complete homogeneity in the areas.

Results

1. *Herpetofauna composition in Serra das Confusões Caatinga-Cerrado region*

In total, for ICMB and RdG, we collected 2,563 individuals of 73 amphibian and reptile species. For ICMB, we recorded 25 reptile species (16 lizards, seven snakes, one amphisbaenian, and one turtle) and 13 amphibian species. For RdG, we recorded 39 reptile species (17 lizards, 15 snakes, three amphisbaenians, three turtles, and one caiman) and 25 amphibian species (24 anurans and one caecilian). We added 24 new distribution records for the SCNP region (8 snakes, five lizards, six anurans, two amphisbaenians, two turtles, and one caiman). Our findings, combined with previous literature records, yielded 94 species of amphibians and reptiles for the SCNP region, 71 species for ICMB and 65 species for RdG. Specifically, 65 reptiles: 25 lizard species in 11 families, 29 snakes in six families, six amphisbaenians in one family, four turtles in two families, and one caiman); and 29 amphibians: 28 anuran species in 6 families and one caecilian (Figures 3–9; Table 2).

Amphibians—In ICMB, Leptodactylidae was the richest family (9 species), followed by Hylidae (6) and Bufonidae (2). In RdG, Leptodactylidae was the richest family (12 species), followed by Hylidae (8) and Bufonidae (2). Microhylidae, Odontophrynidae, and Siphonopidae occurred in both localities with one species each, while Ceratophryidae only occurred at ICMB (Figures 3–4).

Reptiles—The richest lizard families in ICMB were Gymnophthalmidae and Teiidae (4 spp. each), followed by Scincidae and Tropiduridae (3 spp. each). In RdG, Teiidae was the richest (4), followed by Gymnophthalmidae, Phyllodactylidae, Scincidae, and Tropiduridae (2 spp. each). Gekkonidae, Hoplocercidae, Iguanidae, and Polychrotidae each had a single species collected that occurred in both localities. Leiosauridae was only found in ICMB. For snakes, Dipsadidae was the richest family in both localities (4 spp. in ICMB and 9 in RdG). Colubridae was the second richest family in ICMB, but only one species was found in RdG. Boidae was represented by two species in each locality (4 spp. total). Leptotyphlopidae was richer in ICMB (2) than RdG (1), and only one species of Elapidae and Viperidae was found in both localities. The only amphisbaenian family, Amphisbaenidae, occurred in both ICMB

Figure 3. Amphibians from the Serra das Confusões National Park region. Bufonidae: (a) *Rhinella granulosa*, (b) *R. jimi*, (c) *R. mirandaribeiroi*. Ceratophryidae: (d) *Ceratophrys joazeirensis*. Hylidae: (e) *Boana raniceps*, (f) *Corythomantis greeningi*, (g) *Dendropsophus minutus*, (h) *D. nanus*, (i) *D. soaresi*, (j) *Pithecopus gonzagai*, (k) *Scinax x-signatus*, (l) *Trachycephalus typhonius*. Leptodactylidae: (m) *Adenomera juikitam*, (n) *Leptodactylus fuscus*, (o) *L. macrosternum*.

and RdG, each with three different species. For turtles, Chelidae occurred in both localities (2 in ICMB and 2 in RdG) and Testudinidae only occurred in RdG (1 sp.). We only detected crocodilians in RdG with Alligatoridae (1) (Figures 5–9).

The rarefaction-extrapolation curve estimated for both localities indicated that the sampling of amphibians and lizards reached stability. In contrast, the curves for reptiles and overall herpetofauna in both areas did not stabilize, suggesting that both areas hold more species

Figure 4. Amphibians from the Serra das Confusões National Park region. Leptodactylidae: (a) *Leptodactylus mystaceus*. (b) *L. syphax*, (c) *L. troglodytes*, (d) *L. vastus*, (e) *Physalaemus albifrons*, (f) *P. cuvieri*, (g) *P. nattereri*, (h) *Pleurodema diplolister*, (i) *Pseudopaludicola cf. mystacalis*. Microhylidae: (j) *Dermatonotus aff. muelleri*. Odontophrynidae: (k) *Proceratophrys cristiceps*. (l). *Siphonopidae*: (m) *Siphonops paulensis*.

than we detected. The richness estimator suggests a 95% confidence interval of 40.6 ± 3.4 (38.4–56.9) species for the whole herpetofauna, 13 ± 0.3 (13–13.9) for amphibians, 28.9 ± 5.2 (25.6–53.7) for reptiles, and 16 ± 0.5 (16–17.9) for lizards in ICMB, and 74 ± 9 (66.26–109.25) species for the herpetofauna, 25 ± 0.3 (25–25.9) for amphibians, 52.4 ± 12.4 (41.9–101.8) for reptiles, and 17 ± 0.4 (17–17.9) for lizards in RdG (Figure 10).

2. *Beta diversity between areas of Caatinga and biogeographical patterns*

Overall, species composition similarities among sites ranged from 18% to 72%, with an average similarity of 31.4% ± 10.5%. This indicates a high variation in species composition throughout the Caatinga. Chapada Diamantina National Park and ICMB in Serra das Confusões National Park were the most heterogenous (18%), while Seridó Ecological Station and Aiuaba Ecological Station were the most homogenous (72%) (Figure 11; Table 3).

When comparing only ICMB and RdG to other areas, similarities ranged from 18% to 49% (Figure 11; Table 3). Despite their geographical proximity, the similarity between ICMB and RdG was only 42%. Redenção do Gurguéia was most homogenous to Aiuaba Ecological Station than to Serra da Capivara National Park, with similarity indices of 49% and 28%, respectively. The ICMBio field base was most homogenous to Serra da Capivara National Park (42%) than to Catimbau National Park (28%) (Table 3; Figure 11).

Figure 5. Reptiles from the Serra das Confusões National Park region. Alligatoridae: (a) *Caiman crocodilus*. Amphisbaenidae: (b) *Amphisbaena frontalis*, (c) *A. miringoera*, (d) *A. vermicularis*. Gekkonidae: (e) *Hemidactylus brasilianus*. Phyllodactylidae: (f) *Gymnodactylus geckoides*. Scincidae (g) *Brasiliscincus heathi*, (h) *Copeoglossum nigropunctatum*. Gymnophtalmidae: (i) *Calyptommatus confusionibus*, (j) *Colobosaura modesta*, (k) *Micrablepharus maximiliani*, (l) *Procellosaurinus erythrocercus*.

Discussion

Characterizing biodiversity and patterns of species turnover within and among ecosystems is increasingly important, particularly for understudied regions like the dry Neotropics (Sala et al. 2000, Leal et al. 2005, Bellard et al. 2014). Our findings add to understanding the diversity and distribution patterns of the herpetofauna at the Caatinga-Cerrado transition. Specifically, we demonstrate that the Serra das Confusões region is one of the richest areas for amphibians and reptiles in the Caatinga (Dal Vechio et al. 2016, Mesquita et al. 2017). We provide the first herpetofauna inventory for Redenção do Gurguéia. Madella-Auricchio et al. (2017) reported only *Leptodeira tarairiu* Costa, Graboski, Grazziotin, Zaher, Rodrigues & Prudente, 2022 and *Apostolepis cearensis* Gomes, 1915 for the municipality. Moreover, we added six records to the Serra das Confusões National Park: *Ceratophrys joazeirensis* Mercadal de Barrio, 1986, *Adenomera juikitam* Carvalho & Giaretta, 2013, *Scinax x-signatus* (Spix, 1824), *Polychrus acutirostris* Spix, 1825, *Micrurus* aff. *ibiboboca*, and *Trilepida brasiliensis* (Laurent, 1949). Also, we provide the first voucher-based record of *Epicrates crassus* Cope, 1862 to the state of Piauí. The occurrence of *E. crassus* in Piauí has been disputed (see Nogueira et al. 2019, Costa et al. 2021) primarily due to the lack of voucher specimens (Pantoja et al. 2022).

We used published inventories to assess community similarity and species turnover across nine Caatinga sites. Overall, we found high values (>50%) of beta diversity, even between nearby sites. Together, these results suggest that biodiversity patterns in Caatinga are likely

Figure 6. Lizards from the Serra das Confusões National Park region. Teiidae: (a) *Ameiva ameiva*, (b) *Ameivula confusioniba*, (c) *Ameivula ocellifera*, (d) *Glaucomastix venetacauda*, (e) *Salvator merianae*. Iguanidae: (f) *Iguana iguana*. Tropiduridae: (g) *Tropidurus hispidus*, (h) *Tropidurus oreadicus*, (i) *Tropidurus semitaeniatus*. Hoplocercidae: (j) *Hoplocercus spinosus*. Leiosauridae: (k) *Enyalius bibronii*. Polychrotidae: (l) *Polychrus acutirostris*.

maintained via high habitat heterogeneity and an abundance of ecotones. The species richness of ICMBio field base and Redenção do Gurguéia were higher than other areas in Caatinga sampled with similar effort and methods (Garda et al. 2013, Cavalcanti et al. 2014, Pedrosa et al. 2014, Caldas et al. 2016, Costa et al. 2018) but equivalent to other highly diverse sites from transitional and enclave areas (see Magalhães et al. 2015, Castro et al. 2019). Our rarefaction-extrapolation analyses indicated that diversity is likely even higher, mainly because of reptiles.

ICMB has more reptile species, whereas RdG has more amphibian species than other areas in Caatinga that we used in comparison. Such amphibian diversity is evident considering that Piauí state has 67 amphibian species (Roberto et al. 2013, Pantoja et al. 2017), and ICMB and Redenção do Gurguéia have 31% and 37% of this total richness, respectively. We highlight that Miranda et al. (2017) report *Dendropsophus rubicundulus* (Reinhardt and Lütken, 1862) for Guaribas municipality without specific locality information. A large portion of this municipality is within SCNP boundaries, and it is possible that this species also occurs in the study area. Another species with probable occurrence within the SCNP is *Colobosauroides carvalhoi* Soares & Caramaschi, 1998 (Magalhães–Júnior et al. 2017, Pantoja et al. 2022), with confirmed records within the Serra da Capivara National Park and surroundings (Recoder et al. 2018), a nearby protected area (~100 km).

When compared to other inventories in transitional areas in Piauí, ICMB and RdG surpass the overall reptile richness of Barras and Batalha municipalities (Benício et al. 2014, Silva et al. 2015). However, if we break into groups, amphibian and snake richness are lower than those

Figure 7. Snakes from the Serra das Confusões National Park region. Leptotyphlopidae: (a) *Trilepida brasiliensis*. Boidae: (b) *Boa constrictor*, (c) *Corallus hortulana*, (d) *Epicrates assisi*, (e) *Epicrates crassus*. Colubridae: (f) *Drymarchon corais*, (g) *Drymoluber brazili*, (h) *Leptophis dibernardoi*, (i) *Oxybelis aeneus*, (j) *Spilotes pullatus*, (k) *Tantilla melanocephala*. Dipsadidae: (l) *Adelphostigma occipitalis*, (m) *Apostolepis cearensis*, (n) *Erythrolamprus miliaris*, (o) *E. poecilogyrus*. Photo g by A. Sena.

reported for Barras, Castelo do Piauí, and Sete Cidades National Park (Rocha & Prudente 2010, Rodrigues & Prudente 2011, Benício et al. 2014, Araújo et al. 2020). Moreover, our results demonstrate that the overall richness of SCNP region is equivalent to the richest protected areas from Caatinga: Chapada Diamantina National Park (74 spp.) in Bahia state and Ubajara National Park (71 spp.) in Ceará state (Magalhães et al. 2015, Castro et al. 2019), and are richer than other areas throughout the domain (Table 3).

Figure 8. Snakes from the Serra das Confusões National Park region. Dipsadidae: (a) *Erythrolamprus viridis*, (b) *Leptodeira tarairiu*, (c) *Oxyrhopus trigeminus*, (d) *Philodryas nattereri*, (e) *P. olfersii*, (f) *Pseudoboa nigra*, (g) *Rodriguesophis iglesiasi*, (h) *Dryophylax phoenix*, (i) *Xenodon merremii*, (j) *X. nattereri*. Elapidae: (k) *Micrurus* aff. *ibiboboca*. Viperidae: (l) *Crotalus durissus*. Photos g and j by A.S.O. Meneses, and photos a and i by M.L.T. Oliveira.

In the São Francisco-Gurguéia ecoregion, the high herpetofauna diversity of the SCNP region is likely due to the transitional placement between Caatinga and Cerrado (Silva et al. 2017a). Ecotonal areas support increased species richness due to the vegetation mosaic (Kark 2013). Other surveys at ecotonal areas found a similar pattern of high species richness (Lantyer Silva et al. 2013, Silva et al. 2015, 2016). The ICMB is in a typical caatinga habitat, separated by only 100 km from RdG, which harbors Caatinga and Cerrado habitats, yet these two sites only shared 42% of species (Table 3; Figure 11). The two most similar localities, Aiuaba Ecological Station, located in the Depressão Sertaneja Setentrional ecoregion, and Seridó Ecological Station, located in a transition between Depressão Sertaneja Setentrional and Ibiapaba-Araripe complex ecoregion, shared 72% of species despite being three times further apart than ICMB and RdG (Caldas et al. 2016, Costa et al. 2018).

Silva et al. (2017a) proposed nine ecoregions for the Caatinga, each established according to specific features (e.g., vegetation, soil, climate, relief, and altitude). Since Aiuaba Ecological Station and Seridó Ecological Station share an ecoregion with the same features, we believe it contributed to a higher resemblance of species composition in caatinga *stricto sensu* habitat. In contrast, RdG is in a western ecotonal area with Cerrado, in the São Francisco-Gurguéia ecoregion along with ICMB and Serra da Capivara National Park (Silva et al. 2017a), but had higher species similarity with Aiuaba Ecological Station and Seridó Ecological Station. The Chapada Diamantina National Park and Ubajara National Park, which had the highest species richness (Table 3), are in

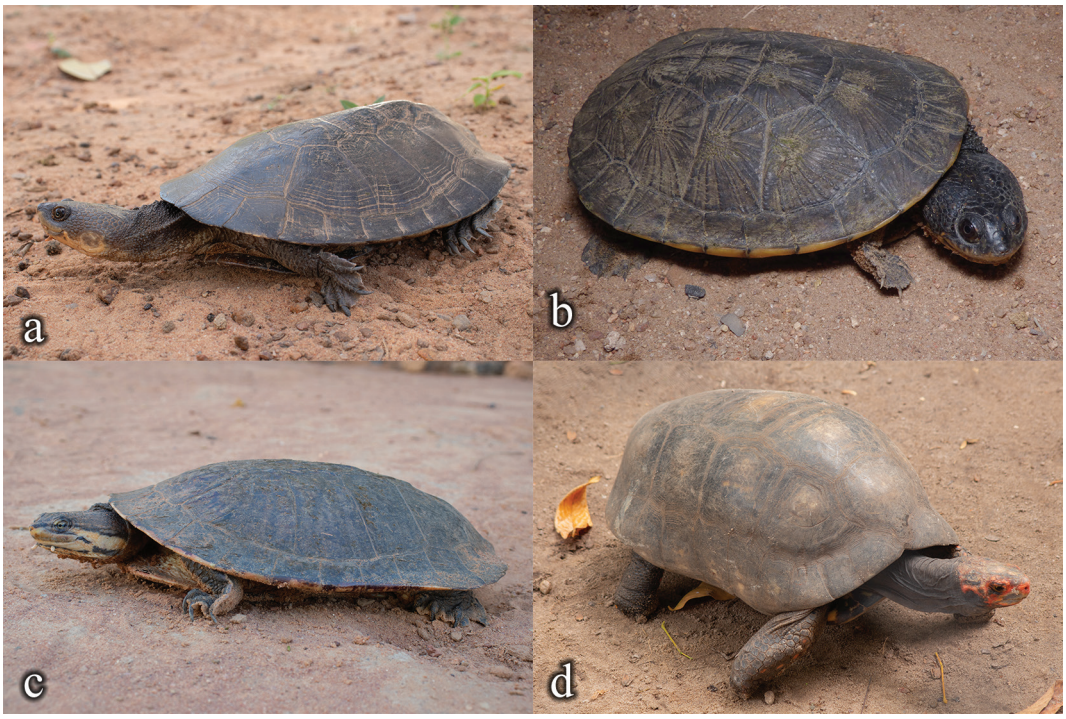

Figure 9. Turtles from the Serra das Confusões National Park region. Chelidae: (a) *Mesoclemmys perplexa*, (b) *M. tuberculata*, (c) *Phrynops geoffroanus*. Testudinidae: (d) *Chelonoidis carbonaria*.

Table 2. Amphibians and reptiles from the Serra das Confusões National Park region, ICMBio field base (ICMB), and Redenção do Gurguéia (RdG) in Piauí state, Brazil. Abundances of primary records (N), presence in ICMB or RdG, sample locality as in Table 1, and sources of additional species records: Dal Vechio et al. 2016 (A), Madella–Auricchio et al. 2017 (B). (*) New records for Serra das Confusões National Park region and (—) indicate abundance absence in primary records.

Taxon	N	ICMB	RdG	Locality	Source
AMPHIBIANS (29 spp.)					
Anura (28 spp.)					
Bufonidae (3 sp.)					
Rhinella granulosa (Spix, 1824)	50	✓		1,2,5–8	A
Rhinella jimi (Stevaux, 2002)	57	✓	✓	2,6,8,9,12–14,15–18,20,22,24	A
Rhinella mirandaribeiroi (Gallardo, 1965)*	42		✓	12,13,15–18,23,24	
Ceratophryidae (1 sp.)					
Ceratophrys joazeirensis Mercadal de Barrio, 1986*	2	✓		4	
Hylidae (10 spp.)					
Boana raniceps (Cope, 1862)*	12		✓	20	
Corythomantis greeningi Boulenger, 1896	18	✓	✓	8,12,17,19	A
Dendropsophus minutus (Peters, 1872)*	22		✓	20	
Dendropsophus nanus (Boulenger, 1889)*	25		✓	20–22	
Dendropsophus soaresi (Caramaschi & Jim, 1983)	4	✓	✓	17,22	A
Scinax gr. *ruber*	—	✓		—	A
Scinax sp.	—	✓		—	A
Scinax x-signatus (Spix, 1824)	73	✓	✓	1,8,12,13,17,18,20,22,24,25	

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Taxon	N	ICMB	RdG	Locality	Source
Pithecopus gonzagai Andrade, Haga, Ferreira, Recco-Pimentel, Toledo, & Bruschi, 2020	56	✓	✓	12,17,19,20,22,25	A
Trachycephalus typhonius (Linnaeus, 1758)	7		✓	12,17,20	
Leptodactylidae (12 spp.)					
Adenomera juikitam Carvalho & Giaretta, 2013*	60	✓	✓	2,19	
Leptodactylus fuscus (Schneider, 1799)	19	✓	✓	12,13,17,18,22,24	A
Leptodactylus macrosternum Miranda-Ribeiro, 1926	35	✓	✓	4,8,12,20,21,24,25,27	A
Leptodactylus mystaceus (Spix, 1824)	33	✓	✓	12,14,15,17,18,22	A
Leptodactylus syphax Bokermann, 1969	13	✓	✓	2,6,8,16,19	A
Leptodactylus troglodytes Lutz, 1926	76	✓	✓	2,5,8,12–17,22,25	A
Leptodactylus vastus Lutz, 1930	27	✓	✓	2,6,8,12,18,22,25	A
Physalaemus albifrons (Spix, 1824)	29	✓	✓	13,14,17,22,24	A
Physalaemus cuvieri Fitzinger, 1826	163	✓	✓	2,6,8,13–19,22,24	A
Physalaemus nattereri (Steindachner, 1863)	6		✓	12,13	
Pleurodema diplolister (Peters, 1870)	35		✓	12–14,17,22	
Pseudopaludicola cf. *mystacalis*	7		✓	27	
Microhylidae (1 sp.)					
Dermatonotus aff. *muelleri*	35	✓	✓	2,4,5,13–17	A
Odontophrynidae (1 sp.)					
Proceratophrys cristiceps (Müller, 1883)	69	✓	✓	2,8,12–14,17,18,25	A
Gymnophiona (1 sp.)					
Siphonopidae (1 sp.)					
Siphonops paulensis Boettger, 1892	2	✓	✓	13,16	A
REPTILES (64 spp.)					
Crocodylia (1 sp.)					
Alligatoridae (1 sp.)					
Caiman crocodilus (Linnaeus, 1758)*	1		✓	21	
Squamata – amphisbaenians (6 spp.)					
Amphisbaenidae (6 spp.)					
Amphisbaena aff. *miringoera*	—	✓			A
Amphisbaena frontalis Vanzolini, 1991	18	✓		2,5	A
Amphisbaena miringoera Vanzolini, 1971*	1		✓	15	
Amphisbaena polystega (Duméril, 1851)	—	✓		—	A
Amphisbaena sp.1*	1		✓	16	
Amphisbaena vermicularis Wagler, 1824	12	✓	✓	12–14,20,22,29	A
Squamata – lizards (25 spp.)					
Gekkonidae (1 sp.)					
Hemidactylus brasilianus (Amaral, 1935)	61	✓	✓		A
Phyllodactylidae (2 spp.)					
Gymnodactylus geckoides Spix, 1825*	33		✓	13–15,17,24	
Phyllopezus pollicaris (Spix, 1825)	62	✓	✓	2,3,5,6,8,12,16,19,22,24,26,28	A

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Taxon	N	ICMB	RdG	Locality	Source
Sphaerodactylidae (2 spp.)					
Coleodactylus brachystoma (Amaral, 1935)	—	✓		—	A
Coleodactylus meridionalis (Boulenger, 1888)*	27		✓	12–16,25	
Scincidae (3 spp.)					
Brasiliscincus heathi (Schmidt & Inger, 1951)	75	✓	✓		A
Copeoglossum nigropunctatum (Spix, 1825)	18	✓	✓		A
Notomabuya frenata (Cope, 1862)	—	✓		—	A
Gymnophthalmidae (4 spp.)					
Calyptommatus confusionibus Rodrigues, Zaher & Curcio, 2001	28	✓		2,5	A
Colobosaura modesta (Reinhardt & Luetken, 1862)	53	✓	✓	2,5,15,16	A
Micrablepharus maximiliani (Reinhardt & Luetken, 1862)	95	✓	✓	2,5,13–16	A
Procellosaurinus erythrocercus Rodrigues, 1991	46	✓		2,5	A
Teiidae (6 spp.)					
Ameiva ameiva (Linnaeus, 1758)	73	✓	✓	2,5,12,14–16	A
Ameivula confusioniba (Arias, Carvalho, Rodrigues & Zaher, 2011)	148	✓		2,5,9	A
Ameivula ocellifera (Spix, 1825)*	80		✓	12–16	
Ameivula sp.	—	✓		—	A
Glaucomastix venetacauda (Arias, Carvalho, Rodrigues & Zaher, 2011)	25	✓	✓	2,9,15,16	A
Salvator merianae (Duméril & Bibron, 1839)	8	✓	✓	2,14,15,16	A
Iguanidae (1 sp.)					
Iguana iguana (Linnaeus, 1758)	4	✓	✓	20	A
Tropiduridae (4 spp.)					
Stenocercus squarrosus Nogueira & Rodrigues, 2006	—	✓			A
Tropidurus hispidus (Spix, 1825)	307	✓		2,3,5	A
Tropidurus oreadicus Rodrigues, 1987*	187		✓	12–17,28	
Tropidurus semitaeniatus (Spix, 1825)	108	✓	✓	2,9,16,28	A
Hoplocercidae (1 sp.)					
Hoplocercus spinosus Fitzinger, 1843	24	✓	✓	2,5,15,16	A
Leiosauridae (1 sp.)					
Enyalius bibronii Boulenger, 1885	—	✓		—	A
Polychrotidae (1 sp.)					
Polychrus acutirostris Spix, 1825*	4	✓	✓	2,12–14	
Squamata – snakes (29 spp.)					
Leptotyphlopidae (2spp.)					
Trilepida cf. *fuliginosa*	—	✓		—	A
Trilepida brasiliensis (Laurent, 1949)*	18	✓	✓	2,15,16	

Continue...

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Taxon	N	ICMB	RdG	Locality	Source
Boidae (4 spp.)					
Boa constrictor Linnaeus, 1758*	1		✓	12	
Corallus hortulana (Linnaeus, 1758)	—	✓		—	A
Epicrates assisi Machado, 1945	—	✓		—	A
Epicrates crassus Cope, 1862*	1		✓	12	
Colubridae (6 spp.)					
Drymarchon corais (Boie, 1827)	—	✓		—	A
Drymoluber brazili (Gomes, 1918)	—	✓		—	A
Leptophis dibernardoi (Albuquerque, Santos, Borges-Nojosa & Ávila, 2022)	—	✓		—	A
Oxybelis aeneus (Wagler, 1824)	1	✓	✓	12	A
Spilotes pullatus (Linnaeus, 1758)	—	✓		—	A
Tantilla melanocephala (Linnaeus, 1758)	2	✓		2,5	A
Dipsadidae (15 spp.)					
Adelphostigma occipitalis (Jan, 1863)*	1		✓	15	
Apostolepis cearensis Gomes, 1915	6	✓	✓	2,5,14,15	A
Dryophylax phoenix (Franco, Trevine, Montingelli & Zaher, 2017)*	4		✓	15,16	
Erythrolamprus miliaris (Linnaeus, 1758)	—	✓		—	A
Erythrolamprus poecilogyrus (Wied, 1824)*	3		✓	12,17,22	
Erythrolamprus viridis (Günther, 1862)	1	✓	✓	22	A
Leptodeira tarairiu Costa, Graboski, Grazziotin, Zaher, Rodrigues & Prudente, 2022	—		✓	—	B
Lygophis paucidens Hoge, 1953*	2		✓	13	
Oxyrhopus trigeminus Duméril, Bibron & Duméril, 1854	12	✓	✓	12–14,16,22,25,26	A
Philodryas nattereri (Steindachner, 1870)	9	✓	✓	10,12–14	A
Philodryas olfersii (Liechtenstein, 1823)	1	✓		5	A
Pseudoboa nigra (Duméril, Bibron & Duméril, 1854)	6	✓	✓	11–13,16,17,22	A
Rodriguesophis iglesiasi (Gomes, 1915)	—	✓		—	A
Xenodon merremii (Wagler, 1824)	—	✓		—	A
Xenodon nattereri (Steindachner, 1867)	—	✓		—	A
Elapidae (1 sp.)					
Micrurus aff. *ibiboboca**	4	✓	✓	2,12,22	
Viperidae (1 sp.)					
Crotalus durissus Linnaeus, 1758	4	✓	✓	12	A
Testudines (4 spp.)					
Chelidae (3 spp.)					
Mesoclemmys perplexa Bour & Zaher, 2005	7	✓	✓	8,23,25	A
Mesoclemmys tuberculata (Luederwaldt, 1926)	—	✓		—	A
Phrynops geoffroanus (Schweigger, 1812)*	3		✓	15,20,21	
Testudinidae (1 sp.)					
Chelonoidis carbonaria (Spix, 1824)*	1		✓	13	
Total	2563	71 spp	65 spp		

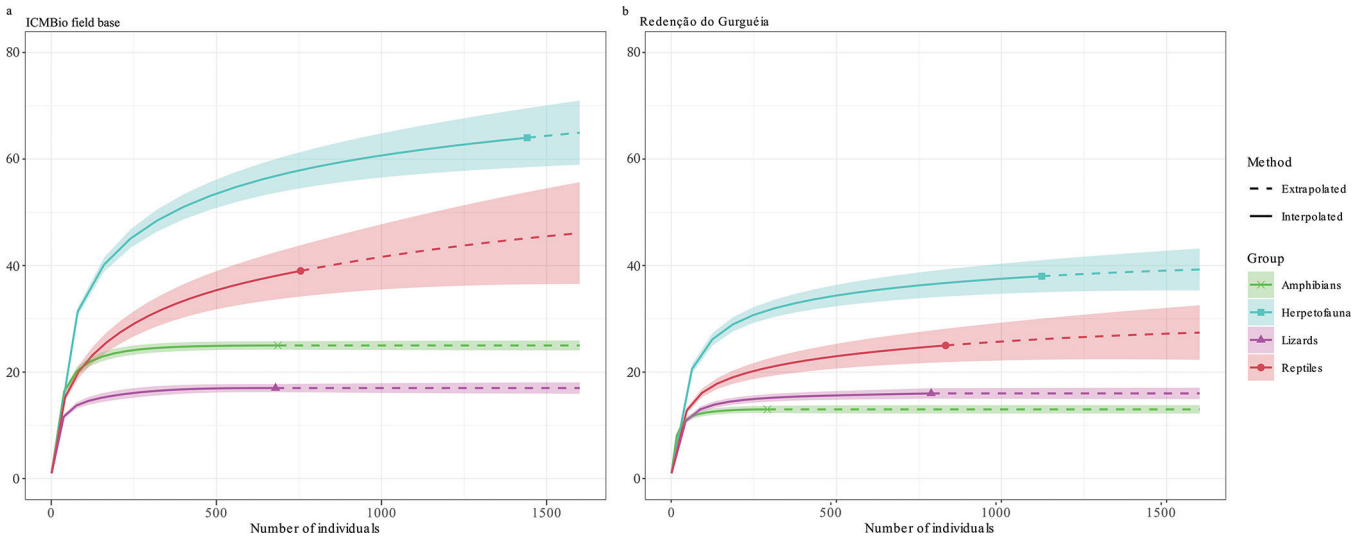

Figure 10. Individual-based rarefaction-extrapolation curves for amphibians, reptiles, lizards and the whole herpetofauna in the Serra das Confusões National Park region, state of Piauí: (a) ICMBio field base and (b) Redenção do Gurguéia. Solid lines represent the collected specimens, dotted lines are extrapolation, and translucid bars are the 95% confidence interval for each curve.

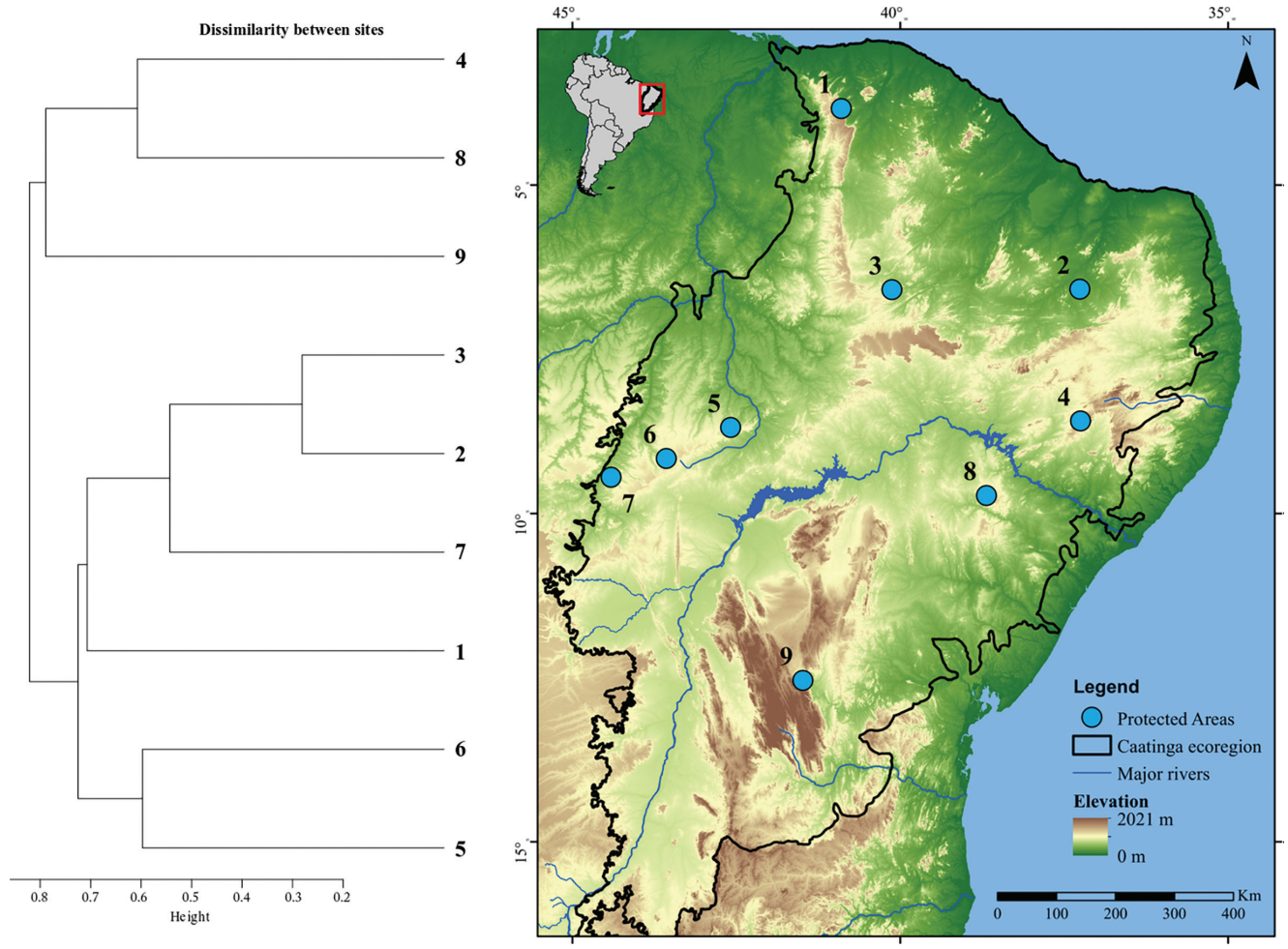

Figure 11. Dendrogram representation of the Jaccard dissimilarity between protected areas of Caatinga and their distribution map. Blue dots are sampled sites in Protected Areas from Caatinga: (1) Ubajara National Park, (2) Seridó Ecological Station, (3) Aiuaba Ecological Station, (4) Catimbau National Park, (5) Serra da Capivara National Park, (6) ICMBio field base in Serra das Confusões National Park, (7) Redenção do Gurguéia, (8) Raso da Catarina Ecological Station, and (9) Chapada Diamantina National Park.

Table 3. Similarity index between nine areas sampled with similar methods and effort.

Area	Richness	1	2	3	4	5	6	7	8
1. Ubajara National Park	71								
2. Seridó Ecological Station	53	0.32							
3. Aiuaba Ecological Station	57	0.29	0.72						
4. Catimbau National Park	58	0.25	0.41	0.40					
5. Serra da Capivara National Park	37	0.29	0.32	0.29	0.30				
6. Serra das Confusões National Park (ICMB)	71	0.29	0.36	0.39	0.30	0.40			
7. Redenção do Gurguéia	65	0.31	0.46	0.49	0.29	0.28	0.43		
8. Raso da Catarina Ecological Station	52	0.20	0.34	0.33	0.39	0.22	0.23	0.24	
9. Chapada Diamantina National Park	74	0.21	0.27	0.25	0.21	0.19	0.18	0.21	0.23

elevated regions with different rainfall regimes and floral composition than the other seven areas. Chapada Diamantina National Park is in the Espinhaço Mountain Range, a biodiverse region with unique features from the overall Caatinga region, such as "campos rupestres"—vegetation at high elevations with the predominance of herbs and considered a center of endemism for many organisms (Echternacht et al. 2011, Camardelli & Napoli 2012, Bitencourt & Rapini 2013). Ubajara National Park is in a "*brejo de altitude*" region of the Ibiapaba Plateau, a highly diverse mesic enclave within the semi-arid Caatinga due to recurrent connections between humid forests during past climatic fluctuations (Pennington et al. 2000, Wang et al. 2004). The "*brejos de altitude*" can be richer in herpetofauna species than in strict caatinga areas, as the Ibiapaba Plateau harbors more than 100 amphibians and reptiles (Loebmann & Haddad 2010). Yet, ICMB and RdG are richer than brejos de altitude areas (Freitas et al. 2019). These results suggest that conserving the variety of ecoregions within Caatinga would ultimately help maintain the highest levels of biodiversity.

Species composition was highly different between ICMB and RdG; notably, we recorded more Caatinga-related species in ICMB and more Cerrado-related species in RdG. For example, *Epicrates assisi* Machado, 1945 is predominantly distributed in northeastern Brazil in the semi-arid Caatinga, while *E. crassus* occurs typically in Cerrado formations (Passos & Fernandes 2008). The same pattern applies to *Rhinella granulosa* (Spix, 1824) (Caatinga) vs. *R. mirandaribeiroi* (Gallardo, 1965) (Cerrado) and *Lygophis dilepis* Cope, 1862 (Caatinga, Chaco, and Pantanal) vs. *Lygophis paucidens* Hoge, 1953 (mostly Cerrado) (Narvaes & Rodrigues 2009, Nogueira et al. 2019). We only recorded *E. assisi* and *R. granulosa* for ICMB, and *E. crassus*, *R. mirandaribeiroi*, and *L. paucidens* for RdG. Other species typical of Cerrado were detected only in RdG (*Physalaemus nattereri* (Steindachner, 1870)) and ICMB-RdG (*Mesoclemmys perplexa* Bour & Zaher, 2005). While most of the species collected were widespread, only one endemic lizard species were collected: *Calyptommatus confusionibus* Rodrigues, Zaher & Curcio, 2001, endemic to the area of ICMB (Uchôa et al. 2022). The high beta diversity among sites suggests that while many species are widespread geographically, they are specialized for specific ecoregions, which are patchily distributed across the region.

The large spatial scale of this study provides a means to assess the distribution ranges of some species. For example, we extend the known geographical range of *Glaucomastix venetacauda* (Arias, Carvalho, Rodrigues & Zaher, 2011) from ICMB 89 km southwest to RdG (Dal Vechio et al. 2016). Other species require a taxonomic comment. Specifically, recent molecular data showed two allopatric evolutionary lineages on the dry diagonal of open formations attributed to *Dermatonotus muelleri* (Boettger, 1885), separated by the Brazilian Plateau, with no gene flow, suggesting the lineage in northeastern Brazil is an undescribed species (Oliveira et al. 2018). *Dermatonotus muelleri* was described from Paraguay (Boettger 1885); hence we treated the sampled individuals herein as *D.* aff. *muelleri*. *Amphisbaena* sp. was detected only in RdG and did not resemble any other amphisbaenian in the region (Madella-Auricchio et al. 2017). Finally, due to morphological differences between the holotype of *Micrurus ibiboboca* (Merrem, 1820) and the specimens found in semi-arid regions from northeastern Brazil, we adopted *M.* aff. *ibiboboca,* as proposed by Marques et al. (2021). As taxonomic revisions are made, our results can aid in delineating species distributions.

Conservation efforts and our understanding of biogeographic patterns rely on accurate species richness measurements across the landscape (Antonelli et al. 2018). We provided new data for the SCNP region and novel information for its southwestern portion, the Serra Vermelha. Our findings suggest that Serra das Confusões is a priority area for conservation for amphibians and reptiles, as they have an equivalent richness to other highly biodiverse areas from Caatinga.

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Conflicts of Interest

The authors declares that they have no conflict of interest related to the publication of this manuscript.

Data Availability

Supporting data is available at: https://doi.org/10.48331/scielodata.71XORF.

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