DIVERSITY OF AMPHIBIANS AND REPTILES OF THE PARQUE SESC SERRA AZUL: A TRANSITION ZONE IN MIDWESTERN BRAZIL

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Abstract.—Although the Cerrado ecoregion of Brazil is among the most diverse environments on the planet, herpetological knowledge of the western border of this ecoregion is poor. We assessed the species richness, abundance, and community structure of amphibians and reptiles inhabiting the Parque Sesc Serra Azul, Mato Grosso, Brazil. We also explored seasonal variations in abundance and compared species composition with other Cerrado areas and surrounding ecoregions. We sampled amphibians and reptiles with funnel traps, pitfall traps with drift fences, and active searches across 11 mo, spanning dry and rainy seasons from 2022–2023. We also gathered community science records to complement the species composition data. We recorded 36 amphibian and 63 reptile species, and the community science initiative resulted in 38 reptile species, 11 of which were not encountered in our traps or active searches. While amphibian community structure varied seasonally, that of reptiles did not change across the sampled months. Cluster analyses revealed that amphibians from the study area shared greater compositional similarity with regions of the Chiquitano Dry Forest, whereas reptiles showed stronger affinities with sites from the Cerrado. Our research provides a baseline for understanding how species richness, community composition, and abundance of amphibians and reptiles vary across a transition zone in midwestern Brazil. Studies such as ours provide a benchmark against which to measure the effects of agricultural expansion and climate change in the coming decades, both of which are greatly impacting the Cerrado ecoregion.

Key Words.—Cerrado; Chiquitano; community science; seasonality; adventure park

INTRODUCTION

Globally, Tropical Savannas have substantially decreased in area over the last two decades due to agricultural expansion and land clearing (Strassburg et al. 2017; Alencar et al. 2020). The Cerrado is a Neotropical Savanna ecoregion encompassing gallery and dry forests, palm tree wetlands, savannas with sparsely distributed small trees, and grasslands (Ribeiro and Walter 2008), with a strongly seasonal climate (Nascimento and Novais 2020). Boundaries between the Cerrado and surrounding ecoregions (see Dinerstein et al. 2017) are usually not well defined, with flooded grasslands and forests gradually replacing the typical elements of the Cerrado (Marques et al. 2020). In the western limits of the Cerrado near the Brazil-Bolivia border, however, there are distinctive environmental conditions in the lowlands (Cerrado-Pantanal) and surrounding plateaus (Cerrado-Chiquitano Dry Forest). The environmental heterogeneity in these ecological transitional zones promotes biodiversity, with high estimates of both richness and rarity (Madella-Auricchio et al. 2017). Like other transition zones in the Cerrado, these western limits are undergoing frontier settlement driven by agroindustrial biofuel production (Rausch et al. 2019).

Landscape modifications such as those occurring in the Cerrado transition zones are known to negatively impact biodiversity (With et al. 2024; Mesquita et al. 2025), particularly amphibians and reptiles. This vulnerability is mainly associated with dispersal limitations, close association with microhabitat, and in the case of amphibians, desiccation proneness (Crump 2015; Watling and Braga 2015). For reptiles, restrictions related to thermal tolerance and

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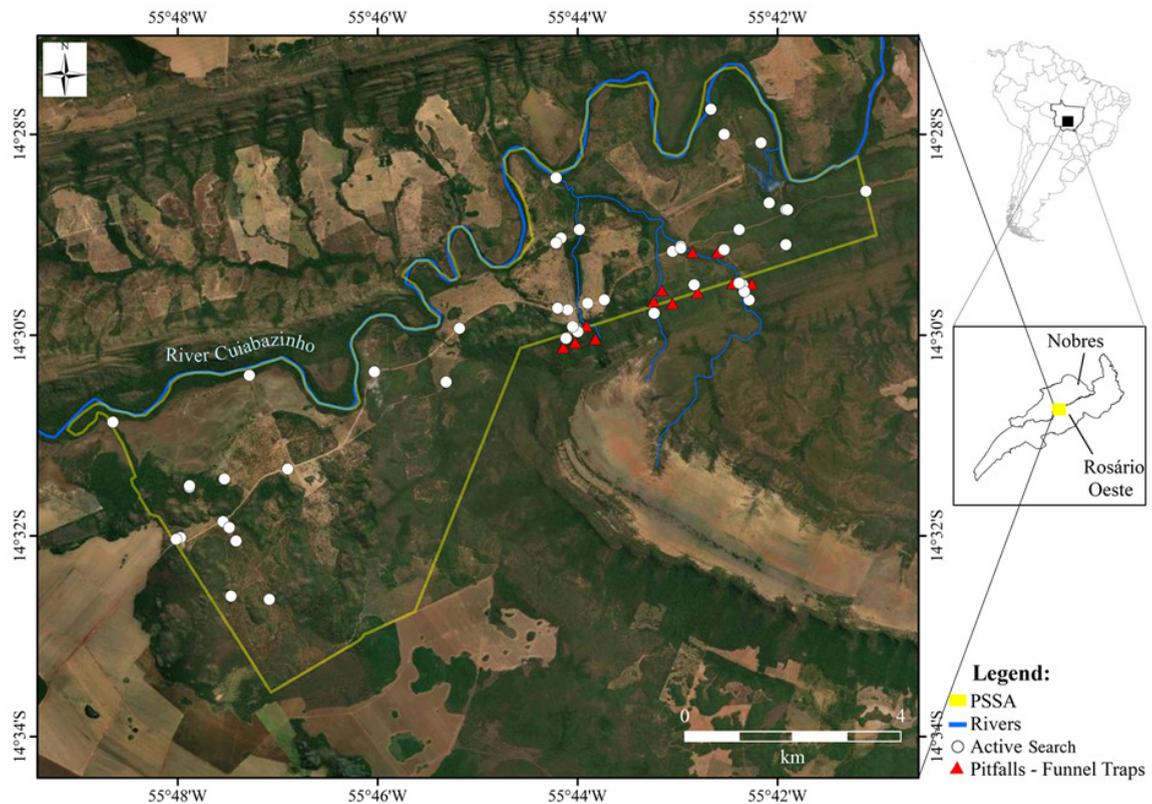
Figure 1. Geographic location of the Parque Sesc Serra Azul (PSSA) in the municipality of Rosário Oeste (inset map), Midwestern Brazil (upper right panel).

association with particular substrates play a crucial role in the microhabitat choice of species (Nogueira et al. 2009; Diele-Viegas et al. 2018).

These threats underscore the urgency of improving biodiversity knowledge in vulnerable regions. Despite the recent improvements in biodiversity data (e.g., Guerra et al. 2020), significant knowledge gaps persist regarding Brazilian herpetofauna. Undersampled regions likely harbor incomplete records of species composition, limiting our understanding of extant biodiversity patterns. This issue is particularly evident in non-forest biomes, such as the Cerrado Savanna, where sampling efforts for lizards and snakes remain disproportionately low (Teixido et al. 2021). While past and ongoing inventories are helping to address these biases (e.g., Silva et al. 2015; Neves et al. 2019; Guerra et al. 2022), critical limitations persist, including unresolved taxonomic uncertainties and sparse distributional data, which hinder a comprehensive assessment of amphibian and reptile diversity in these ecosystems.

Here, we provide information on amphibian and reptile species recorded in Parque Sesc Serra Azul, a private adventure park located in a transition zone in the western Cerrado. We assessed parameters of community structure and compared herpetofauna species composition with that in other Cerrado areas and surrounding ecoregions. We compared species richness and abundance detected by different capture methods, as well as variation in abundance across 11 mo of sampling. In addition, we examined seasonal abundance peaks and temporal variation between amphibians and reptiles.

Materials and Methods

Study area.—The Parque Sesc Serra Azul (PSSA) is a private area designed for adventure tourism and ecotourism, located between the municipalities of Nobres and Rosário Oeste (14.4986°S, 55.7342°W, Datum = WGS84) in the state of Mato Grosso (Fig. 1), Brazil, in the Cerrado ecoregion. The PSSA is maintained by the non-profit Brazilian institution Serviço Social do Comércio, which aims to convert about 20% of the area into a private natural heritage reserve. The PSSA spans about 5,000 ha and lies

inside a sustainable-use protected area (Área de Proteção Ambiental-APA Cabeceiras do Rio Cuiabá), which encompasses grassland and savanna mosaics on both alluvial and rocky soils, riparian habitats, and dry forests, distributed in lowlands and fairly rugged relief areas between 250–650 m elevation. As in most areas of the Cerrado ecoregion, agricultural activity is the dominant land use (https://mapbiomas.org). Land cover in PSSA thus varies among original Cerrado vegetation, distinct land reclamation stages, and areas still in use for extensive cattle ranching. The region has a tropical savanna climate with an annual mean rainfall of 1,500 mm, concentrated from October to March (Alvares et al. 2013). Monthly precipitation often falls below 60 mm between May and September.

Field methods.—From February 2022 to January 2023, we conducted 11 monthly sampling campaigns at PSSA. Each campaign lasted seven days, during which we sampled the herpetofauna in vegetation mosaics (Fig. 1) along distinct contour lines by using funnel traps, pitfall traps with drift fences, and active searches to assess species richness and community structure. During the rainy season, many lowland areas are subjected to flash floods, constraining trap sampling, so we installed most of the 12 trap sets (Fig. 1) in areas of intermediate relief located 0.2–3.6 km apart. Half of the trap sets were close (< 100 m) to headwater streams. Each trap set was composed of four pitfalls 10 m apart and four funnel traps 3 m apart following a linear drift fence. The pitfalls consisted of 60 L plastic buckets with small (3 mm) holes to allow water to drain. The funnel traps were cylinders of polyethylene plastic mesh (25 × 75 cm) supported by a metal frame, with a plastic funnel (5 cm opening) on each extremity. We fitted each pitfall trap with damp cloths (to provide moisture and a sheet of polystyrene foam to provide a floating substrate at the bottom of the trap), and with a plastic lid suspended by metallic rods for shade. We used dead tree bark or palm leaves as cover over the funnel traps. During each sampling campaign, we left traps open for seven consecutive days. Each day, we transported all captured individuals to the field laboratory, marked them individually, and released them in the original capture location on the morning of the next day, except for voucher specimens of each species. We used different marking methods for each group: visible implant elastomer tags for amphibians, nontoxic nail polish on the claws of the forelimbs for lizards, subcutaneous microchips and ventral scale

clipping of snakes, nontoxic painted numerals on the upper shell of turtles, and subcutaneous microchips for crocodilians.

The active searches consisted of random transects performed by three or four researchers between 1800 and 2000. We located animals visually or acoustically during four nights of each campaign. During the day, we checked the candidate sites (usually one or two) for accessibility, then came back at dusk and searched for individual animals for 90 min. We concentrated active searches in lower relief areas, with higher areas included intermittently (Fig. 1). When the taxonomic identification required further examination, we captured individuals, transported them to the field laboratory, and preserved them or later released them at the same sampled site. We euthanized voucher specimens with an overdose of lidocaine (amphibians) or xylazine-ketamine mixture (reptiles). We preserved voucher specimens in 10% formalin and deposited them in the Coleção Zoológica da Universidade Federal de Mato Grosso (UFMT-Cuiabá).

To obtain additional data on the composition of the herpetofauna of PSSA, we conducted 10–15 min talks with the local park staff, encouraging them to photograph and record amphibians and reptiles observed during their daily activities. These sessions were led by the authors and repeated monthly to reach new staff members and reinforce guidance throughout the study period. We oriented them about safety and how to use the Timestamp Camera app (https://play.google.com/store/apps/details?id=com.jeyluta.timestampcamerafree; or similar timestamping tools) during the records. This approach ensured verified documentation of species encountered during their routine activities. At the end of the sampling campaigns, we received records from 15 volunteers. Our final species list also included records from opportunistic encounters and road-killed individuals found during the campaigns.

Data analyses.—We assessed sampling saturation overall and per sampling method with rarefaction and extrapolation curves using Hill numbers (Chao et al. 2014). We also estimated species richness per sampling method with the Chao 1 Abundance-based Richness Estimator. We generated sampling curves in R (R Core Team 2022) with the iNext package (Hsieh et al. 2016). We used a Permutational Multivariate Analysis of Variance (PERMANOVA) to assess differences in community structure related to seasonality, analyzing amphibians and reptiles
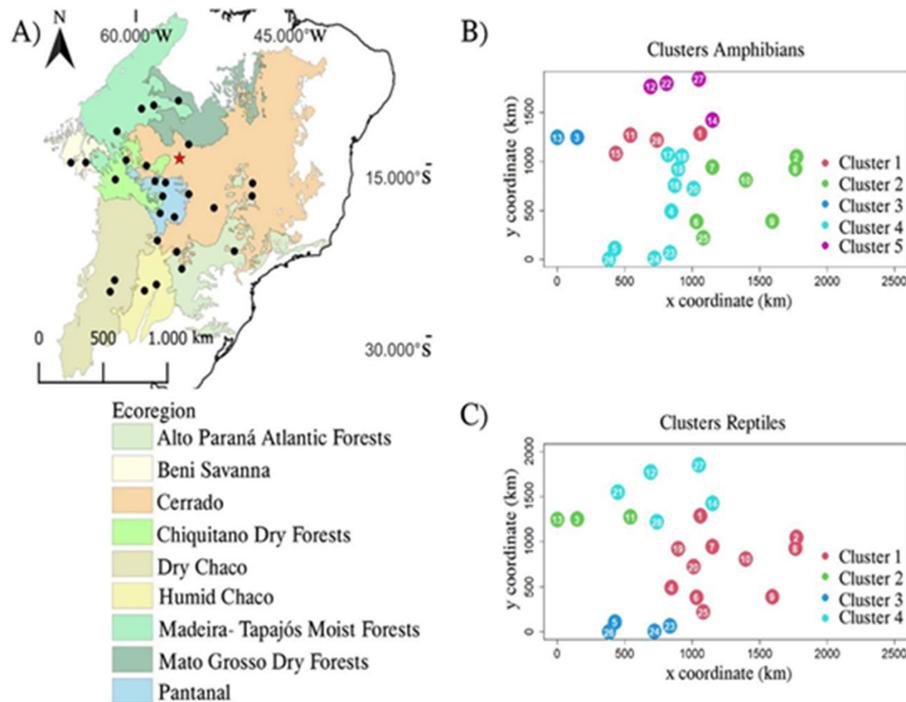
Figure 2. Comparison of the composition of amphibian and reptile species from Parque Sesc Serra Azul, Brazil, with adjacent ecoregions. (A) Geographic location of PSSA (red star) and other study areas included in the analyses (black circles). Map of detected clusters for (B) amphibian data and (C) reptile data. Information about the study areas numbered in B and C is found in Supplemental Information Table S1.

separately. We tested for differences in species composition across sampling months to examine potential species responses to seasonality using quantitative biotic matrices with each day as a sampling unit, with data from traps and active search. We did not consider marked individuals recaptured in the same sampling period in the analysis. Before PERMANOVA, quantitative data were Hellinger-transformed (Legendre and Gallagher 2001). We used a compound graph (https://raw.githubusercontent. com/csdambros/R-functions/master/poncho.R) to characterize abundance variation patterns across months.

We compared local species composition with that of 27 areas (26 for amphibians and 22 for reptiles) previously studied in nine South American ecoregions (*sensu* Dinerstein et al. 2017): Alto Paraná Atlantic Forest, Beni Savanna, Cerrado, Chiquitano Dry Forest, Dry Chaco, Humid Chaco, Madeira-Tapajós Moist Forest, Mato Grosso Tropical Dry Forest, and Pantanal. We only included inventories using similar sampling methods and field campaigns during rainy and dry periods (Fig. 2; Supplemental Information Table S1 and Material S1). We excluded species mentioned in the original manuscripts as undetermined (cf., gr. and aff.) or unidentified to the

species level (sp.). Using an average agglomerative method (UPGMA), we performed a cluster analysis on the Jaccard dissimilarity matrix among the 28 areas. We assessed the robustness of the generated dendrograms using an Approximately Unbiased Index (AU) calculated from multiscale bootstrap resampling (1,000 replicates; Suzuki and Shimodaira 2006). We considered nodes with AU values > 70% to have moderate support and values > 90% to have strong support for a given cluster (Borcard et al. 2018). We conducted all analyses using the pvclust and vegan packages in R (Suzuki and Shimodaira 2006; Oksanen et al. 2025).

Results

We recorded 36 amphibian and 63 reptile species in the Parque Sesc Serra Azul (PSSA). During systematic active searches and trap set inspection, we encountered individuals from 34 amphibian species (Supplemental Information Table S2, Figs. S1 and S2) and 31 reptile species (Supplemental Information Table S3, Figs. S3-S5), totaling 46 genera from 21 families. Opportunistic records added two amphibian species (*Ameerega braccata* and *Rhinella stanlaii,* no common names) and 32 reptile species (one worm
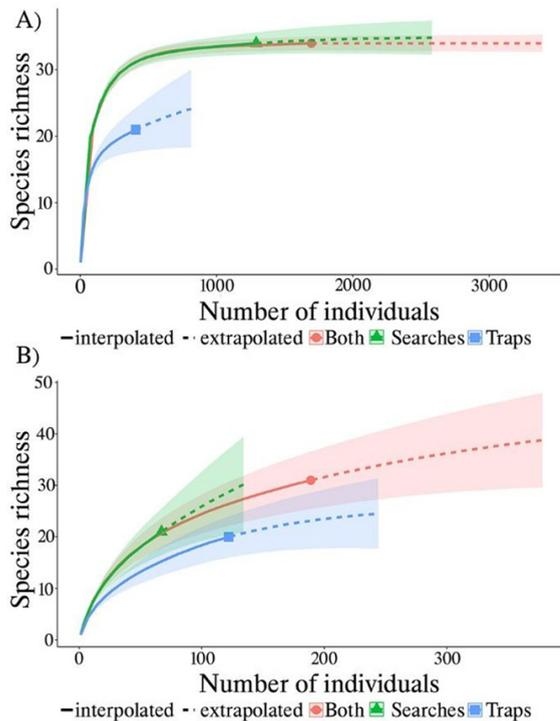
FIGURE 3. Individual-based rarefaction (solid line segment) and extrapolation (dotted line segment) curves according to different sampling methods: (A) amphibian data; (B) reptile data. Shaded areas represent 95% confidence intervals.

lizard, seven lizards, 23 snakes, and one turtle; Table S3). We could not assign two anuran species (genera *Adenomera* and *Pithecopus*) and four reptiles (genera *Apostolepis*, *Dipsas*, and *Dryophylax*) to any recognizable species. *Adenomera* aff. *hylaedactyla* (n = 248) and Giant Ameiva (*Ameiva ameiva*, n = 48) were the most abundant amphibian and reptile, respectively. Most reptile species (n = 41) were represented by five individuals or fewer (Table S3). We recaptured only three amphibian species: two Menwig Frogs (*Physalaemus albonotatus*), one Central Dwarf Frog (*P. centralis*), and one Snouted Treefrog (*Scinax fuscovarius*). For reptiles, we recaptured only one Giant Ameiva and three Spiny Weapontail (*Hoplocercus spinosus*).

Species rarefaction curves reached an asymptote in the individual-based sampling curves for amphibian data (Fig. 3). The confidence interval of abundance-based estimators did not support differences between the overall estimated richness (34–36) and active search sampling (34–41). In contrast, richness estimates based solely on pitfall trap data were markedly lower and did not overlap with estimates from either the combined data set or

the active searches (Fig. 3). For reptiles, rarefaction curves did not reach an asymptote (Fig. 3). The confidence intervals of the Chao 1 estimator were overlapping among the combined data set, the pitfall traps, and active search sampling (Fig. 3). The similar observed species richness by opportunistic records and regular sampling methods supported the large confidence interval for estimated richness (31–85). Traps accounted for only five exclusive records: Brongersma's Worm Snake (*Amerotyphlops brongersmianus*), *Apostolepis* sp. 1, *Apostolepis* sp. 2, Spiny Weapontail, and Wagler's Snake (*Xenodon merremii*).

There was strong evidence that amphibian community structure varied seasonally ($F_{10,67}$ = 2.654, P = 0.001), with sampling month explaining 31% of the variability observed. Species with explosive breeding behavior (e.g., Interior Treefrog, *Dendropsophus melanargyreus*, Cuyaba Dwarf Frog, *Physalaemus nattereri*, Cururu Toad, *Rhinella diptycha*, and Snouted Treefrog) were most abundant in the early rainy season (October to December; Fig. 4). Most Leptodactylidae species were recorded in similar abundances through the year, even in dry months, but *A.* aff. *hylaedactyla* had peaks in abundance during the transition from rainy to dry months (Fig. 4). For reptiles, there was weak evidence that community structure is associated with sampling month ($F_{10,67}$ = 1.291, P = 0.071). Three abundant species (Giant Ameiva, Spectacled Caiman, *Caiman crocodilus*, and Bahia Colobosaura, *Colobosaura modesta*) were recorded throughout the year (Fig. 5), but the Spiny Weapontail was more abundant during the early rainy season (Fig. 5).

Cluster analyses based on the occurrence of 179 amphibian species across 27 areas revealed two main clusters with strong to moderate support (AU ≥ 80%, Supplemental Information Fig. S6): a group comprising seven areas from Alto Paraná and Cerrado ecoregions; and a group of 10 areas from the Pantanal and Chaco ecoregions. The species composition at PSSA was more closely related to a smaller, well-supported cluster (86% AU) that included areas from the Chiquitano Dry Forest, suggesting ecological affinity between these sites (Fig. 2). For reptiles, cluster analyses based on the occurrence of 265 species from 23 areas indicated four distinct and well-supported clusters (AU ≥ 80%, Fig. 2): (1) three areas located in Bolivia; (2) 11 areas primarily from the Cerrado and Pantanal ecoregions; (3) four areas from the Gran Chaco; and (4) five areas associated to Amazonian forests. Species composition at PSSA
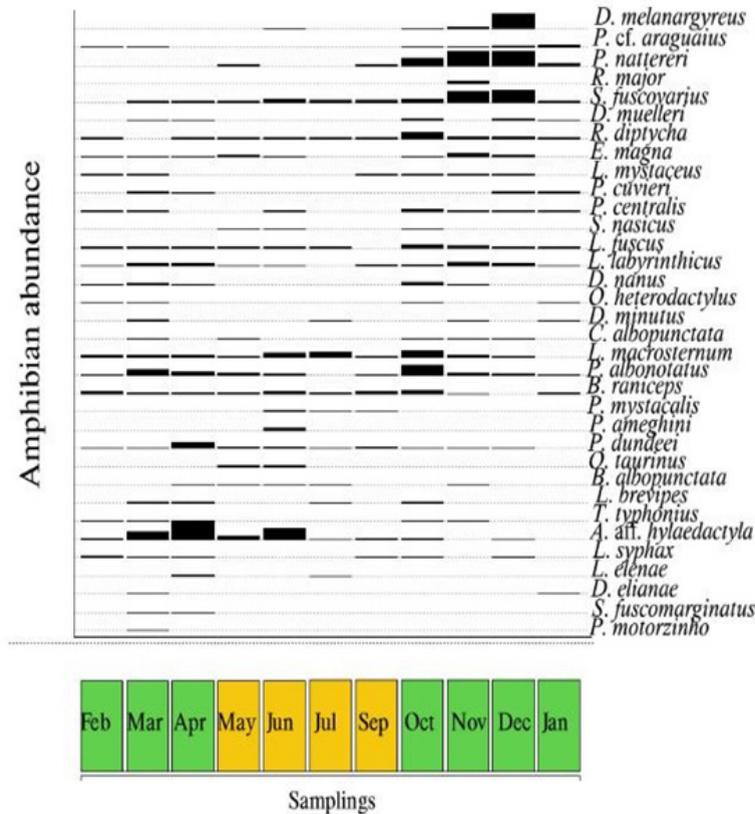
Figure 4. Distribution of amphibian species in relation to season (rainy season: green bars; dry season: yellow bars) in the Parque Sesc Serra Azul, Rosário Oeste, Mato Grosso, Brazil. Bar thickness is proportional to abundance. Common names appear in Supplemental Information Table S2.

was grouped within the Cerrado cluster, although with only moderate support (77% AU; Fig. S6).

Discussion

The species richness recorded here represents about 20% of the amphibians and reptiles known from Mato Grosso state (Ávila et al. 2021; Guedes et al. 2023). Nevertheless, our results for species composition showed distinct similarity patterns between amphibian and reptile communities across the analyzed ecoregions. These findings are not unexpected because the PSSA lies in the transition between Cerrado, Pantanal, Chiquitano, and Mato Grosso Tropical Dry Forests. The presence of the Spectacled Caiman provides additional evidence of a shared history between highland areas now belonging to the Upper Paraguay River Basin and upland drainage basins from the Upper Tapajós River, as previously reported for some fish species (Ribeiro et al. 2013). The presence of amphibian and reptile species typical from Amazon moist broadleaf forests was similarly reported in other nearby transitional

areas (Strüssmann 2000; Rossi et al. 2023; Dorado-Rodrigues et al. 2025). Interestingly, the absence of endemic species and communities with moderate species richness seems to be a recurrent pattern in amphibians and reptiles inhabiting transitional zones of South America (Miranda et al. 2012; Lantyer Silva et al. 2013; Mesquita et al. 2015).

Many of the amphibian and reptile species in the PSSA are widespread. This pattern was similar for abundant species such as Cuyaba Dwarf Frog and Giant Ameiva, as well as for species with few records (e.g., Black-Spotted Skink, *Copeoglossum nigropunctatum*, and *Dendropsophus elianeae*, no common name). Additionally, we also expanded the known distribution of Tocantins Blackhead (*Apostolepis sanctaeritae*; UFMT R-12844). Until now, Tocantins Blackhead had a distribution linked to the eastern Cerrado (Entiauspe-Neto et al. 2020). Here, we extend the known species range by about 360 km westward of the previously known locality (Nova Xavantina, Mato Grosso). Insufficient sampling, methodological difficulties in collecting fossorial organisms, and taxonomic issues can be
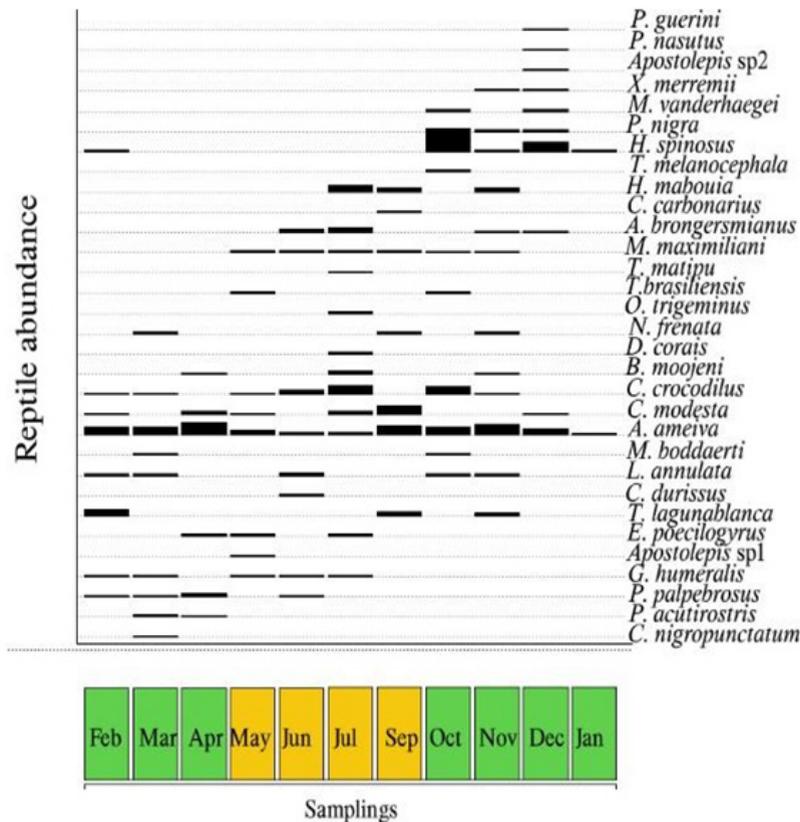
FIGURE 5. Distribution of reptile species in relation to season (rainy season: green bars; dry season: yellow bars) in the Parque Sesc Serra Azul, Rosário Oeste, Mato Grosso, Brazil. Bar thickness is proportional to abundance. Common names appear in Supplemental Information Table S3.

argued as possible reasons for the missing species in the rarefaction curves from Cerrado localities (e.g., Fermiano et al. 2020; Guerra et al. 2022).

Pitfall traps (with and without drift fences) are a widely used sampling method because of their claimed efficiency and ability to detect certain groups (e.g., semi-fossorial snakes; Cechin and Martins 2000; Ribeiro-Júnior et al. 2011). Trap-induced mortality, however, is an issue that needs attention (Edwards and Jones 2014). Despite our mitigation of the impact on trapped animals (e.g., wet cloths to provide moisture and plastic lids suspended by metal rods for pitfalls and dead tree bark over funnels to provide shade), we found nine frogs and six gymnophthalmid lizards dead inside traps (i.e., 0.4% of all amphibians sampled and 2.6% of all lizards sampled). Although to address the effectiveness of different sampling methods is beyond the scope of this study, our findings highlight the need for innovative approaches to study reptile communities in megadiverse regions, given the labor-intensive nature and limited efficiency of pitfall traps. Community-based science (e.g., citizen monitoring) could help

address this gap, as demonstrated by our volunteer initiative, which documented 38 species (11 of which were recorded exclusively by PSSA staff).

Similar to other studies showing temporal segregation in amphibian communities from South America (Prado et al. 2005; Kopp and Eterovick 2006), our results showed that amphibian activity varied throughout the year. A higher abundance of amphibians during the rainy season is expected due their reproductive activity (e.g., Smaniotto and Moreira 2023). Proneness to desiccation has been identified as a key factor structuring amphibian communities in the Chiquitano Dry Forest (Watling and Braga 2015). Furthermore, extreme weather events during the dry season are already affecting anuran populations in the Chiquitano region (Jansen et al. 2009). We therefore speculate that desiccation tolerance gradients among species may play a role in the observed temporal segregation of species, as well as in the amphibian community resemblance of the PSSA to the Chiquitano Dry Forest.

At least for reptiles, water loss is much lower than for amphibians. Our results showed that reptile

species in the PSSA seem to be active during dry and rainy periods. A subtle issue was that imperfect detection could have biased our results for relative abundance. For example, the low abundance (less than five individuals considering both traps and active search data) recorded for many species (n = 21) constrains the assessment of seasonal trends and probably would be a limitation of our sampling methods. Rarefaction curves not reaching asymptote and low abundance values, mainly for snakes, seem to be the rule for reptile inventories in megadiverse areas (e.g., Recoder et al. 2011; Frazão et al. 2020; Ramalho et al. 2022). Our findings supported that the PSSA reptiles have a species pool similar to the eastward portions of Cerrado and Pantanal. In Savannas of central Brazil, there is evidence that habitat mosaics with distinct heterogeneity are crucial factors in structuring reptile communities (Costa et al. 2007).

Our study highlighted the importance of the PSSA in the context of surrounding ecoregions and also demonstrated the singularities of amphibians and reptiles from midwestern Brazil. Future studies should result in increments for the local herpetofauna species list. In addition, this study suggests that areas destined for tourism can help to conserve an essential fraction of the amphibian and reptile species in Brazilian Cerrado, acting as refuges for biodiversity. When tourists and operators exhibit careless behavior, they may risk wildlife and their habitats (e.g., roadkill, disrupting feeding or nesting sites, harmful wildlife interactions). In this sense, best practice management guidelines should be a tool to minimize impacts during wildlife encounters. For example, offering information on the importance of avoiding wildlife handling, keeping a safe minimal distance, and driving carefully, especially at dusk and night. We hope our results highlight the role of studies dedicated to faunal inventories and abundance patterns. Such data are crucial to understanding biodiversity responses to agricultural expansion, increased human-wildlife contact through ecotourism, and ongoing climate changes.

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