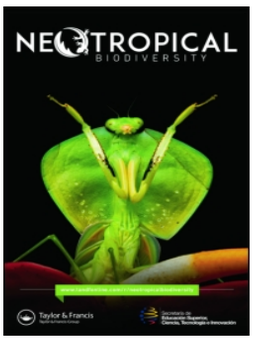

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Structure and regional representativeness of the herpetofauna from Parque Estadual da Serra de Caldas Novas, Cerrado, Central Brazil

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ABSTRACT

Amphibians and reptiles are diversified in the Cerrado biome but have been threatened by habitat loss and fragmentation, as well as lack of understanding of their distribution. Therefore, collection and organization of information about species in natural environments are essential for conservation, especially in Protected areas (PAs) and their adjacent zones. We present information about the composition and structure of the herpetofauna from Parque Estadual da Serra de Caldas Novas (PESCAN) and its representativeness in comparison to other PAs in the Cerrado. Fieldwork was conducted in 12 sampling sites from February 2009 to February 2010, using active search and pitfall traps. We recorded 41 species of amphibians, with greatest richness in sites with open vegetation and water bodies. Reptiles were represented by 32 species, with the greatest species richness in cerrado open environments. Both amphibian and reptile communities were more similar to those from geographically closer PAs and located in the central region of the Cerrado (State of Goiás and Distrito Federal). The PESCAN holds 24.85% and 17.98% of amphibians and reptiles species occurring in Cerrado PAs, respectivelly. This large representativeness and the high number of endemisms (18 amphibians and 7 reptiles) emphasize the importance of the PESCAN, together with other PAs, for the maintenance of regional biodiversity. In addition, we also encourage researches evaluating amphibian and reptile communities outside PAs, such as legal reserves, and we suggest new approaches to study the biodiversity of protected areas.

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Amphibians; conservation; inventory; PESCAN; protected areas; reptiles

Introduction

Situated in the central region in comparison to the other Brazilian biomes, the Cerrado is the largest South American savanna [1,2]. The biome consists of a mosaic of different vegetation types, which is constituted by grassland, forests and savannas [3]. It is considered a global biodiversity hotspot due to its high number of endemic species and considerable anthropogenic threats [4,5]. Some of the challenges for species conservation in the Cerrado biome are in demonstrating the importance of its high habitat diversity [6], in which the fauna differs substantially in composition and species richness [7–10]. Differences in species composition between areas can be favored by the position of the Cerrado and their transition zones with other biomes, such as Amazon, Atlantic Forest, Caatinga, and Chaco [9], where species may be restricted to environmental conditions imposed by the different vegetation types [8–10]. Thus, it is important to evaluate the species distribution, especially the herpetofauna, which is a relatively poorly studied group (but see [11,12]) and extremely threatened [13,14].

Amphibians and reptiles are important components in the global biodiversity and are key groups in the food chain, acting as carnivores, herbivores (tadpoles), predators, and preys, besides connecting aquatic and terrestrial ecosystems [15]. For the Cerrado, the amphibian and reptile richness is considered elevated due to the biome's geographic extension and its physiognomies heterogeneity [9,16,17]. However, the richness is underestimated, since new species of amphibians (e.g. [18,19]) and reptiles (e.g. [20,21]) have been described periodically. The difference in species composition among Cerrado physiognomies has been reported for amphibians [22,23] and reptiles [8]. Both groups show low species overlap between open and forest environments [8,23], but for anurans, the distributions are frequently associated with the presence of water bodies and/or humid environments [23]. Thus, comparing communities inhabiting distinct vegetal formations and different localities in the Cerrado biome can enhance the knowledge about species and help to improve conservation strategies, aiming the preservation of species.

PAs are effective strategies for long-term biodiversity conservation *in situ*, especially for endangered species, besides maintaining the genetic variability of species [24,25]. Such areas, together with adjacent forest remnants, act as habitat corridors and stepping

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stones, forming a heterogeneous landscape that directly affects species dispersion [24,26]. However, PAs cover only 9.6% of the Cerrado biome area [27] and few of those areas have been inventoried at the biodiversity level. The data collection and organization in natural environments, especially in PAs, are essential for the advancement of conservation strategies, once the lack of knowledge about the composition and distribution of species, in general, might be a source of mistakes in conservation planning [28].

In order to contribute to the knowledge about biodiversity in protected areas (PAs) of the Cerrado biome, the aim of this study was to survey the anuran and reptile species from Parque Estadual da Serra de Caldas Novas (PESCAN), Central Brazil, and its surrounding area. Furthermore, we compared the regional representativeness of the PESCAN with other PAs in the Cerrado biome.

Materials and methods

Study area

The Parque Estadual da Serra de Caldas Novas (PESCAN; 17°46'10,31"S; 48°39'30,37"W) is located in the southwestern state of Goiás, in the municipalities of Caldas Novas and Rio Quente, at an average elevation of 1000 m a.s.l [29] (Figure 1). The PESCAN was the first PA created in Goiás [29]. It covers an area of 120 km^2 and consists of different vegetation types, predominantly cerrado *sensu stricto*, a typical savanna

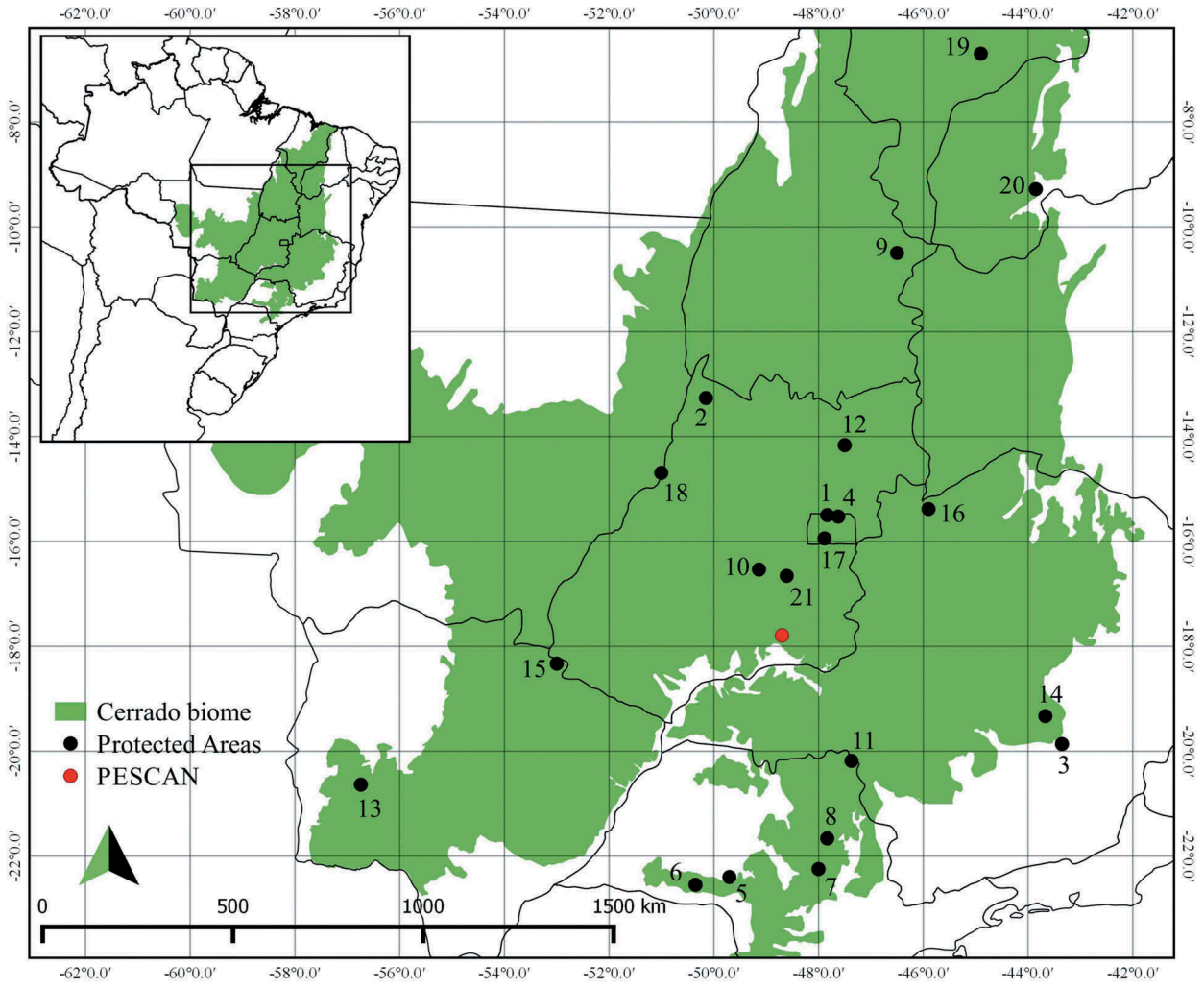

Figure 1. Geographical location of the Parque Estadual da Serra de Caldas Novas (PESCAN; red circle) and other protected areas (black circles) in the Cerrado biome. 1. Área de Proteção Ambiental Cafuringa (APAC); 2. Área de Proteção Ambiental Meandros do Araguaia (APAMA); 3. Estação Ambiental de Peti (EAP); 4. Estação Ecológica Águas Emendadas (EEAE); 5. Estação Ecológica dos Caetetus (EEC); 6. Estação Ecológica de Assis/Floresta Estadual de Assis (EEA/FEA); 7. Estação Ecológica de Itirapina (EEI); 8. Estação Ecológica de Jataí (EEJ); 9. Estação Ecológica Serra Geral do Tocantins (EESGT); 10. Floresta Nacional de Silvânia (FNS); 11. Parque Estadual Furnas de Bom Jesus (PEFBJ); 12. Parque Nacional Chapada dos Veadeiros (PNCV); 13. Parque Nacional da Serra da Bodoquena (PNSB); 14. Parque Nacional da Serra do Cipó (PNSC); 15. Parque Nacional das Emas (PNE); 16. Parque Nacional Grande Sertão Veredas (PNGSV); 17. Reserva Ecológica do IBGE (REIBGE); 18. Reserva Extrativista Lago do Cedro (RELC); 19. Parque Estadual do Mirador (PEM); 20. Parque Nacional da Serra das Confusões (PNCF); 21. Parque Estadual Altamiro de Moura Pacheco (PEAMP).

vegetation with a variable diversity of trees and shrubs. Other vegetation types include forests and grassland *lato sensu* formations [3].

Sampling methods

Fieldwork was conducted in February (five days), March (11 days), April (five days), June (six days), August (five days), October (three days), and November 2009 (three days) and in February 2010 (four days), totaling 42 sampling days. We sampled 12 sites covered by different vegetation types, including cerrado grasslands (*campo limpo, campo sujo* and *campo rupestre*), savannas (cerrado *sensu stricto* and palm grove marsh [*vereda*]), forests (dry forest and gallery forest), and aquatic environments, as temporary and permanent streams in natural environments, and permanent ponds in open areas (Table 1). The Cerrado vegetation types were described according to Ribeiro & Walter [3].

We consider as primary data a combination of direct and indirect sampling methods: pitfall traps [30] and visual and auditory active search for limited time [31]. We selected four sites to set up pitfall traps (Table 1). Each site was subdivided in three substations to set up the pitfall traps, where each contained four plastic buckets of 60 l buried in the soil, arranged in a "Y" form and interconnected by a barrier of black plastic sheeting of 50 cm high and 5m long. The pitfall traps were reviewed daily, in the mornings, during every sampling day. Total sampling effort with this method was approximately 48,384 h with open buckets. Active search for a limited time was carried out through visual and acoustic detection of species along transects of 1 km at each sampled site during the morning (09:00–12:00 am), the afternoon (3:00–6:00 pm), and at night (7:00–10:00 pm). The searches lasted for one hour and were conducted by two researchers slowly moving along the trail and actively searching for reptiles and amphibians in microhabitats which served as shelters and vocalization sites (Table 1). Total sampling effort with this method was approximately 126 h of search. We also used secondary data, in which we considered all individuals registered through occasional encounters or collected by third parties. We considered as occasional encounters the individuals found outside the established sampling sites, usually during circulation among sites (e.g. on the roads). The individuals collected by third parties were those found by other fauna team members who were conducting a study in PESCAN at the same sampling period, but not necessarily herpetologists. Bibliographical searches were conducted to know if there was any species from PESCAN that we have not sampled.

Voucher amphibians were anesthetized and killed with 5% xylocaine, fixed in 10% formalin solution and preserved in 70% alcohol. Reptiles were anesthetized and killed in ether chambers and subjected to the same fixation procedure as described for amphibians. The specimens were deposited in the herpetological collection of the Centro de Estudos e Pesquisas Biológicas (CEPB) of the Pontifícia Universidade Católica de Goiás (PUCGO) and the herpetological collection of the Universidade Federal de Goiás (ZUFG) (Appendix 1).

Data analysis

To estimate anuran and reptile species richness, we performed individual-based accumulation curves [32] with 1000 randomizations of an abundance matrix where rows correspond to species and columns to sites. The data matrix was composed of species registered through pitfall traps and active search in the sampled sites (primary data). We used the species richness estimator Jackknife 1 to obtain the expected richness of anurans and reptiles. Both analyses were performed in the EstimateS software v. 9.1.0 [33].

To characterize the amphibian and reptile communities of the PESCAN (including primary and secondary data) and to perform a conservation assessment, we compared the species composition with that of 21 other PAs (19 for amphibians and 12 for reptiles), located in different regions and with different phytophysiognomies of the Cerrado (Figure 1 and Table 2). Most PAs are governmental and are registered in the National System of Conservation Units (*Sistema Nacional* de *Unidades* de *Conservação* [SNUC]) [58] or

Table 1. Sampled sites in the Parque Estadual da Serra de Caldas Novas, Goiás, Brazil, from February 2009 to February 2010.

	Geographical coordinates Datum WGS84		
Method	S	W	Environment
Active search/Pitfall	17°46′11.06″	48°39′31.69″	Dry forest
Active search/Pitfall	17°46′36.62″	48°41′03.09″	Cerrado grassland (*campo sujo*)
Active search/Pitfall	17°46′52.03″	48°41′15.90″	Cerrado *sensu stricto*
Active search/Pitfall	17°46′51.70″	48°44′34.87″	Cerrado grassland (*campo limpo*)
Active search	17°47′12.30″	48°39′57.95″	Cerrado grassland (*campo rupestre*)
Active search	17°46′14.98″	48°39′22.31″	Gallery forest
Active search	17°46′06.04″	48°39′49.13″	Gallery forest
Active search	17°47′38.92″	48°39′44.74″	Palm grove marsh (*vereda*)
Reproductive site	17°44′36.06″	48°41′19.21″	Temporary stream in cerrado *sensu stricto*
Reproductive site	17°46′29.27″	48°44′09.16″	Permanente stream in *campo limpo*
Reproductive site	17°50′47.04″	48°41′46.33″	Temporary stream in *campo rupestre*
Reproductive site	17°52′10.01″	48°41′26.38″	Permanent pond in open area

in State systems, being 18 inserted in the category of integral protection (including the PESCAN) and four of sustainability use. We attribute the same importance to all PAs and the protection category types were not included in the comparisons and statistical analyses. To avoid taxonomic issues, we excluded species mentioned in the original manuscripts as undetermined ("cf.", "gr." and "aff.") or without species identification ("sp."). The comparison between assemblages was performed using the Sørensen dissimilarity (D_{sor}) index [59]. To generate the dissimilarity dendrogram, we used the Unweighted Pair Group Method with Arithmetic mean (UPGMA) and the Cophenetic Correlation Coefficient (CCC) was calculated to assess if the dendrogram adequately represented the original data matrix [60]. We also tested the effects of distance on the dissimilarity in species composition. For this, the distance matrix of species composition generated by the Sørensen dissimilarity index was correlated with the geographic distance matrix (Euclidian distance between geographic coordinates) between PAs using a Mantel test, with Pearson coefficient as correlation measure and 1000 Monte Carlo permutations. The results were generated with significance level of 5% without adjustment method for *P* correction. These analyses were performed using the *vegan* package [61] in the R software [62].

The conservation status of each species was evaluated based on data available from the Red List of Threatened Species of the International Union for Conservation of Nature [63] and from the list of Brazilian threatened fauna [64]. Information about the degree of association between species and the Cerrado biome and their distribution patterns were obtained from data available in Valdujo et al. [9] and Frost [65] for amphibians and Nogueira et al. [17] and Uetz & Hošek [66] for reptiles.

Results

Anurans

We recorded 41 anuran species from primary and secondary data, distributed into 18 genera and 8 families (Table 3). The amphibian family with the greatest richness was Hylidae (16 species), followed by Leptodactylidae (13 species), Bufonidae and Microhylidae (three species each), and Odontophrynidae and Phyllomedusidae (two species each). Dendrobatidae and Craugastoridae were represented by only one species each. We registered eight species from secondary data (species not sampled using pitfall traps or active search), where six, *Rhinella diptycha, Ololygon centralis, Scinax fuscomarginatus, Leptodactylus podicipinus, Pseudopaludicola mystacalis*,

Table 2. Reference and species richness of amphibians and reptiles of protected areas in the Cerrado biome. Vegetation: AC = Arboreal Caatinga, CG = Cerrado grassland, GF = Gallery forest, SF = Seasonal forest, SS = Cerrado *sensu stricto*, VE = Palm grove marsh (*vereda*).

Protected Area	Abbreviation	Category	Vegetation	Amphibians	Reptiles	References
Área de Proteção Ambiental Cafuringa	APAC	SU	CG, GF, SF, SS, VE	35	48	Brandão et al. 2006 [34]
Área de Proteção Ambiental Meandros do Araguaia	APAMA	SU	SF, SS, VE	-	28	Santos et al. 2008 [35]
Estação Ambiental de Peti	EAP	IP	CG, SF, SS, GF	33	31	Bertoluci et al. 2009 [36]
Estação Ecológica Águas Emendadas	EEAE	IP	CG, GF, SF, SS, VE	27	50	Brandão & Araújo 1998 [37]
Estação Ecológica de Assis/ Floresta Estadual de Assis	EEA/FEA	IP	CG, GF, SS, SF	27	53	Ribeiro-Júnior & Bertoluci 2009 [38]; Araujo & Almeida-Santos 2011 [39]
Estação Ecológica de Itirapina	EEI	IP	CG, GF, SF, SS	28	-	Brasileiro et al. 2005 [40]
Estação Ecológica de Jataí	EEJ	IP	CG, GF, SF, SS	21	-	Prado et al. 2009 [41]
Estação Ecológica dos Caetetus	EEC	IP	SS, GF, SF	34	-	Brassaloti et al. 2010 [42]
Estação Ecológica Serra Geral do Tocantins	EESGT	IP	CG, GF, SS, VE	36	45	Valdujo et al. 2011 [43], Recoder et al. 2011 [44]
Floresta Nacional de Silvânia	FNS	SU	GF, SF, SS	33	32	Morais et al. 2012 [45]
Parque Estadual Altamiro de Moura Pacheco	PEAMP	IP	GF, SF, VE	35	29	Ramalho et al. 2018 [46]
Parque Estadual da Serra de Caldas Novas	PESCAN	IP	CG, GF, SF, SS, VE	41	32	This work.
Parque Estadual do Mirador	PEM	IP	CG, GF, VE	31	-	Andrade et al. 2017 [47]
Parque Estadual Furnas de Bom Jesus	PEFBJ	IP	CG, GF, SF, SS	24	-	Araujo et al. 2009 [48]
Parque Nacional Chapada dos Veadeiros	PNCV	IP	CG, GF, SF, SS, VE	54	-	Santoro & Brandão 2014 [49]
Parque Nacional da Serra da Bodoquena	PNSB	IP	CG, GF, SF	38	-	Uetanabaro et al. 2007 [50]
Parque Nacional da Serra das Confusões	PNCF	IP	AC, SF, VE	19	47	Vechio et al. 2016 [51]
Parque Nacional da Serra do Cipó	PNSC	IP	CG, GF, SF, SS, VE	43	-	Eterovick & Sazima, 2004 [52]
Parque Nacional das Emas	PNE	IP	CG, GF, SF, SS, VE	25	87	Valdujo et al. 2009 [53], Kopp et al. 2010 [54]
Parque Nacional Grande Sertão Veredas	PNGSV	IP	CG, GF, SF, SS, VE	-	50	Recorder & Nogueira 2007 [55]
Reserva Ecológica do IBGE	REIBGE	IP	CG, GF, SF, SS, VE	38	63	Colli et al. 2011 [56]
Reserva Extrativista Lago do Cedro	RELC	SU	CG, GF, SF, SS, VE	36	-	Melo et al. 2013 [57]

Table 3. List of amphibian species sampled in the Parque Estadual da Serra de Caldas Novas and their abundance, habitats of occurrence, sampling method, and distribution pattern in the Cerrado biome. N = Abundance; Habitat: Site number in the Table 1; Method: AS = Active search, OR = Occasional record, BL = Bibliography, PF = Pitfall; Distribution: END = Endemic, GEN = Generalist, AM = Amazonian, CE = Cerrado, DA = Open domains, MA = Atlantic Forest . Underlined numbers indicate sites with greater abundance.

Family/Species	*N*	Habitat	Method	Distribution
Bufonidae				
Rhinella diptycha (Cope, 1862)	-	-	OR	GEN
Rhinella ocellata (Günther, 1858)	4	8	AS	END
Rhinella rubescens (Lutz, 1925)	2	7	AS	END
Craugastoridae				
Barycholos ternetzi (Miranda-Ribeiro, 1937)	80	1, 9, 7, 8, 12	AS, PF	END
Dendrobatidae				
Ameerega flavopicta (Lutz, 1925)	5	5, 8, 11, 12	OR, AS	END
Hylidae				
Boana albopunctata (Spix, 1824)	58	5, 6, 8, 10, 12	AS	GEN
Boana goiana (Lutz, 1968)	79	6	AS	END
Boana lundii (Burmeister, 1856)	45	6, 7, 10, 12	AS	END
Boana paranaiba Carvalho, Giaretta, & Facure, 2010	23	8, 10	AS	END
Boana raniceps Cope, 1862	5	12	AS	GEN
Bokermannohyla sapiranga Brandão, Magalhães, Garda, Campos, Sebben, & Maciel, 2012	15	7, 8, 10	AS	END
Dendropsophus cruzi (Pombal & Bastos, 1998)	25	8, 12	AS	END
Dendropsophus minutus (Peters, 1872)	186	8, 10, 11, 12	AS	GEN
Dendropsophus nanus (Boulenger, 1889)	31	10, 12	AS	GEN
Dendropsophus rubicundulus (Reinhardt & Lütken, 1862)	37	12	AS	END
Dendropsophus melanargyreus (Cope, 1887)	3	5	AS	GEN
Pseudis bolbodactyla Lutz, 1925	170	12	AS	MA, CE
Ololygon centralis (Pombal & Bastos, 1996)	-	-	OR	END
Scinax fuscomarginatus (Lutz, 1925)	-	-	OR	GEN
Scinax fuscovarius (Lutz, 1925)	32	1, 3, 5, 7, 8, 11	OR, AS	GEN
Trachycephalus typhonius (Linnaeus, 1758)	3	11	AS	GEN
Leptodactylidae				
Adenomera sp.	27	1, 5, 6, 8, 9	AS, PF	-
Leptodactylus fuscus (Schneider, 1799)	32	5, 8, 10, 11, 12	AS	AM, CE
Leptodactylus labyrinthicus (Spix, 1824)	18	5, 8, 10, 12	OR, AS	GEN
Leptodactylus latrans (Steffen, 1815)	6	8, 10, 12	AS	GEN
Leptodactylus podicipinus (Cope, 1862)	-	-	OR	GEN
Leptodactylus gr. melanonotus	1	11	AS	-
Leptodactylus syphax Bokermann, 1969	23	4, 5, 6, 7, 10, 11	OR, AS, PF	DA
Physalaemus centralis Bokermann, 1962	1	12	AS	END
Physalaemus cuvieri Fitzinger, 1826	93	1, 4, 5, 8, 10, 11, 12	OR, AS, PF	GEN
Physalaemus nattereri (Steindachner, 1863)	3	2, 4, 10	OR, AS	GEN
Pseudopaludicola facureae Andrade & Carvalho, 2013	57	5, 6, 10, 11	AS	END
Pseudopaludicola mystacalis (Cope, 1887)	-	-	OR	GEN
Pseudopaludicola sp.	68	5, 7, 10, 11	AS	-
Microhylidae				
Chiasmocleis albopunctata (Boettger, 1885)	-	-	OR	END
Dermatonotus muelleri (Boettger, 1885)	1	6	AS	DA
Elachistocleis cesarii (Miranda-Ribeiro, 1920)	2	11	AS	GEN
Odontophrynidae				
Proceratophrys goyana (Miranda-Ribeiro, 1937)	8	6	AS	END
Proceratophrys vielliardi Martins & Giaretta, 2011	-	-	BL	END
Phyllomedusidae				
Pithecopus hypochondrialis (Daudin, 1800)	2	12	AS	END
Pithecopus oreades (Brandão, 2002)	-	-	BL	END

and *Chiasmocleis albopunctata*, were occasionally registered outside the sampled sites; and two species, *Proceratophrys vielliardi* and *Pithecopus oreades*, are from bibliographic search [67,68].

We recorded 1145 anuran specimens in the sampled sites, distributed into 33 species, 17 genera, and 8 families. The species accumulation curves presented stabilization tendencies, although such an asymptote had not been reached. The observed species richness represented 79% of the richness estimated by Jackknife 1 (42 ± 3.08) (Figure 2). We recorded 33 species through active searches during daytime and night-time, with 25 species exclusively recorded by this method. Four species were collected by pitfall traps. The most abundant amphibian species in the study area were *Dendropsophus minutus, Physalaemus cuvieri*, and *Pseudis bolbodactyla*, representing together 39.21% of all sampled specimens. The sites with the greatest anuran species richness were PT12 (permanent pond in open area; 16 species), PT8 (*vereda*; 14 species), and PT10 (permanent stream in *campo limpo*; 14 species), while the sites with the smallest species richness were PT2 (*campo sujo*), PT3 (cerrado *sensu stricto*), and PT9 (temporary stream in cerrado *sensu stricto*), all with one species (Table 3).

Cluster analysis based on the occurrence of 165 species in 20 PAs, including PESCAN, resulted in the formation of two main groups (CCC = 0.90): (1) a group of five PAs in the State of São Paulo, located within the Cerrado

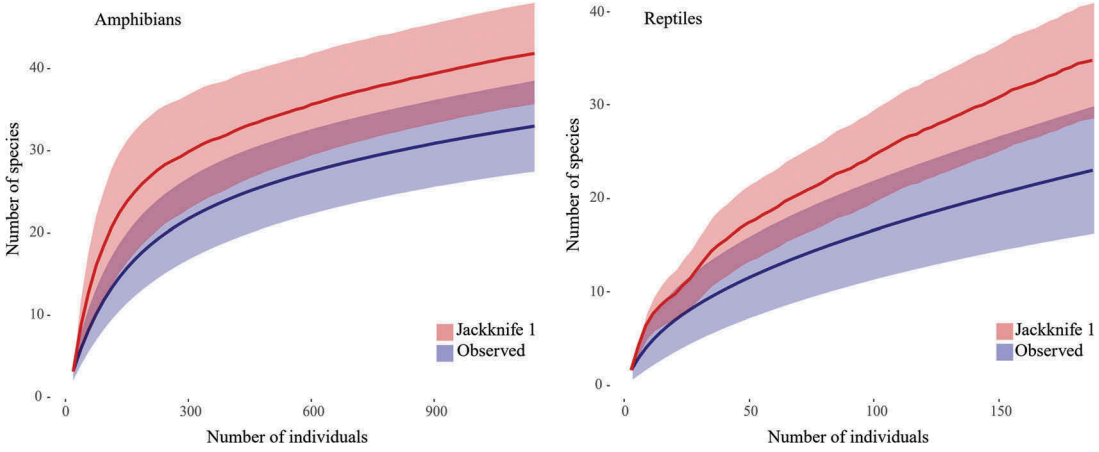

Figure 2. Observed and estimated species accumulation curves for amphibians and reptiles recorded in the Parque Estadual da Serra de Caldas Novas, Goiás, Brazil.

biome and transition area with the Atlantic Forest biome; and (2) a group of five PAs in the State of Goiás, three PAs in the Distrito Federal and one PA in the State of Tocantins, located in the core region of the Cerrado biome (Figure 3). We obtained a positive correlation between distance and dissimilarity in amphibian composition (R^2 = 0.68; p < 0.01) between PAs. The smallest dissimilarities to PESCAN were obtained for Floresta Nacional de Silvânia (FNS) (D_{Sor} = 0.27), Parque Estadual Altamiro de Moura Pacheco (PEAMP) (D_{Sor} = 0.28), Estação Ecológica da Serra Geral do Tocantins (EESGT) (D_{Sor} = 0.33) and Reserva Extrativista Lago do Cedro (RELC) (D_{Sor} = 0.41). The highest dissimilarities were obtained for PAs located in the Caatinga and Atlantic Forest transition areas, such as the Parque Nacional da Serra das Confusões (PNCF) (D_{Sor} = 0.85), Estação Ecológica de Peti (EEP) (D_{Sor} = 0.78), Parque Nacional da Serra do Cipó (PNSC) (D_{Sor} = 0.69) and the Parque Estadual do Mirador (PEM) (D_{Sor} = 0.64).

Reptiles

We recorded 32 reptile species from primary and secondary data, distributed into 28 genera, 16 families, and 3 orders (Table 4). The families of Squamate with the greatest species richness were Dipsadidae (six species), followed by Gymnophthalmidae (five species), Boidae, Teiidae, and Viperidae (three species each), and Mabuyidae (two species). Anguidae, Gekkonidae, Dactyloidae, Polychrotidae, Tropiduridae, Amphisbaenidae, Typhlopidae, and Colubridae were represented by one species each. The families Chelidae and Alligatoridae, from the Testudines and Crocodylia orders, respectively, were represented by one species each. Nine species, *Paleosuchus palpebrosus, Ophiodes* aff. *striatus, Hemidactylus mabouia, Amphisbaena alba, Amerotyphlops brongersmianus, Eunectes murinus, Chironius flavolineatus, Oxyrhopus rhombifer* and *Sibynomorphus mikanii*, were registered occasionally outside the sampled sites.

We recorded 188 reptile specimens in the sampled sites, distributed into 23 species, 20 genera, 10 families, and 2 orders. The accumulation curves for reptile species did not present a stabilization tendency, where the observed species richness represented 66% of the richness estimated by the Jackknife 1 (35 ± 3.10) (Figure 2). Reptile sampling was more effective using active

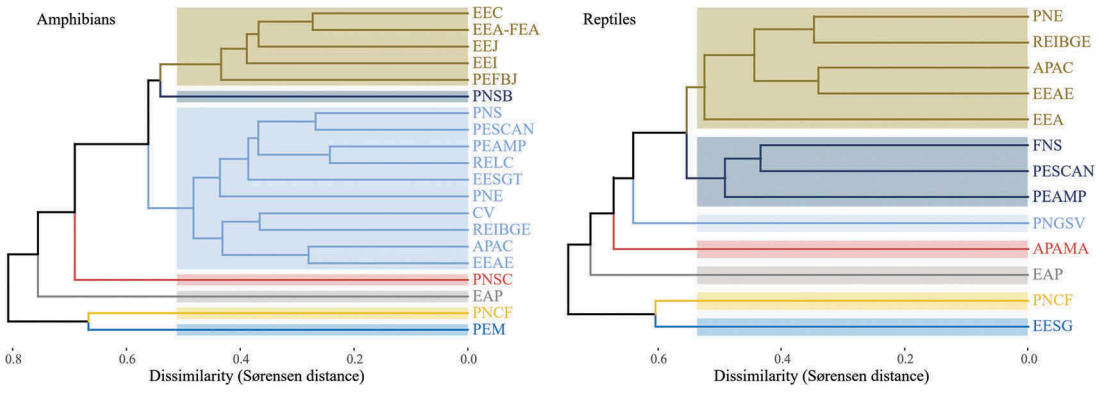

Figure 3. Dissimilarity dendrogram generated by UPGMA from amphibians and reptiles composition recorded in the Cerrado protected areas. Each of the different colors represents groups (or single) of protected areas with similar species composition. Abbreviations of protected areas are found in Table 2.

Table 4. List of reptile species sampled in the Parque Estadual da Serra de Caldas Novas and their abundance, habitats of occurrence, sampling method, and distribution pattern in the Cerrado biome. N = Abundance; Habitat: Site number in the Table 1; Method: AS = Active search, OR = Occasional record, PF = Pitfall; Distribution: END = Endemic, GEN = Generalist, AM = Amazonian, CE = Cerrado. Underlined numbers indicate sites with greater abundance.

Order/Family/Species	*N*	Habitat	Method	Distribution
Testudines				
Chelidae				
Mesoclemmys vanderhaegei (Bour, 1973)	1	12	AS	GEN
Crocodylia				
Alligatoridae				
Paleosuchus palpebrosus (Cuvier, 1807)	-	-	OR	GEN
Squamata				
Sauria				
Gekkonidae				
Hemidactylus mabouia (Moreau de Jonnès, 1818)	-	-	OR	GEN
Mabuyidae				
Copeoglossum nigropunctatum (Spix, 1825)	8	1, 6, 8, 9	AS	CE, AM
Notomabuya frenata (Cope, 1862)	1	1	AS	GEN
Dactyloidae				
Norops brasiliensis (Vanzolini & Williams, 1970)	12	3, 4	AS, PF	GEN
Polychrotidae				
Polychrus acutirostris Spix, 1825	1	3	AS	GEN
Tropiduridae				
Tropidurus itambere Rodrigues, 1987	49	1, 2, 3, 4, 5, 7, 8, 10, 11	AS, OR, PF	END
Anguidae				
Ophiodes aff. *striatus*	-	-	OR	GEN
Gymnophthalmidae				
Colobosaura modesta (Reinhardt & Luetken, 1862)	3	4	AS	AM, CE
Cercosaura ocellata Wagler, 1830	1	4	PF	GEN
Cercosaura schreibersii Wiegmann, 1834	5	4, 5, 7	AS	GEN
Micrablepharus atticolus Rodrigues, 1996	5	2, 3	AS, PF	END
Micrablepharus maximiliani (Reinhardt & Luetken, 1862)	13	2, 4	AS, PF	GEN
Teiidae				
Ameiva ameiva (Linnaeus, 1758)	23	1, 2, 3, 4, 6, 7, 10	AS, OR, PF	GEN
Ameivula gr. *ocellifera*	53	1, 3, 4, 5, 7, 8, 9, 10	AS, OR, PF	GEN
Salvator merianae (Duméril & Bibron, 1839)	2	1, 6	AS, OR	GEN
Amphisbaenia				
Amphisbaenidae				
Amphisbaena alba Linnaeus, 1758	-	-	OR	GEN
Serpentes				
Typhlopidae				
Amerotyphlops brongersmianus (Vanzolini, 1976)	-	-	OR	GEN
Boidae				
Boa constrictor (Stull, 1932)	1	8	AS	GEN
Epicrates crassus Cope, 1862	1	3	AS	END
Eunectes murinus (Linnaeus, 1758)	-	-	OR	GEN
Colubridae				
Chironius flavolineatus (Jan, 1863)	-	-	OR	END
Dipsadidae				
Erythrolamprus almadensis (Wagler in Spix, 1824)	1	10	AS	GEN
Oxyrhopus rhombifer Duméril, Bibron e Duméril, 1854	-	-	OR	GEN
Oxyrhopus trigeminus Duméril, Bibron & Duméril, 1854	2	9	AS, OR	GEN
Philodryas olfersii (Liechtenstein, 1823)	1	1	AS	GEN
Rhachidelus brazili Boulenger, 1908	1	3	AS	END
Sibynomorphus mikanii (Schlegel, 1837)	-	-	OR	GEN
Viperidae				
Bothrops pauloensis Amaral, 1925	2	3, 5	AS	END
Bothrops moojeni Hoge, 1966	1	6	AS	END
Crotalus durissus Amaral, 1926	1	2	AS	GEN

search method (22 species), with 14 species recorded exclusively by this method. Seven species were collected by pitfall traps, and one was recorded exclusively by this method. The most abundant reptile species were *Ameivula* gr. *ocellifera, Tropidurus itambere*, and *Ameiva ameiva*, representing together 71.02% of all lizards and 66.49% of all reptiles. All snake species occurred in low abundance. The sites with the greatest species richness were PT3 (cerrado *sensu stricto*; nine species), PT4 (*campo limpo*; eight species), and PT1 (dry forest; seven species). Only one species was found in the sites PT11 (rocky outcrop) and PT12 (permanent pond) (Table 4).

Cluster analysis based on the occurrence of 178 species of 13 PAs, including PESCAN, indicated the formation of two main clusters (CCC = 0.86) from nearby locations in central Cerrado: (1) a group of three PAs in the State of Goiás; and (2) a group of four PAs in the Distrito Federal and one PA in the State of São Paulo. The remaining PAs are located in the marginal portions and transition areas between the Cerrado and other biomes (Figure 3). We obtained a positive correlation between distance and dissimilarity in the reptile composition between PAs (Mantel test, $R^2 = 0.64$; $p = 0.01$). The smallest dissimilarities to PESCAN were obtained for Floresta

Nacional de Silvânia (FNS) (D_{Sor} = 0.43), Área de Proteção Ambiental Cafuringa (APAC) (D_{Sor} = 0.45), Parque Estadual Altamiro de Moura Pacheco (PEAMP) (D_{Sor} = 0.49) and Estação Ecológica Águas Emendadas (EEAE) (D_{Sor} = 0.50). The highest dissimilarities were related to PAs located in the marginal regions of the Cerrado biome, such as Parque Nacional da Serra das Confusões (PNCF) (D_{Sor} = 0.76) and Estação Ambiental de Peti (EAP) (D_{Sor} = 0.75).

Discussion

Amphibians

The anuran species richness (41 species from PESCAN and surrounding areas) is elevated in comparison to other studied PAs (Table 2) and represents 19.62% of the species recorded for the Cerrado biome [9]. The species composition follows the known pattern for the Cerrado, with a predominance of families Hylidae and Leptodactylidae [9,63–65]. Despite the tendency toward stabilization of the species accumulation curves, the regional species pool was not fully reached from primary data, thus complemented with secondary data (occasional and third-part y encounters and bibliographies). This may have occurred because anurans have seasonal reproduction [66,67] and the sampling time series in this study did not cover the entire rainy season. Mostly anuran records were obtained through active search method, which allowed a good characterization of the communities since only four species were collected by pitfalls. In this case, we did not observe a complementarity between the methods.

We found the greatest richness in sites with open or anthropogenic vegetation with water bodies (e.g. permanent pond in open area, *vereda* and permanent stream in *campo limpo*), while the lowest richness was associated to open and dry environments (e.g. *campo sujo*, cerrado *sensu stricto*) and temporary lotic water bodies. Wetlands, lentic or lotic water bodies, are responsible for a considerable part of the anuran communities structure in the Cerrado biome, mainly when they are associated with a heterogeneous vegetation structure and intermediate hydroperiods [23,68,69]. The restriction of some species (e.g. *Rhinella rubescens, Boana goiana* and *Proceratophrys goyana*) to forest environments is evidence of spatial segregation in anuran distribution known in this biome [22,23,70]. However, the connectivity among the entire environmental complex of the PESCAN, including natural remnants in the buffer zone, is essential to maintain species flow and avoid local extinction by isolation [13].

PAs in the Cerrado accommodate a total of 71.29% of the amphibian species known in this biome [9] and the PESCAN holds 24.85% of this richness. Overall, closest PAs showed similar species compositions, sharing species with restricted distribution and overlap in their biogeographic history. Nearest regions have more similar vegetation types and weather conditions, and most amphibian species are restricted to habitats with characteristics in accordance with their adaptations and life history [9,10]. However, even nearby PAs in the State of Goiás have divergences in the predominant vegetation typology, such as the seasonal forest vegetation in PEAMP [63] and the combination of forest and savanna vegetation in FNS [71]. Due to these intrinsic characteristic many PAs also have species with few or no records in other regions (e.g. *Rhinella sebbeni* in PEAMP [63], *Allobates goianus* and *Ischnocnema penaxavantinho* in FNS [72,73], and *P. vielliardi* in PESCAN), indicating the importance of each area for maintaining natural populations and genetic diversity [24,74].

Eighteen anuran species (43.90%) found in the PESCAN are endemic of the Cerrado [9]. This high endemism shows the importance of the PA on a local scale for the conservation of the Cerrado's biodiversity. Thus, in a combined way, PAs are able to maintain fauna and flora representatives of a domain, which is extremely important when taking into account the high degree of degradation of the Cerrado [75]. None of the amphibian species recorded are included in categories of extinction threat [55,56]. However, the lack of information about some species can be an immeasurable threat. Species such as *Elachistocleis cesarii, Bokermannohyla sapiranga, Boana paranaiba* and *Pseudopaludicola facureae*, have their conservation status not assessed yet and *P. vielliardi* and *P. oreades* are data deficient [55]. Thus, knowing and understanding the occurrence sites and distribution patterns of these and other species is the first step toward understanding the importance of the mechanisms by which these communities are assembled and mainly the factors that threaten and limit their occurrences.

Reptiles

The reptile species richness (32 species from PESCAN and surrounding areas) is similar to the richness reported in other studies conducted in the Cerrado (Table 2) and represents 11.34% of the species known of the biome [16,17]. This richness follows the pattern found in other Cerrado areas [70,72,76], where richness is heterogeneous between areas and may range from 15 to more than 70 species [11]. Species accumulation curve of reptiles showed no tendency toward asymptote, which was also found in other studies [72,76,77]. Despite our significant effort and complementary characteristics of the sampling methods used, many reptiles, especially snakes and amphisbaenians, have fossorial

habits, cryptic behavior, and color patterns that hinder visual encounter. Thus, to adequately evaluate reptile communities, long-term studies with larger sampling efforts are needed [78,79], employing specific sampling methods (e.g. traps with larger containers, artificial shelters, funnel traps) which are more resource- and time-intensive.

The most abundant reptile species in the study area are the most resilient lizards, numerous locally and, less cryptic lizards, and those foraging actively during the day, such as *A.* gr. *ocellifera, A. ameiva*, and *T. itambere*. These species were common in most study sites, mainly in open environments. The frequent record of these species on roads, forest edges, near or within human settlements, and grazing environments surrounding the PESCAN reflects their generalist habits. By contrast, some species were found exclusively in open (e.g. *Norops brasiliensis, Micrablepharus atticolus*, and *Micrablepharus maximiliani*) or forest environments (e.g. *Notomabuya frenata, Salvator merianae*, and *Bothrops moojeni*). These findings can indicate the limitation that open and forest environments represent for the distribution of reptiles [8] and should be better explored in future studies.

The reptile fauna in the PAs of the Cerrado represents 57.45% of all species known for the biome [16,17] and the PESCAN holds 17.98% of this richness. Reptiles also showed cluster formations for species composition in geographically closer PAs, inserted in the State of Goiás and Distrito Federal. The remaining PAs, located in marginal regions near domains such as the Amazon and the Atlantic Forest, diverged from this cluster. This dissimilarity relationship with increasing distance indicates the influence of regional evolutionary processes on species composition. According to Nogueira et al. [8], despite the importance of the habitat type in the local distribution of species (open and forest habitats as barriers), variations in richness and composition throughout the Cerrado seem to be more related to historical biogeographic factors than to local factors (e.g. habitat diversity and variations in topography). These biogeographic factors have also been associated with the effect of speciation by vicariance on a great part of the Cerrado and in the Neotropical biodiversity, resulting in high endemism rates for diverse fauna groups with limited dispersal ability [17].

The reptile communities of the PESCAN includes seven endemic species (21.88%) and some "uncommon" species that occur in few PAs, as the snakes *Bothrops pauloensis, Erythrolamprus almadensis, Rhachidelus brazili*, and *A. brongersmianus* and the chelonian *Mesoclemmys vanderhaegei*. These results reinforces that studies with significant sampling efforts, both in PAs and in unprotected forest fragments, need to be performed to better understand the population status of most snake species [14,80]. Regarding the chelonian *M. vanderhaegei*, although it occurs in open and altered habitats (rivers, lakes, low-order streams, oligotrophic streams, ponds with aquatic vegetation, and artificial dams), the lack of information on the natural history, and intensive destruction and degradation of their natural habitats justify its inclusion into the category "Lower Risk/Near Threatened" according to the IUCN criteria [55]. Ecological studies and monitoring of *M. vanderhaegei* populations are crucial to assess their current situation and potential threats, and consequently, to demonstrate the need for conservation [81].

Conclusion

The amphibian and reptile fauna of PESCAN is greatly representative of the regional biodiversity, sheltering species that occupy diverse environments of the Cerrado, such as generalist species, habitat specialists, and endemic species that present some degree of concern regarding their conservation. The richness of amphibians and reptiles in the analyzed PAs is representative of the Cerrado biome, and there is a similarity in species composition among geographically closer PAs. The PESCAN shows species composition of amphibians and reptiles similar to PAs located in the Distrito Federal and in the State of Goiás. This high regional representativeness emphasizes the importance of this PA for the maintenance of regional populations. PAs, such as PESCAN, are important because they are able of maintaining viable species populations, mainly because they do not suffer directly from the negative anthropogenic effects, such as advancement of agriculture and livestock, which are the main causes of fragmentation and habitat loss in the Cerrado [75]. Even so, deforestation does occur, sometimes pervasively, within PAs [27]. Although all reserves compared in our results are considered PAs, some of these areas are private reserves and, therefore, there is no guarantee of how long these areas will remain preserved. In addition, we believe that different categories of PAs (e.g. integral protection and sustainable use) may differ in terms of efficiency in maintaining local biodiversity since sustainable use PAs are subject to losing native vegetation [27]. We suggest that future studies should adopt specific designs to identify the influence of anthropogenic activities on the biodiversity of PAs with different protection categories.

Knowledge about the biological diversity in PAs is extremely important for the quantification of species, populations, and communities in PAs and to understand the true species conservation status in order to develop preservation strategies [24,28,74]. It is also necessary to assess situations and trends of anuran and reptile populations in areas outside of PAs, such as legal reserves on private property, since

PAs do not accommodate all species in biogeographical terms [80]. The maintenance of natural vegetation fragments through legal reserves would be an alternative to maintain populations of restricted endemic species, allowing the dispersal of species between preserved and unpreserved areas through ecological corridors [75,80]. Since many areas have not been sampled, it is essential to conduct other studies to know which species are present in the PAs as this enables the development of new conservation strategies, involving the choice of areas that have species not yet registered in PAs. As populations of many species of amphibians and reptiles have been threatened by habitat loss [13,82] and global warming [83–85], it is very important to invest in studies regarding PAs and extinction risk in these groups. Finally, we reinforce the conclusions of recent studies [27], that urgent actions to create new PAs in the Cerrado are necessary to ensure the representativeness and persistence of biodiversity in the biome.

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Author contributions

All author contributed to data collect. WPR and VG wrote the paper. All authors contributed during the paper review process.

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