

Lizards from Estação Ecológica de Santa Bárbara, a remnant of Cerrado in the state of São Paulo, Brazil

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ABSTRACT: Although the reptile fauna in the state of São Paulo is the best known in Brazil, there are still important sampling gaps, especially within the natural remnants of the Cerrado. Only 0.5% of this region is protected in the state, and the remaining fragments suffer threats that include risk of extinctions due to fragment isolation, risk of fire, and invasion by exotic plant species. In this study, we provide information on lizard diversity from the Estação Ecológica de Santa Bárbara, one of the few remaining remnants of Cerrado in the state of São Paulo. We sampled lizards using pitfall traps monthly from October 2008 to March 2009 and October 2011 to November 2012. We recorded 12 lizard species from nine genera and five families (Gymnophthalmidae, Polychrotidae, Scincidae, Teiidae, and Tropiduridae). Our study expands the knowledge about lizard diversity in the Brazilian Cerrado, a global biodiversity hotspot.

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INTRODUCTION

There are 44 species of lizards found in the state of São Paulo (Zaher *et al.* 2011), representing about 18% of the total lizard richness of Brazil (Bérnils and Costa 2012). Although the lizard fauna of São Paulo is considered the best known in the country, there are sampling gaps for lizards in the north, west, and southwest regions of the state (Zaher *et al.* 2011). Indeed, there are few published studies regarding lizard communities in Cerrado remnants in São Paulo (Vanzolini 1948; Dixo *et al.* 2006; Kiefer *et al.* 2006; Nogueira *et al.* 2009; Araujo and Almeida-Santos 2011).

The Cerrado is the second largest region in the Neotropics, and of the 34 global biodiversity hotspots, it is the only one in which savanna vegetation predominates (Mittermeier *et al.* 2004). The Cerrado landscape includes plateaus, depressions, and plains covered mainly by rich savannas, but a small proportion of the Cerrado consists of riparian and semideciduous forest (Oliveira-Filho and Ratter 2002; Silva and Bates 2002; Ab'Sáber 2005; Ribeiro and Walter 2008). The environmental heterogeneity is reflected in the Cerrado biota, which is recognized as one of the most species-rich regions in the world. The Cerrado also has high rates of endemism, and is severely endangered by human activities (Colli *et al.* 2002; Mittermeier *et al.* 2004; Klink and Machado 2005; Diniz-Filho *et al.* 2008). This savanna, which covered 23% of the land area in Brazil in the past, is now severely devastated:

only 40% of its original cover remains (Sano *et al.* 2010). The southern portion of the Cerrado is the most affected, with only 15% of its original cover remaining (Sano *et al.* 2010). In the state of São Paulo, the Cerrado vegetation is found in patches, especially in the Peripheral Depression and Western Plateau (Durigan *et al.* 2004). Only 0.5% of the Cerrado in São Paulo is protected by conservation units (Durigan *et al.* 2007). Nevertheless, these few remnants are subject to threats associated with their isolation, the risk of fire, and invasion by exotic plant species (Pivello *et al.* 1999; Durigan and Ratter 2006; Durigan *et al.* 2007).

Recent studies show a high species richness of reptiles in the Order Squamata in the Cerrado: there are 267 species, of which 103 (39%) are endemic (Nogueira *et al.* 2011). For lizards, open habitats support the highest species richness and harbor more endemic species than forests in the region (Nogueira *et al.* 2011). Unlike mammals and birds, which use both forested and open areas (Johnson *et al.* 1999; Silva and Bates 2002), the lizard fauna in the Cerrado is composed mainly of habitat specialists, resulting in low overlap in habitat use between these environments (Nogueira *et al.* 2005; Vitt *et al.* 2007; Nogueira *et al.* 2009).

Data obtained in inventories such as this one contribute to a better evaluation of the conservation status of species, including population declines and local extinctions, which is necessary for the development of effective measures for management and conservation of the biota (Verdade

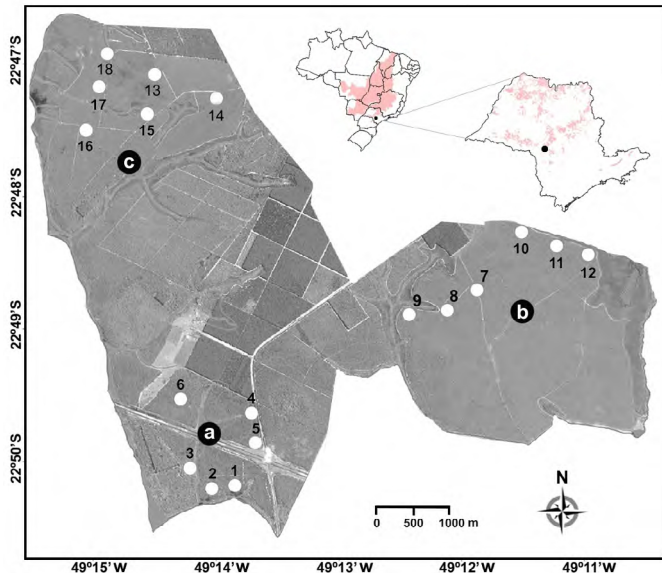


FIGURE 1. Original extent of the Cerrado in Brazil and the state of São Paulo (the black dot represents the Estação Ecológica de Santa Bárbara). The aerial photograph shows pitfall traps (white dots) installed in the forested site (a) and open sites (b, c).

et al. 2012). In this context, this study aims to provide information about the diversity and distribution of lizards in the Estação Ecológica de Santa Bárbara, an open Cerrado remnant in the hydrographic basin of Middle Paranapanema, state of São Paulo, Brazil.

MATERIALS AND METHODS

The Estação Ecológica de Santa Bárbara (22°46'–22°41' S, 49°16'–49°10' W; 600–680 m elevation) is located in the Águas de Santa Bárbara municipality, in the state of São Paulo in Southeastern Brazil. It has a total area of 2,712 ha (Melo and Durigan 2011) (Figure 1). The regional climate is *Cwa* Köppen, with a dry and a rainy season (Peel *et al.* 2007). The average temperature is 24°C in the warmest months (January and February) and 17°C in the coldest months (June and July) (Melo and Durigan 2011). The average annual rainfall is about 1,400 mm, with the highest average monthly rainfall occurring in December (206 mm) and the lowest occurring in August (44 mm) (Melo and Durigan 2011). The vegetation consists predominantly of grasslands and savanna, such as *cerrado (sensu stricto)* (34.4%), dense *cerrado* (10.2%), *campo cerrado* (7%) and marshes (6.5%) (Durigan *et al.* 2011). The natural forest formations are *cerradão* (11.9%), riparian forest (4%), and semideciduous forest (0.7%) (Durigan *et al.* 2011). Descriptions of Cerrado physiognomies are in Oliveira and Ratter (2002), Durigan and Ratter (2006), and Ribeiro and Walter (2008).

We sampled lizards monthly in two separate periods. We did the first inventory from October 2008 to March 2009, with six field surveys of five days each, totaling 30 days of sampling. We did the second inventory from October 2011 to November 2012, with 14 five-day surveys, totaling 70 sampling days. We utilized pitfall traps with drift fences (Corn 1994) in one area of forest (*cerradão* and semideciduous forest), and in two areas of savanna (*cerrado (sensu stricto)* and *campo cerrado*) (Figures 1 and 2, Appendix 1). In the first inventory period, we installed 18 trap rows in all three areas (72

buckets; sampling effort = 2,160 trap-days). In the second inventory period, we installed only 12 trap rows in the two open vegetation areas (48 buckets; sampling effort = 5,040 trap-days). Each row (sampling unit) was composed of four 60-liter buckets and was separated by at least 500 m from all other rows (Figure 1, Appendix 1). The buckets were placed 15 m apart from each other and buried in the soil along a 50 cm high drift fence. Traps were checked daily and we collected a maximum of ten individuals per species for voucher specimens. We identified other captured individuals and marked them by toe-clipping the distal phalanx of the third toe of the right anterior limb (Lüddecke and Amézquita 1999; Phillott *et al.* 2007). We marked individuals this way to avoid counting recaptured individuals. After that, we released them near the locality in which they were captured (collection permits IBAMA/RAN 10423-1 and 13706-2, SISBIO 30833-2 and COTEC/SMA 260108–011291/2011). We deposited voucher specimens in the Coleção Herpetológica do Museu de Zoologia da Universidade de São Paulo (MZUSP) (Appendix 2).

We evaluated the sampling efficiency by creating a rarefaction curve and using the richness estimator Jackknife-1 (Gotelli and Colwell 2001). Considering that the sampling effort in the first and the second period was different (18 and 12 trap rows, respectively), we included in the analysis only the trap rows that were present in both sampling periods (open areas of Cerrado). Therefore, we considered the number of species found in the 12 rows each day as one sample. One hundred samples were obtained in both sampling periods. We chose the Jackknife-1 among the several other richness estimators available (Magurran 2004; Walther and Moore 2005; Hortal *et al.* 2006). Although some authors indicate that non-parametric estimators are very dependent on the species richness observed and the number and size of the samples (Melo and Froehlich 2001; Melo 2004), the richness estimation in this inventory still can provide basis for comparison with other inventories performed in other Cerrado localities that also used the Jackknife-1 estimator (e.g. Nogueira *et al.* 2005; Araujo and Almeida-Santos 2011). We did the analysis using the program EstimateS v.9.1.0, with 1,000 randomizations (Colwell 2013). We



FIGURE 2. Pitfall traps in the Cerrado sampled at the Estação Ecológica de Santa Bárbara, state of São Paulo, Brazil. a = semideciduous forest (row 3); b = *cerradão* (row 5); c = *cerrado (sensu stricto)* (row 8); d = *campo cerrado* (row 14).



FIGURE 3. Lizard species from Estação Ecológica de Santa Bárbara, state of São Paulo, Brazil. a = *Cercosaura ocellata*; b = *Cercosaura schreibersii*; c = *Micrablepharus atticolus*; d = *Anolis meridionalis*; e = *Mabuya dorsivittata*; f = *Mabuya frenata*; g = *Ameiva ameiva*; h = *Ameiva* sp. (aff. *jacuba*); i = *Cnemidophorus* gr. *ocellifer*; j = *Kentropyx paulensis*; k = *Tupinambis merianae*; l = *Tropicurus itambere*. Photos: Cybele O. Araujo and Fábio Maffei.

obtained the conservation status of each species in the international red list of threatened species (IUCN 2013), red list of threatened Brazilian Fauna (Machado *et al.* 2008), and list of threatened species of the state of São Paulo (São Paulo 2014).

RESULTS

We found 375 individuals in 12 species belonging to five families: Gymnophthalmidae (three species), Polychrotidae (one species), Scincidae (two species), Teiidae (five species), and Tropicuridae (one species) (Figure 3, Table 1). The most abundant species was *Micrablepharus atticolus* (40.8%), followed by *Ameiva ameiva* (26.2%) and *Ameiva* sp. (aff. *jacuba*) (10.9%) (Table 1). We captured most of the lizards (11 species) in the open savanna areas (Table 1, Appendix 1). In the forested areas, we captured only *Mabuya dorsivittata*, *M. frenata*, and *Tupinambis merianae* (Table 1, Appendix 1).

Only the two open areas were sampled during both periods of this inventory. Therefore, we did not include

the data about the forested area in the rarefaction curve and richness estimator calculations. *Mabuya frenata* was the only species encountered exclusively in the forested area, and thus it was not considered in the analysis. The rarefaction curve shows a rise to stabilization, indicating that most of the species present in the area, if not all, were sampled (Figure 4). Indeed, it is not possible to differentiate the actual richness from the richness estimated by the Jackknife-1 estimator for the open areas (12.98 ± 1.39 SD) (Figure 4).

Among the sampled species, *Anolis meridionalis*, *Cercosaura ocellata*, *Kentropyx paulensis*, and *Micrablepharus atticolus* are on the list of threatened species of the state of São Paulo (São Paulo 2014).

DISCUSSION

The lizard richness of Estação Ecológica de Santa Bárbara represents 27% of the lizard fauna of the state of São Paulo (Zaher *et al.* 2011). The number of species observed in this study is less than the richness estimates

TABLE 1. Species composition, abundance, and capture sites (pitfall traps) of the lizard species sampled between 2008/2009, and 2011/2012 at the Estação Ecológica de Santa Bárbara, state of São Paulo, Brazil.

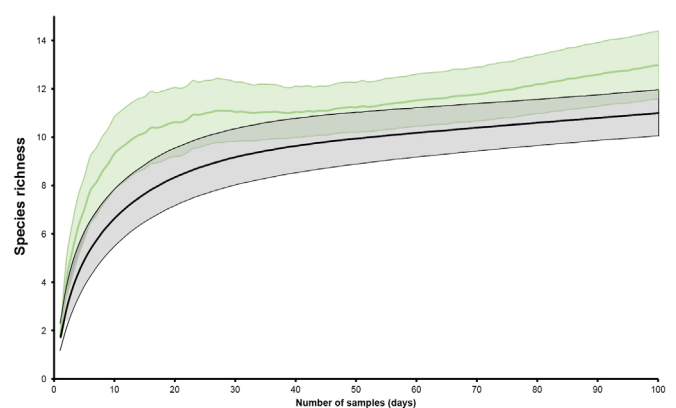
FAMILY/SPECIES	ABUNDANCE		CAPTURE SITES
	N	%	
Gymnophthalmidae			
<i>Cercosaura ocellata</i> (Wagler, 1830)	23	6.1	7, 10, 12, 13, 14, 15, 16, 17, 18
<i>Cercosaura schreibersii</i> (Wiegmann, 1834)	14	3.7	7, 8, 9, 10, 11, 14, 16
<i>Micrablepharus atticolus</i> Rodrigues, 1996	153	40.8	7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18
Polychrotidae			
<i>Anolis meridionalis</i> (Boettger, 1885)	7	1.9	7, 9, 12, 13, 16
Scincidae			
<i>Mabuya dorsivittata</i> (Cope, 1862)	20	5.3	4, 7, 8, 10, 11, 12, 14, 15, 16, 17, 18
<i>Mabuya frenata</i> (Cope, 1862)	3	0.8	1, 3, 4
Teiidae			
<i>Ameiva ameiva</i> (Linnaeus, 1758)	98	26.2	8, 13, 14, 15, 16, 17, 18
<i>Ameiva</i> sp. (aff. <i>jacuba</i>)	41	10.9	7, 8, 9, 10, 11, 13, 15, 16, 17
<i>Cnemidophorus</i> gr. <i>ocellifer</i>	7	1.9	15, 16, 17
<i>Kentropyx paulensis</i> (Boettger, 1893)	6	1.6	8, 9, 13, 15, 16, 17, 18
<i>Tupinambis merianae</i> (Duméril & Bibron, 1839)	2	0.5	6, 8, 9
Tropiduridae			
<i>Tropidurus itambere</i> Rodrigues, 1987	1	0.3	17
Total	375		

(between 13 and 28 species) for well-sampled areas of Cerrado (Colli *et al.* 2002; Nogueira *et al.* 2009). However, it has an intermediate richness when compared to other conservation units in the state that also have Cerrado formations, such as the Estação Ecológica de Assis (10 species; Araujo and Almeida-Santos 2011), Estação Ecológica de Itirapina (15 species; Kiefer *et al.* 2006), and Parque Estadual do Morro do Diabo (8 species; Dixo *et al.* 2006). The difference in lizard diversity in Cerrado areas can be related more to the unique local historical processes than to the physiognomy of vegetation in each locality (Nogueira *et al.* 2009). Costa *et al.* (2007) modeled the distribution patterns of Squamata reptiles in the Cerrado, and demonstrated that the localities in the periphery of the biome have the lowest richness. The area in this study may present a similar case, because it consists of naturally isolated patches of Cerrado, in the southernmost portion of the Cerrado region.

The most common species in the studied locality were *Micrablepharus atticolus*, a species endemic to the Cerrado (Rodrigues 1996), and *Ameiva ameiva*, a lizard considered a habitat-generalist (Vitt and Colli 1994; Colli *et al.* 2002). Until now, there is only one published study that presents information about relative species abundance of Cerrado lizards in the state of São Paulo (Araujo and Almeida-Santos 2011). In that locality (Estação Ecológica de Assis), *Ameiva ameiva* (42.5%) and *Colobosaura modesta* (12.3%) were the most common species (Araujo and Almeida-Santos 2011). Studies in other Cerrado regions show a significant variation in the dominant species sampled by pitfall traps. In one locality in the Distrito Federal region, Nogueira *et al.* (2005) observed that *Cercosaura ocellata* (20.1%) and *Micrablepharus atticolus* (19.2%) were the most frequent species. In the Parque Nacional Grande Sertão Veredas (state of Minas Gerais), the most abundant lizards were *Vanzosaura rubricauda* (34.1%) and *Cnemidophorus* cf. *ocellifer* (28.4%) (Recoder *et al.*

2007). In the Estação Ecológica Serra Geral do Tocantins (states of Tocantins and Bahia), *Tropidurus* cf. *oreadicus* (20.6%) and *Cnemidophorus mumbuca* (17.9%) were the most captured species (Recoder *et al.* 2011). It is likely that the observed variation in the dominant species among the localities is a result of historical factors, differences in the vegetation structure, or even temporal variation of the dominant species. The composition of lizard communities can vary across time so that the predominant species in one year can become rare or absent in the next year (Brandão and Araújo 2002).

Considering only the lizards identified to species level (which excludes *Ameiva* sp. (aff. *jacuba*) and *Cnemidophorus* gr. *ocellifer*), most of them are widely distributed, commonly found in many regions of Brazil, such as *Ameiva ameiva*, *Cercosaura ocellata*, *C. schreibersii*, *Mabuya dorsivittata*, *M. frenata*, and *Tupinambis merianae* (Vitt and Colli 1994; Ávila-Pires 1995; Brandão and Araújo 2002; Costa *et al.* 2008). However, a significant portion (40%) is strongly

**FIGURE 4.** Rarefaction curve representing the species richness observed (black line) and the richness estimated by the Jackknife-1 estimator (green line) for 100 sampling days of pitfall traps in the open habitats at the Estação Ecológica de Santa Bárbara, state of São Paulo, Brazil. The grey and pale green areas represent the standard deviations.

associated with the open habitats of the Cerrado, such as *Anolis meridionalis*, *Kentropyx paulensis*, *Micrablepharus atticolus*, and *Tropidurus itambere* (Nogueira et al. 2005; Recoder and Nogueira 2007; Nogueira et al. 2009). Recent analyses suggest that populations of *Anolis meridionalis*, *Kentropyx paulensis*, and *Micrablepharus atticolus* are declining, and these species could disappear from the state of São Paulo (Marques et al. 2009). They are therefore, together with *Cercosaura ocellata*, included in the list of threatened species of the state of São Paulo (São Paulo 2014).

Open Cerrado habitats contain higher lizard species richness and rates of endemism than forests (Nogueira et al. 2011). Additionally, the lizard fauna of the Cerrado is mainly composed of habitat specialists, and there is little overlap in the habitats used (Nogueira et al. 2005; Vitt et al. 2007; Nogueira et al. 2009). In our study, we sampled only *Mabuya dorsivittata* and *Tupinambis merianae* in both open and forested areas. Despite the low structural heterogeneity in most of the savanna environments compared to forests, savannas still have the necessary complexity that promotes the coexistence of several lizard species that can exploit different microhabitats, resulting in high species richness in these areas (Colli et al. 2002; Nogueira et al. 2009). Our results reinforce the importance of the open Cerrado habitats, which are rare in the state of São Paulo and have been suffering intense habitat loss and fragmentation over the years.

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APPENDIX 1. Rows of pitfall traps installed at the Estação Ecológica de Santa Bárbara, state of São Paulo, Brazil.

NUMBER	VEGETATION FORMATIONS	HABITAT TYPES	GEOGRAPHIC COORDINATES
1	<i>cerradão</i>	forest	22°50'11" S, 49°13'56" W
2	<i>cerradão</i>	forest	22°50'13" S, 49°14'04" W
3	semideciduous forest	forest	22°50'04" S, 49°14'15" W
4	<i>cerradão</i>	forest	22°49'37" S, 49°13'45" W
5	<i>cerradão</i>	forest	22°49'52" S, 49°13'44" W
6	<i>cerradão</i>	forest	22°49'31" S, 49°14'21" W
7	<i>cerrado (sensu stricto)</i>	open	22°48'42" S, 49°11'57" W
8	<i>cerrado (sensu stricto)</i>	open	22°48'50" S, 49°12'09" W
9	<i>cerrado (sensu stricto)</i>	open	22°48'51" S, 49°12'30" W
10	<i>cerrado (sensu stricto)/ campo cerrado</i>	open	22°48'13" S, 49°11'30" W
11	<i>cerrado (sensu stricto)</i>	open	22°48'18" S, 49°11'14" W
12	<i>cerrado (sensu stricto)</i>	open	22°48'23" S, 49°10'59" W
13	<i>campo cerrado</i>	open	22°47'06" S, 49°14'29" W
14	<i>campo cerrado</i>	open	22°47'13" S, 49°14'05" W
15	<i>cerrado (sensu stricto)</i>	open	22°47'24" S, 49°14'37" W
16	<i>cerrado (sensu stricto)</i>	open	22°47'30" S, 49°15'07" W
17	<i>cerrado (sensu stricto)</i>	open	22°47'13" S, 49°14'59" W
18	<i>cerrado (sensu stricto)</i>	open	22°46'56" S, 49°14'56" W

APPENDIX 2. Lizard species collected at the Estação Ecológica de Santa Bárbara, state of São Paulo, Brazil, and deposited in the Coleção Herpetológica do Museu de Zoologia da Universidade de São Paulo, São Paulo (MZUSP).

Ameiva ameiva (104305), *Ameiva* sp. (aff. *jacuba*) (104304), *Anolis*

meridionalis (104307), *Cercosaura ocellata* (104309), *Cercosaura schreibersii* (104301), *Cnemidophorus* gr. *ocellifer* (104303), *Kentropyx paulensis* (104302), *Mabuya dorsivittata* (104306), *Mabuya frenata* (104308), *Micrablepharus atticolus* (104300), and *Tropidurus itambere* (104571).