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Article

Concrete survivors: the herpetofauna of an urban green area over 100 years of increasing urbanization

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Abstract: Low biodiversity in urban areas is associated with habitat loss. However, the effects of urbanization on biodiversity should also consider the historical background of land-use, explored herein. Our goal was to evaluate changes in the assemblage of reptiles in an urban habitat over 100 years, aiming to identify which ecological attributes allowed the persistence of species that can be found in the area today. We accessed historical records in scientific collections and carried out fieldwork to access reptile assemblage in an urban green area, in São Paulo, Brazil. Considering land-use changes in the area, we defined three-time intervals between 1901 and 2020. We established species richness for each time interval, categorizing them into three ecological attributes: habitat preference, substrate use, and food habits. We recorded 27 reptile species from 1901 until 2020, 14 resulting from historical data, eight from both historical and fieldwork, and five species exclusively in fieldwork. Amphibians were also sampled during fieldwork, but not used in historical comparison. Reptile's species richness decreased 59% regardless of ecological attributes, and snakes were the group with most species' loss. Fossorial reptiles were the least affected group. We concluded that habitat loss culminated in a species richness decline, and the reptiles that remain until today were likely present since the fragment isolation. Ecological attributes of the remaining taxa include species that use terrestrial substrates and feed on prey commonly found in urban environments.
Keywords: *urban biodiversity, landscape history, reptiles, amphibians, urban ecology.*

Sobreviventes do concreto: a herpetofauna de uma áreaverde urbana ao longo de 100 anos de urbanização

Resumo: A baixa biodiversidade em áreas urbanas está associada à perda de habitat. No entanto, os efeitos da urbanização sobre a biodiversidade também devem considerar o histórico de uso da terra, explorado aqui. Nosso objetivo foi avaliar as mudanças na comunidade de répteis em um habitat urbano ao longo de 100 anos, visando identificar quais atributos ecológicos permitiram a persistência de espécies que podem ser encontradas na área hoje. Acessamos registros históricos em coleções científicas e realizamos trabalho de campo para levantar as espécies de répteis em uma área verde urbana, em São Paulo, Brasil. Considerando as mudanças de uso da terra na área amostrada, definimos três intervalos de tempo entre 1901 e 2020. Estabelecemos a riqueza de espécies para cada intervalo de tempo, categorizando-as em três atributos ecológicos: preferência de habitat, uso de substrato e hábitos alimentares. Registramos 27 espécies de répteis de 1901 até 2020, sendo 14 resultantes de dados históricos, oito de dados históricos e de campo e cinco espécies amostradas exclusivamente de campo. Anfíbios também foram amostrados durante o trabalho de campo, mas não foram usados na comparação histórica. A riqueza de espécies de répteis diminuiu 59% independentemente dos atributos ecológicos, e serpente foi o grupo com maior perda de espécies. Os répteis fossoriais foram o grupo menos afetado. Concluímos que a perda de habitat culminou em um declínio da riqueza de espécies, e os répteis que permanecem até hoje provavelmente estavam presentes desde o isolamento do fragmento. Os atributos ecológicos dos táxons remanescentes incluem espécies que utilizam substratos terrestres e se alimentam de presas comumente encontradas em ambientes urbanos.
Palavras-chave: *biodiversidade urbana, histórico da paisagem, répteis, anfíbios, ecologia urbana.*

Introduction

Urban green areas (UGA) are all vegetation patches within and around cities (Miller 1997, Cilliers et al. 2013). These areas are important as refuge for varied species (Turner and Corlett 1996, Ives et al. 2015, Barbosa et al. 2020). Most studies aiming to evaluate biodiversity in UGA show that species richness in these areas is lower than natural habitats (e.g., Nielsen et al. 2014, Concepción et al. 2016, Lourenço-de-Moraes et al. 2018, Ganci et al. 2020). The species-area model is one possible process that explains this pattern, once it predicts that the replacement of vegetation by impervious surfaces reduces biodiversity by losing habitable area (McKinney 2008). However, biodiversity patterns emerging from interactions between different taxonomic groups and urban environments are not straightforward. The biodiversity in UGA varies according to several factors, including landscape composition (Aronson et al. 2017) and sensitivity of individual species to urbanization (Pena et al. 2017). Therefore, the information about what landscape characteristics and species life-history traits drive the success of biodiversity in urban habitats is essential for conservation in an increasingly urban world (Schochat et al. 2006, Aronson et al. 2017, Lepczyk et al. 2017).

Biodiversity patterns in UGA are usually assessed by comparing patches in urban or urban-rural environments; on the other hand, temporal comparisons are less common in the literature (but see Tait et al. 2005, Hahs et al. 2009, Marques et al. 2009). However, historical backgrounds in cities differ in several ways, such as cities' age or the presence of natural landscapes (von der Lippe et al. 2020). Therefore, comparing historical data with current information from the same locality allows to evaluate changes in community composition throughout the years (Acosta et al. 2005) in order to answer how anthropic impacts affects the activity and survival of the remaining taxa (Pearman 1997, Schlaepfer and Gavin 2001, Loehle et al. 2005).

Birds, arthropods, and plants communities are often assessed in UGA studies (e.g., Saari et al. 2016, Palacio et al. 2018), but the effect of urbanization on communities of reptiles and amphibians are less understood (Almeida-Corrêa et al. 2020). In a recent review, French et al. (2018) suggests a general negative impact of urbanization on reptiles. In Brazil, recent empirical studies are suggesting a pattern of decline in species richness (e.g., de Andrade et al. 2019, Avila-Pires et al. 2018), and possible trophic cascades consequences (Siqueira and Marques 2018). São Paulo is the largest city in South America and its forests support a high diversity of reptiles and amphibians (e.g., Malagoli 2008, Marques et al. 2009, Barbo et al. 2011). A recent study carried out in an UGA in São Paulo city recorded an impressive amount of anuran and reptiles, representing respectively 10 and 12% of the total richness known for these taxa in the Atlantic Forest in São Paulo state (Lisboa et al. 2021). The authors highlight the importance of studies that assess the ecology of extant species to better understand their ability to thrive in urban environments.

Here, we characterized the herpetofauna community in an UGA within the city of São Paulo, Brazil, aiming to evaluate the temporal changes in species richness and community composition from 1901 until 2020, identifying the ecological attributes that allowed the resistance of herpetofauna in this urbanized environment. With two important scientific collections in the city of São Paulo, data on fauna diversity has been recorded since early 20th century, allowing us to access knowledge from the past and integrate it in new discoveries.

Material and Methods

1. Study site

The study was conducted in the UGA of Instituto Butantan (IBu) (Figure 1), a research institute located amidst 80 hectares of green area, in São Paulo, Brazil (23°34'03.96"S, 46°43'06.16"W), one of the most populous cities in the world (Instituto Brasileiro de Geografia e Estatistica [IBGE], 2018). Historically, the city of São Paulo is part of the range of the Ombrophile Semidecidual Atlantic Forest interspersed with open grasslands that were either part of the Brazilian Cerrado biome or the result of the action of pre-European human settlements (Usteri 1911, Joly 1950, Ab'Saber 1963). Currently, the urban matrix of São Paulo city still contains numerous small parks and is surrounded by two large patches of Atlantic Forest, the Serra da Cantareira to the northwest and the Serra do Mar to the southwest. The rainfall and hottest months predominate from November to March.

In 1901, the IBu was a 400-hectare farm that comprised a flooded area, formed mainly by crops, pasture, Eucalyptus grove, and its limits extended over rivers that came from inland to the city of São Paulo (Joly 1950). During 50 years of infrastructure adequacy, most of the rivers were rectified, and, consequently, IBu lost its flooded boundaries (Diasas 2019). Meanwhile, the city of São Paulo grew exponentially, and urbanization reached the western region of the town, modifying the urban matrix surrounding IBu. A significant urban development occurred during 1951 and 1990, with new buildings, pavements, and the rivers' silting. At the same time, more than 600 seedlings of Atlantic Forest native trees were intentionally planted to replace the former pasture area. Today, besides being a worldwide reference in the study of venomous animals and public health, the IBu is a significant UGA in the western zone of São Paulo. With 80 hectares of green area in an urban environment, only a quarter of its original area 120 years ago, 62% of its current area is covered by native and exotic vegetation within an urban environment (Teixeira-Costa et al. 2014, Secretaria do Verde e Meio Ambiente [SVMA], 2020). It is possible to find small and shallow water bodies inside the forest that remain full throughout the year, although dryer between May and September.

2. Data collection

We searched for reptile species recorded in scientific collections from 1901 to the present day; we also carried out fieldwork throughout 2016 to assess the current herpetological community. The Collections examined were: Herpetological Collection "Alphonse Richard Hoge" (IBSP) and the Museu de Zoologia da Universidade de São Paulo (MZUSP), two centenary scientific collections in the city of São Paulo.

During the fieldwork in 2016, we employed active and passive methods (Auricchio and Salomão 2002): pitfalls traps with drift-fences (Corn 1994, Cechin and Martins 2000), visual surveys (Crump and Scott 1994), and records of occasional encounters from the authors and third parties (Auricchio and Salomão 2002). Five lines of pitfall traps were installed, in 50m long transects, each with five 100-liter plastic buckets buried in the ground. Every bucket was connected to another

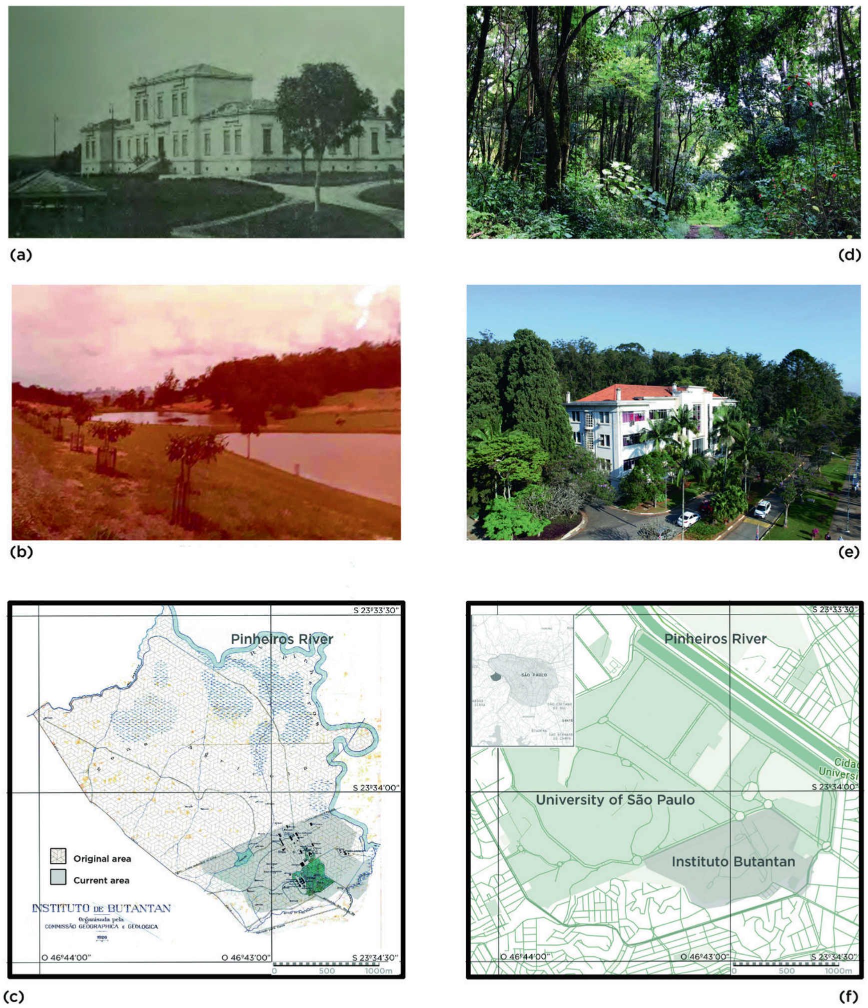

Figure 1. Urban green area of the Instituto Butantan, São Paulo, Brazil. (a) IBu in 1928, showing the main building and surrounding grasses; (b) IBu in 1983, showing artificial lakes, grass, and secondary forest; (c) Manipulated map of IBu in 1926 showing the original area of 400 hectares (dotted area) and the current area of 80 hectares (shaded area). Note the Pinheiros river before rectification; (d) secondary forest of IBu in 2021; (e) aerial view of IBu in 2014, showing a building, pavements, and secondary forest; (f) current area of IBu (shaded area). Note the Pinheiros river after rectification. Photographs (a) and (b): Butantan Institute Archive/ Memory Center; Original map in (c): Cardoso 1926; photograph (d): Bruno Martins da Costa Batista; photograph (e): Camilla Suescun Marques de Carvalho.

by 10m with drift-fences. The fences were 1m high and were buried approximately 20cm into the ground, passing through the center of each pitfall. The visual survey consisted of walking around in search of reptiles and amphibians turning over leaves and shrubs. Animals found outside the collecting periods were recorded as occasional encounters. All collected animals were identified in the level of species. Because the sampled area has homogeneous vegetation and the pitfall lines were not more than 500m distant from each other, the transects were considered replicas. Sampling took place from January to December 2016, lasting seven days per month and totaling 84 days. The sampling effort and the encounter rate were measured in person-hours of visual search (two researchers in an hour daily for 53 days) and considering the 84 days that the pitfall traps remained open (Martins and Oliveira 1998). The collected specimens were deposited in the IBSP. We carried out the fieldwork under the required permits (SISBIO license nº 51345-1, CEUA Instituto Butantan nº 7717221015).

2.1. Habitat preference and ecological attributes

We categorized the recorded species into ecological attributes in order to evaluate which life-history traits allow species to persist in patches of habitat within an urban area. We divided each sampled species by habitat preference or exclusiveness: forest specialist, open-area specialist, or generalist (i.e., no habitat preference or exclusiveness); the main type of substract: terrestrial, arboreal, aquatic, or fossorial; and the feeding habits. The feeding habitats were classified accordingly with the diet preference of each species, and we considered preferences for invertebrates, anurans, snakes, lizards, mammals, mollusks, earthworm, or generalist if the species doesn't show any diet preference. To determine the ecological attributes of each species recorded, we used data available in literature: Fialho et al. 2000, Parpinelli and Marques 2008, Ghizoni-Junior et al. 2009, Hartmann et al. 2009, Araújo et al. 2010, da Silva et al. 2010, and Marques et al. 2019.

3. Data analysis

Considering data gathered during fieldwork, the efficiency of the sampling method was evaluated using species rarefaction curves (Colwell and Coddington 1994, Thompson et al. 2003, Trevine et al. 2014), with a 95% confidence interval and 1000 randomizations. We assessed the richness through a non-parametric first-order Jackknife index (Heltsche and Forrester 1983, Hellmann and Fowler 1999). Due to the lack of accurate historical records on species abundance, we choose species richness as a method for comparison in the temporal analysis (Tait et al. 2005). We determined the richness of snakes, lizards and amphisbaenians for each time interval using the total number of species recorded in that period, disregarding the lost specimens. No historical record of amphibian species was available in IBSP or MZUSP. Thus, the amphibian species presented here results only from fieldwork, and we did not use it in the temporal comparison.

To make it possible to compare the reptiles richness at different times, we stipulated three time intervals considering major land-use changes in the IBu area (Figure 1): 1901-1950, which includes the initial area of 400 hectares with wetlands and agricultural activities (Figure 1a-c); 1951-1990, including new buildings, rivers and roads paving, and reforestation (Figure 1a-c); 1991-current days, an area of 80 hectares and a well-established secondary forest (Figure 1d-f).

Species were categorized by "present", "absent", or "data not available - NA" for each time interval. If a species were recorded in earlier years but not in years after that (e.g., record available in 1930 but no record after that) we considered the species "absent" in the next years. If a species were recorded in one year but not in years before that (e.g., record available in 2000 but no record before that), we considered that this species has no available data "NA" for years before (see Table 1). We made this decision based on the fact that sometimes historical data can be missed or not kept. We analyzed the proportion of present species against time (e.g., Tait et al. 2005), which produced three lines (Figure 2). The upper line indicates the maximum possible number of species present in that time interval, calculated by adding the total number of present species to the total number of NA species, that is, considering that NA species were present. The central line represents the total number of present species divided by the total number of species recorded as present and absent, excluding NA species. This central line highlights the effect that NA values have on the basic pattern. The lower line indicates the minimum number of species present expected for each time interval, assuming that all species with NA values were absent. Because the proportion of present species against time showed little variation between the upper and the central line, it is more likely that species with no available data (NA) were in fact present in earlier years, but with no records taken or kept. Thus, we utilized the maximum number of species (present + NA) for each time interval to conduct the comparison between different periods.

Data was extrapolated between data points to provide the continuous graphical representation (Tait et al. 2005). It means that the same species recorded as present in 1901 and 2018, but with no data sets for intervening years, was presumed as present in all years between these two time points. If a species was recorded as present in 1901, but no records were found for the remaining years, we assumed that the species was locally extinct and categorized it as absent for the next years. We used the software R (R Development Core Team 2020) to conduct the analyses and to produce the graphics.

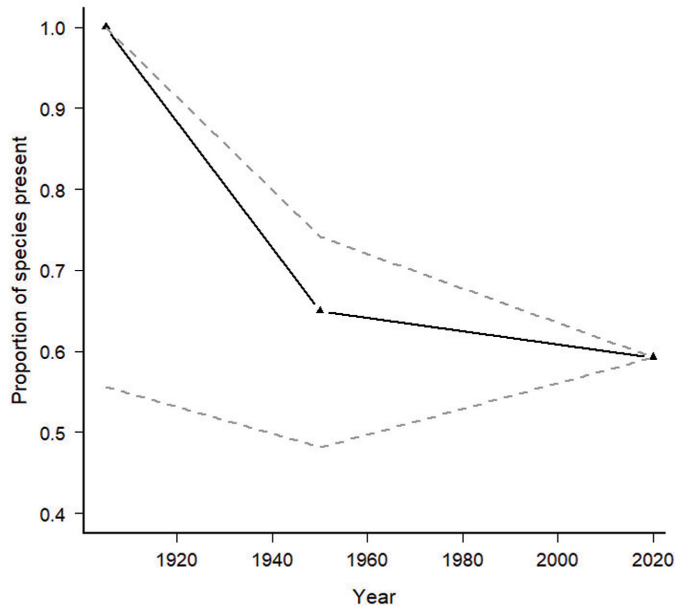

Figure 2. Proportion of species present in three periods. The upper and lower dotted lines (in gray) show the proportion of species present compared to the total number of species (present, absent, and NA). The central line (in black) shows the proportion of species present compared to the total number of species with known status (present and absent), excluding "NA" records.

Results

1. Fieldwork sampling

We recorded six species of anurans (Table 1; Figure 3a) during fieldwork in 2016. The most abundant, *Rhinella ornata*, comprises 30% of the total of individuals sampled. Species rarefaction curves from sampling effort stabilized for amphibians (JACK1 = 5.98 ± 0), corresponding fairly to the number of observed species. Within the sampled amphibians, five species (83%) are forest specialists and one (*Physalaemus cuvieri*) is generalist, occurring in both forest and open areas. Three species (*R. ornata, R. icterica* and *P. cuvieri*) are terrestrial while the other three (*Boana faber, Scinax hiemalis* and *Trachycephalus mesophaeus*) are arboreal. All species feed on invertebrates.

We recorded 13 species of reptiles (Table 1; Figure 3b) during fieldwork in 2016. The most abundant, the snake *Xenodon neuwiedii*, comprises 30% of the total of individuals captured. Species rarefaction curves from sampling effort did not stabilize for reptiles (JACK1 = 17.25 ± 0), indicating that at least four species were missed from our effort.

Considering the lizard species, only one (*Ophiodes fragilis*) is common in forested areas. *Notomabuya frenata* and *Tropidurus* gr. *torquatus* are common in open areas, while *Hemidactylus mabouia* and *Salvator merianae* can be found in both open and forest areas. Four species (80%) are terrestrial and only the exotic *H. mabouia* is arboreal. All species feed on invertebrates or are generalists. Amphisbaenids are common in open areas, except for *Leposternon microcephalum*. All amphisbaenids are fossorial and feed on invertebrates or elongate-shape vertebrates.

Within the sampled snakes, four species (*Liotyphlops beui, Tomodon dorsatus*, *Xenodon neuwiedii,* and *Bothrops jararaca*) are common in

Table 1. Sampled species of herpetofauna in the urban green area of the Instituto Butantan (IBu) in three periods: from 1901 to 1950, 1951 to 1989, and 1990 to current days (1 = presence; 0 = absence; NA = non-available data). The table include the methods (Fw = fieldwork; Mc = museum collection), and the following ecological attributes: habitat use (Fo = forest area; Op = open area; Ge = generalist); substrate use (Fs = fossorial; Ar = arboreal; Te = terrestrial; Aq = aquatic); and feeding habits (In = invertebrates; An = anurans; Sn = snakes; Lz = lizards; Ma = mammals; Mo = mollusks; Ew = earthworm; Ge = generalist). Note: Consider NA as presence (see Figure 2 and text).

Order/family	Species	Periods			Methods	Habitat	Substract	Diet
		1901–1950	1951–1989	1990–2020				
Anura								
Bufonidae	*Rhinella icterica*	0	0	1	Fw	Fo	Te	In
	Rhinella ornata	0	0	1	Fw	Fo	Te	In
Hylidae	*Boana faber*	0	0	1	Fw	Fo	Ar	In
	Scinax hiemalis	0	0	1	Fw	Fo	Ar	In
	Trachycephalus mesophaeus	0	0	1	Fw	Fo	Ar	In
Leptodactylidae	*Physalaemus cuvieri*	0	0	1	Fw	Ge	Te	In
Squamata								
Anguidae	*Ophiodes fragilis*	NA	NA	1	Fw	Fo	Te	In
	Ophiodes striatus	1	0	0	Mc	Ge	Te	In
Gekkonidae	*Hemidactylus mabouia*	1	1	1	Fw/Mc	Ge	Ar	In
Leiosauridae	*Anisolepis grilli*	1	0	0	Mc	Fo	Ar	In
	Enyalius perditus	NA	1	0	Mc	Fo	Ar	In
Mabuyidae	*Notomabuya frenata*	1	1	1	Mc	Op	Te	In
Teiidae	*Salvator merianae*	1	1	1	Fw/Mc	Ge	Te	Ge
Tropiduridae	*Tropidurus* gr. *torquatus*	NA	NA	1	Fw	Op	Te	In
Amphisbaenidae	*Amphisbaena alba*	NA	NA	1	Fw	Op	Fs	In, Sn, Lz
	Amphisbaena dubia	1	1	1	Fw/Mc	Op	Fs	In, Sn, Lz
	Amphisbaena mertensii	NA	NA	1	Fw	Op	Fs	In, Sn, Lz
	Leposternon microcephalum	NA	NA	1	Fw	Fo	Fs	Ew, Sn, Lz
Anomalepididae	*Liotyphlops beui*	NA	1	1	Fw/Mc	Fo	Fs	In
Dipsadidae	*Apostolepis assimilis*	NA	1	1	Mc	Op	Fs	Sn, Lz
	Dipsas mikanii	1	1	1	Fw/Mc	Ge	Te	Mo
	Erythrolamprus aesculapii	NA	1	0	Mc	Ge	Te	Sn
	Erythrolamprus poecilogyrus	NA	1	1	Mc	Ge	Te	An
	Helicops modestus	NA	NA	1	Mc	Op	Aq	Ge
	Oxyrhopus guibei	NA	1	1	Fw/Mc	Ge	Te	Ge
	Philodryas aestiva	NA	NA	1	Mc	Op	Ar, Te	Ge
	Philodryas patagoniensis	NA	1	1	Mc	Op	Te	Ge
	Thamnodynastes cf. *nattereri*	1	0	0	Mc	Fo	Ar, Te	Ge
	Tomodon dorsatus	NA	1	1	Fw/Mc	Fo	Te	Mo
	Xenodon neuwiedii	NA	NA	1	Fw/Mc	Fo	Te	An
Elapidae	*Micrurus corallinus*	NA	1	0	Mc	Fo	Fs, Te	Sn, Lz
Viperidae	*Bothrops jararaca*	NA	NA	1	Mc	Fo	Ar, Te	Ge

forested areas. Four species (*Apostolepis assimilis Helicops modestus, Philodryas aestiva,* and *P. patagoniensis)* dwell in open areas, and *Dipsas mikanii*, *Erythrolamprus poecilogyrus*, and *Oxyrhopus guibei* can be found both in open and forest areas. Six species (54%) are terrestrial, two (18%) are fossorial, two species can use both terrestrial and arboreal substrate (18%), and only *Helicops modestus* is semi-aquatic. There were no predominantly arboreal species sampled. Snakes are mostly generalists (54%). *Liotyphlops beui* feeds on invertebrates, and *D. mikanii* and *T. dorsatus* are malacophagous. *Xenodon neuwiedii* and *E. poecilogyrus* feed on anuran, and *O. guibei* and *B. jararaca* feeds on lizards and small mammals.

2. Reptiles in scientific collections and temporal comparison

We recorded 26 species of reptiles from 1901 to present (Table 1), 13 resulting exclusively from historical data, eight from both historical and fieldwork, and five species sampled exclusively in fieldwork: *Ophiodes fragilis*, *Tropidurus* gr. *torquatus*, *Amphisbaena alba*, *Amphisbaena mertensii*, and *Leposternon microcephalum*. Data from museum records

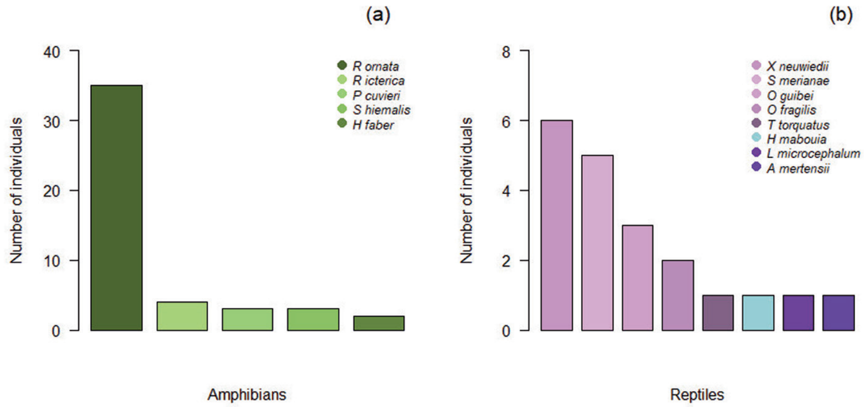

Figure 3. Current herpetofauna community of Instituto Butantan sampled in fieldwork during 2016. (a) Amphibians recorded during fieldwork and number of individuals per species sampled; (b) Reptiles recorded during fieldwork and number of individuals per species samples.

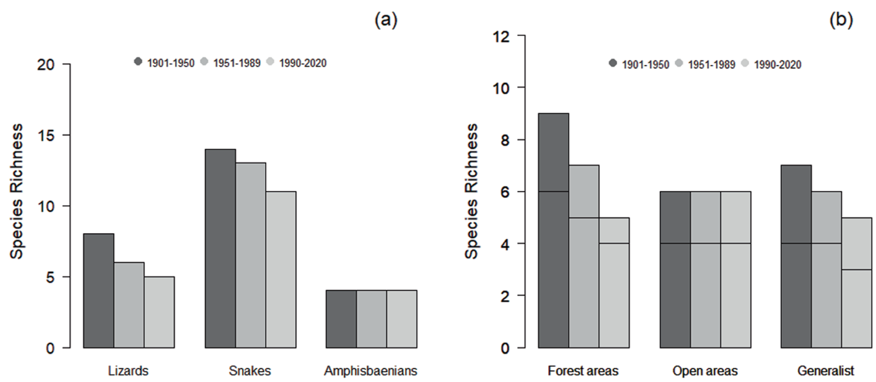

Figure 4. Reptiles species richness in three periods analyzed: 1901-1950 (dark grey), 1951-1989 (grey), 1990-2020 (light gray). (a) Species richness for lizards, snakes and amphisbaenians; (b) Species richness for lizards (upper bar) and snakes (bottom bar) in relation to the ecological attribute of habitat preference (forest areas, open areas, or generalist).

(Table 1) suggests that other seven species of reptiles can be found in current days at IBu, which exceeds the value predicted by the reptile's rarefaction curve (JACK1 = 17.25 ± 0).

The richness of reptile species decreased 23%: 26 species in the first period (1901-1950), to 22 in the second (1951-1990) and 20 in the third period (1991-current). Although the richness of amphisbaenians was constant during all periods (n = 4), species richness decreased 37,5% for lizards, and 21,4% for snakes (Figure 4a). For snakes and lizards, the depletion in species richness occurred regardless the habitat preference of each species, but it kept constant for open-area specialists (Figure 4b).

Discussion

We found six amphibians and 20 reptile species composing the current herpetofauna community at IBu. From 1906 to 2006, IBSP and MZUSP collection gathered a total of 97 species of reptiles from the city of São Paulo, being seven amphisbaenids, 19 lizards and 68 snakes (Marques et al. 2009). From 2003 to 2007, IBu received 38 species of snakes (Barbo 2008). The latest fauna inventory for the city of São Paulo registered 88 species of amphibians and 55 of reptiles sampled in 173 green areas throughout the city, including public and private UGA, water bodies and conservation units (SVMA 2022). However, the IBu area was not assessed in this inventory and our study provides two new records for the city: the lizard *Notomabuya frenata* and the amphisbaenid *Amphisbaenia mertensii*. The species richness and composition we found seem proportionally similar with other urban areas within Atlantic Forest (e.g., Citeli et al. 2016, de Oliveira et al. 2016, França and França 2019, Cavalheri et al. 2021).

The locations in São Paulo city highly sampled for amphibians are the Cantareira and the Serra do Mar State Parks, while other UGA represent sampling gaps (Malagoli 2008). One of these gap areas is the IBu. The amphibians we found are common in urban areas of the city of São Paulo (SVMA 2022), suggesting that these species tolerate environmental change (Santana et al. 2016, Lourenço-de-Moraes et al. 2018). Besides being influenced by climatic variations (Rebouças et al. 2021), declines in amphibians' richness in urban areas are associated with highly anthropic pressure, including habitat loss (Youngquist et al. 2017, Lourenço-de-Moraes et al. 2018; Ganci et al. 2020), low connectivity between fragments (Metzger et al. 2009), and topography of the surrounding matrix (Ribeiro et al. 2018). The low amphibian's richness observed in IBu possibly is related to habitat loss, and to environmental changes in the fragment during urbanization, as already documented in other UGA in the city of São Paulo, for example in the Parque Estadual Fontes do Ipiranga (Lisboa et al. 2021).

Lizards and other snakes sampled in IBu are mostly terrestrial and prey items that seem common in urban environments, which may favor their persistence in UGA. The lizards *O. fragilis, H. mabouia* and *N. frenata* feed on a wide variety of arthropods that occur in undergrowth or herbaceous vegetation (Vrcibradic and Rocha 1998, Bonfiglio et al. 2006, Montechiaro et al. 2011), while *T.* gr. *torquatus* has a diet composed mainly by invertebrates, and occasionally small vertebrates and plants (Teixeira and Giovanelli 1999). *Salvator merianae* is a generalist species with a diversified diet based (Vanzolini et al. 1980, Kiefer and Sazima 2002, Mourthé 2010). *Oxyrhopus guibei* and *B. jararaca* has an ontogenetic shift on diet, and juvenile feeds on lizards while adults feed on small rodents (Andrade and Silvano 1996, Marques et al. 2019). *Dipsas mikanii* and *T. dorsatus* are malacophagous (Bizerra et al. 2005, Marques et al. 2019). *Xenodon neuwiedi* is an anuran-eater (Sazima and Haddad 1992; Marques et al. 2019) and feed mainly on bufonid genus *Rhinella*, including *R. ornata* (Vaz and Chinchilla 2019), the most abundant anuran in IBu.

Fossorial or cryptozoic species (amphisbaenians and snakes) represented 30% of the total reptiles sampled. Considering the historical records, it seems that only one species (*Micrurus corallinus*) was locally extinct or missed from our sampling effort. The snake *A. assimilis* feeds on elongated-shape vertebrates (Ferrarezzi et al. 2005, Marques et al. 2019). Amphisbaenians and the snake *L. beui* are mostly dependent on invertebrates, including earthworm, larvae and pupae of ants (Parpinelli and Marques 2008, Marques et al. 2019). Such prey items are common throughout urban environments (e.g., Pacheco and Vasconcelos 2007, Peng et al. 2020). Although fossorial species may be underestimated (Barbo and Sawaya 2008), their lack of depletion over time suggests that this fauna can remain in small fragments. Thus, subterranean reptiles seem resistant to environmental changes. Additional studies on underground reptiles are still needed to assess the real trend of the impact on this type of fauna due to the loss of habitat and urbanization (cf. Böhm et al. 2013).

Six reptile species, being three lizards and three snakes, were either locally extinct or missed from our sampling effort. *Ophiodes striatus, Anisolepis grilli* and *Thamnodynastes* cf. *nattereri* were recorded only in the first period (from 1901 to 1950), and *Enyalius perditus, Erythrolamprus aesculapii* and *Micrurus corallinus* were recorded only in the second period (from 1951 to 1990). The snakes *T.* cf. *nattereri* and *M. corallinus* are usually found in well-preserved and continuous forests (e.g. Forlani et al. 2010, Giraudo et al. 2012), not the current condition of the IBu. Records available for *A. grilli* and *E. aesculappi* in the city of São Paulo show that these species occur only in continuous forests surrounding the city (SVMA 2022). Therefore, these four species could be locally extinct. However, *O. striatus* and *E. perditus* can be found in urban areas and disturbed habitats, including other UGA in the city of São Paulo (Lisboa et al. 2021, SVMA 2022), indicating that these species might have been missed despite our effort rather than be locally extinct.

Amphibians and reptiles are well-sampled groups in the Brazilian Atlantic Forest, and the urban herpetofauna is becoming a target research subject over the years (e.g., Citeli et al. 2016, Lourenço-de-Moraes et al. 2018, Almeida-Correa et al. 2020, Ganci et al. 2021). Urban environments are typically characterized by lower biodiversity when compared to natural environments (Marzluff 2001; Chace and Walsh 2006). Because the major threat to reptiles and amphibians is habitat loss (Gibbons et al. 2000, Böhm et al. 2013, Vilaseñor et al. 2017), a low diversity of these groups is expected in UGA. For reptiles of different remnants of the Atlantic Forest, the fragment area may be the main predictor for species richness, but matrix quality as well as fragment shape may also be important (Lion et al. 2016). Besides, the likelihood of colonization of new species or exchange with other green areas is restricted due the low connectivity among forest fragments (Laurance et al. 2011), and the intrinsic low dispersion of these animals. Our results show that there was a decline in the species richness of surface reptiles during a temporal gradient, and we did not observe a different pattern of species loss when analyzing ecological attributes separately. Therefore, we believe that the species currently found in IBu were likely present in the past and persisted over changes in land-use.

In this work we evaluate the current herpetofauna community of an urban green area, comparing the current reptile's assemblage with historical data in a temporal scale. Taxa observed are mainly terrestrial, and feed on prey commonly found in UGA, and these traits can favor their persistence within urban environments. In the temporal comparison, there was a general decline in reptiles' richness regardless of ecological attributes, possibly resulting of loss of habitable area in Instituto Butantan. Fossorial reptiles are the group that most resisted habitat loss, with only one species locally extinct. We suggest that future studies keep monitoring this community, investigating other natural history and morphology traits for sampled species, aiming to record possible local adaptations in comparison with populations living in natural areas.

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Authors' Contribution

Eletra de Souza: conceptualization, resources, methodology, writing – original draft, writing – review & editing.

Jade Lima-Santos: conceptualization, resources, methodology, writing – review & editing.

Otavio Augusto Vuolo Marques: resources, writing – review & editing.

Erika Hingst-Zaher: conceptualization, resources, writing – review & editing.

Conflicts of Interest

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

Ethics

This study did not involve human beings and/or clinical trials that should be approved by one Institutional Committee.

Data Availability

The datasets generated during and/or analyzed during the current study are available at: https://datadryad.org/stash/share/6qnNreavbbAehOPpBD4-FTY3iWGucvdDgZU2iKIrS0o

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