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Herpetofauna From an Atlantic Forest Fragment in São Paulo, Brazil

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***Abstract*.—Habitat loss via urbanization is a cause of decline for reptile and amphibian species around the world. The Atlantic Forest is the second largest rainforest of South America and holds one of the most extraordinary herpetofauna in the world, even after decades of fragmentation. The Parque Estadual das Fontes do Ipiranga (PEFI) is one of the most important remnants of Atlantic Forest inside the city of São Paulo (Brazil), but its herpetofauna richness has not been studied. Between 2011 and 2014, we carried out a herpetofaunal inventory in the PEFI and made notes on habitat use by using pitfall traps with drift fences combined with acoustic and visual encounter surveys. We also collected data from opportunistic encounters and historical information from scientific collections. We found that the PEFI harbors 22 native species of anurans, 24 native species of reptiles, and three exotic species of reptiles. Also, through surveying scientific collections, we found three species of amphibians and one of the snakes that were detected in the past but were not detected during our survey. The composition of amphibian species in the PEFI is similar to proximal small urban and periurban Atlantic Forest fragments, but its species richness is higher than these fragments even when compared to areas with similar or larger size. In conclusion, the highly urban PEFI supports considerable herpetofaunal diversity in comparison with other regional areas and our data reinforce the necessity of conserving this and other urban forest fragments through strategic management across the Atlantic Forest.**

Key Words.—inventory; herpetofauna conservation; habitat fragmentation; urban parks

Introduction

It has been widely demonstrated over the last few decades that species from diverse taxonomic groups from different parts of the world are being threatened due to human alteration of natural ecosystems (Butchart et al. 2010; Barlow et al. 2016). Fragmentation and degradation of the environment for urban and agricultural development are some of the most important human actions linked to biodiversity loss (McKinney 2006; Didham 2010; Seto et al. 2012). These habitat modifications result in rapid reduction of habitat area, increases in edge effects, and changes in biotic and abiotic climatic conditions (Saunders et al 1991; Flather and Bevers 2002; Watling and Donnelly 2008). These effects yield consequences such as decreased species richness (Delis et al. 1996; Becker et al. 2007), population isolation (Shirk et al. 2014), reduced genetic variation and changes in species morphology (Da Silva and Tolley 2013). Reptiles and amphibians are particularly affected by such habitat modifications (Hamer and McDonnell 2008; Bishop et al. 2012; Böhm et al. 2013). For example, their sensitivity to changes in microclimatic conditions can affect their physiological performance, behavior (López-Alcaide and Macip-Rios 2011; Nowakowski et al. 2018; Miller et al. 2018), and their immunology (Belasen et al. 2019). Also, disconnection and destruction of their habitats impact the migration and dispersion of individuals and their survival (Russell et al. 2005; Becker et al. 2007; Whittaker et al. 2013).

The Atlantic Forest is one of the most important morphoclimatic domains (*sensu* Ab'Sáber 1977) of South America because it contains high biodiversity and endemism, including 320 species of reptiles (Tozetti et al. 2017) and 625 species of amphibians (Rossa-Feres et al. 2017). Additionally, this region has been named a global Biodiversity Hotspot (Myers et al. 2000; Ribeiro et al. 2011; Joly et al. 2014); however, due to high exploitation of its natural resources, only 11–16% of the Atlantic Forest retains its original forest cover (Ribeiro et al. 2009; Ribeiro et al. 2011; Joly et al. 2014). Even though some well-preserved expansive forest fragments remain, which are mainly located in the São Paulo

State (Ribeiro et al. 2011), the majority of the habitat consists of small, isolated fragments in heavily human-modified landscapes, often inside urban centers (Freitas et al. 2010; Joly et al. 2014; Scarano and Ceotto 2015). Therefore, the maintenance and preservation of each of these fragments are important for the conservation of the Atlantic Forest (Joly et al. 2014).

The largest city in South America, São Paulo, Brazil, is located entirely within the historical range of the Atlantic Forest. Thirty percent of its area contains natural vegetation (Martins 2017) distributed in forest remnants within an urban matrix, supporting a high diversity of reptiles and amphibians (Malagoli 2008; Marques et al. 2009; Barbo et al. 2011). One of the most significant forest remnants in the city is the Parque Estadual das Fontes do Ipiranga (PEFI), which is isolated inside the city and has a history of severe environmental degradation (Godoy and Trufem 2007; Matheus 2008; Tanus et al. 2012). It is important to note, however, that there have been no previous studies of the herpetofauna community in this area (Bicudo et al. 2002), so its biodiversity is known only from sporadic collections of specimens during the 1950s and 1960s (Malagoli 2008). Because of the lack of data on herpetofauna in this important region, we conducted an inventory of amphibians and reptiles of the PEFI to estimate current diversity in this urban forest island and provide a brief description of their habitat use. In addition, we compared the amphibian richness from the PEFI with that of other fragments of the Atlantic Forest in São Paulo State to assess the importance of this urban fragment in maintaining regional amphibian and reptile diversity.

Materials and Methods

Study site.—The PEFI is located in the southeastern portion of the municipality of São Paulo (23°39'09"S, 46°37'26"W, 770–825 m above sea level; Bicudo et al. 2002) in southeastern Brazil (Fig. 1). This fragment is within in the Atlantic Forest morphoclimatic domain (*sensu* Ab'Saber 1977), covered by vegetation in different successional stages (Gomes et al. 2003) and with vegetational characteristics representing both dense ombrophilous (i.e., rainy) and semideciduous forests (Tanus et al. 2012). The climate of the region is characterized by a dry winter (April to September) and a rainy summer (October to March), with average temperatures varying from 18º C in winter to 22º C in summer (Santos and Funari 2002). The PEFI harbors 24 natural springs and the Pirarungáua Stream, a tributary of the Ipiranga River, which is an important river running through São Paulo (Godoy and Trufem 2007; Matheus 2008). These water features help sustain habitat for

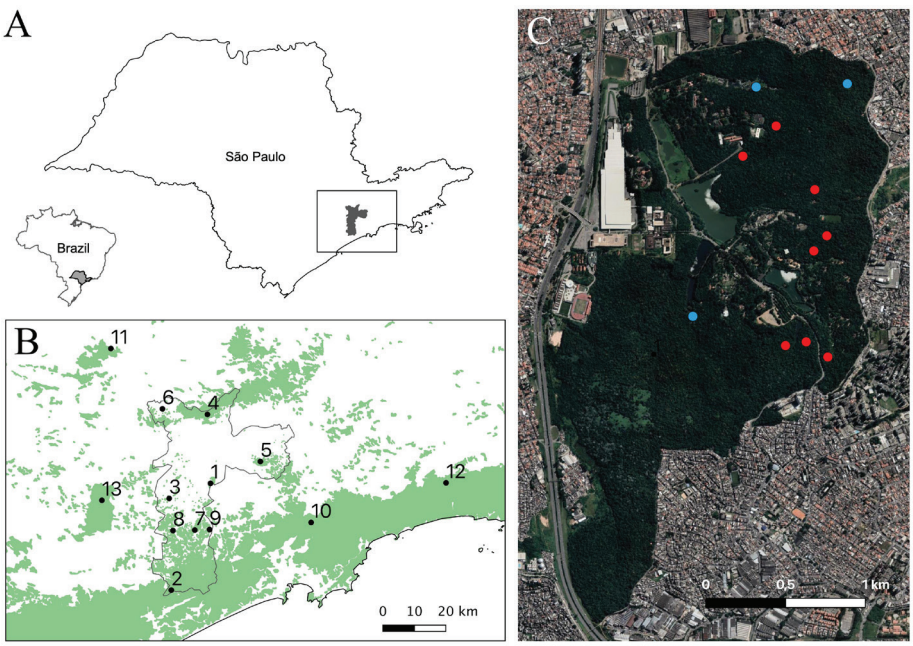

Figure 1. (A) Maps of Brazil and São Paulo State. (B) Atlantic Forest fragments from São Paulo State: (1) Parque Estadual das Fontes do Ipiranga/PEFI; (2) Parque Estadual da Serra do Mar/Curucutu; (3) Parque Ecológico Guarapiranga; (4) Parque Estadual da Cantareira; (5) Parque do Carmo; (6) Parque Anhanguera; (7) Parque Varginha; (8) Parque Jaceguava; (9) Fazenda Castanheiras; (10) Reserva Biológica do Alto da Serra de Paranapiacaba; (11) Área de Proteção Ambiental Jundiaí /Serra do Japi; (12) Estação Biológica de Boracéia; (13) Reserva Florestal de Morro Grande/Cotia. The black line polygon represents the limits of São Paulo municipality. (C) Satellite image of PEFI, sample sites are represented by dots (red = pitfall-traps and blue = water bodies).

several species of native flora and fauna (Bicudo et al. 2002). The total area of the PEFI is 526 ha, with 345 ha of disturbed but conserved forest and 181 ha of urbanized area with government agencies inserted (Gomes et al. 2003; Tanus et al. 2012; Formenton-Silva and Rancura 2020). The area surrounding PEFI is highly inhabited and urbanized, completely isolating the park from other forest areas (Formenton-Silva and Rancura 2020).

The PEFI was officially established in 1969, but its boundaries were previously defined in 1895 when the government expropriated areas to conserve the watershed (Bicudo et al. 2002; Godoy and Trufem 2007; Matheus 2008). Before the expropriation, much of the land located within the PEFI was used for coffee plantations and other agricultural practices (Godoy and Trufem 2007). Since 1928, several governmental institutions have been established within the PEFI (Godoy and Trufem 2007). These include the Institute of Botany (IBOT), the São Paulo Zoo (FPZSP), and the Park of Science and Technology of University of São Paulo (CIENTEC), which are open for public visitation and, together, receive about 1.5 million visitors per year (Zoológico de São Paulo. 2021. Visitas e Ingressos. Zoológico de São Paulo. Available from http://www.zoologico.com.br [Accessed 8 March 2021]). The forested areas within IBOT show the most advanced stages of vegetation regeneration. In contrast, the vegetation of CIENTEC is the most disturbed, with discontinuous canopy due to fire activity from an event in 1993 (Pivello and Peccinini 2002). The extensive use of the region by the surrounding community contributes to the pollution of the forest and water bodies (Matheus 2008; Gomes et al. 2003).

Data collection.—We sampled herpetofauna in public, service, and forested areas of PEFI, including artificial and natural water bodies. The forested areas are within the perimeter of the institutions, and the public and service areas are composed of buildings, paved roads, gardens, and artificial lakes. We conducted Acoustic Encounter Surveys (AES) and Visual Encounter Surveys (VES; *sensu* Crump and Scott Jr. 1994; Zimmerman 1994) from September 2011 to December 2014. Although we primarily surveyed at night (1800–2200), we also conducted occasional daytime searches. We sampled in groups of two to three people each night over 29 d of sampling. We also used pitfall traps (PT; *sensu* Corn 1994) arranged in eight stations (Fig. 1), with four placed in a line and four in a Y-formation. Each station included five 60 L plastic buckets buried in the ground and placed 5 m apart enclosed with 0.9 m (height) plastic canvas as a fence. We opened traps monthly for three to five consecutive days, with daily inspection, between September 2011 to December 2012, totaling 58 d of sampling. During the period between samples, pitfall traps remained safely closed.

We also included opportunistic encounters (OE) for specimens found by local people (citizens, visitors, and employees) or by the authors from January 2010 to December 2015, totaling 128 d of encounter records. The specimens found by local people were reported to the Herpetology Department of FPZSP and captured by its biologists, because this institution is responsible for protecting and documenting local fauna. The identification was always performed by one of the authors before depositing them in scientific collection or releasing them in the PEFI. Also, we referred to scientific collections at Museu de Zoologia da Universidade de São Paulo (MZUSP), Museu de Zoologia da Universidade Estadual de Campinas (ZUEC), and the Instituto Butantan (IBSP) to obtain historical information on the herpetofauna of the PEFI as these institutions keep specimens collected from the region in the past (Appendix Table 1).

We collected one to seven voucher specimens per species. These specimens were euthanized by a veterinarian with an intracardiac injection of T61® (embutramide, mebezonium iodide, and tetracaine hydrochloride) after exposure to an adequate level of anesthesia using isoflurane (100%) inhalation for amphibians and ketamine (100 mg/kg) intramuscular injection for reptiles, following the ethical guidelines of the Brazilian Veterinary Council (Conselho Federal de Medicina Veterinária 2013). We deposited specimens in the scientific collections of MZUSP and ZUEC (Appendix Table 1). We followed Frost (2021) for the taxonomic nomenclature and for the common names for amphibians. For the taxonomic nomenclature for reptiles, we followed Costa and Bérnils (2018) and for the common names we followed the Reptile Database (Reptile Database. 2021. Peter Uetz. Available from http://www.reptile-database.org/ [Accessed 16 March 2021]).

Data analysis.—We compared the composition of the amphibian assemblage of the PEFI with those of 12 fragments of Atlantic Forest located 16–75 km from the PEFI: Parque Estadual da Serra do Mar/Curucutu, Parque Ecológico Guarapiranga, Parque Estadual da Cantareira, Parque do Carmo, Parque Anhanguera, Parque Varginha, Parque Jaceguava, Fazenda Castanheiras (Lourenço-de-Moraes et al. 2018), Reserva Biológica do Alto da Serra de Paranapiacaba (Verdade et al. 2009), Área de Proteção Ambiental Jundiaí /Serra do Japi (Haddad and Sazima 1992; Ribeiro et al. 2005), Estação Biológica de Boracéia (Heyer et al. 1990), and Reserva Florestal de Morro Grande/Cotia (Dixo and Verdade 2006; Fig.1; Appendix Table 2). These

fragments had their amphibian assemblage sampled by the same methods used here, such as AES, VES, and PT (see Heyer et al. 1990; Haddad and Sazima 1992; Dixo and Verdade 2006; Verdade et al. 2009; Lourenço-de-Moraes et al. 2018). We made comparisons using a Cluster Analysis with the weighted pair group method with arithmetic averaging (WPGMA; Krebs 1999), and by using a Similarity Analysis (Wolda 1981) with absence and presence data, both based on Jaccard index.

We determined the consistency of the analyses by the Cophenetic Correlation Coefficient (*r*; Romesburg 1984) by correlating the original similarity matrix with that obtained from the dendrogram, with *r* values ≥ 0.9 considered a very good fit, $0.8 \leq r < 0.9$ good fit; $0.7 \leq r < 0.8$ poor fit, and $r < 0.7$ very poor fit (Rohlf 2000). Additionally, we performed a Mantel Test based on the Pearson's Correlation Coefficient (*r* value) to verify if the geographic distance among analyzed fragments was correlated with similarity in species composition between fragments. We used the Dice Index (equivalent to Sørensen Index) for species similarity (considering presence/absence), and the Euclidean Distance Coefficient for geographic distances (in decimal degrees) between the fragments with 5,000 permutations and the significance level set at $\alpha = 0.05$ (Zar 1999). We performed all analyses with the software Past 2.17 (Hammer et al. 2001). We excluded species classified as undetermined, such as: sp. (unidentified species), gr. (species group), aff. (*affinis*), or cf. (*confer*), and exotic species (American Bullfrog, *Lithobates catesbeianus*). We did not include reptile assemblages in these analyses because there are only three areas with data available for reptiles.

Results

Species composition and habitat use: *Amphibians*.— We documented 22 species of anurans in the PEFI (Appendix Table 3; Fig. 2), with most (54%) belonging to Hylidae. We recorded 20 species by VES, 18 by AES, nine by OE and, eight by PT. Overall, we recorded 72% of species by more than one method. We found that 27.3% of species occurred in all sampled areas of PEFI, 31.8% occurred in two areas, and 22.7% exclusively in the forest area (Appendix Table 3). We found the Burmeister's Treefrog (*Boana prasina*), the Yellow Cururu Toad (*Rhinella icterica*), and the Butter Frog (*Leptodactylus latrans*) only in public areas of IBOT, using artificial lakes for calling. Other species, such as Campo Belo Snouted Treefrog (*Scinax crospedospilus*), Hay's Snouted Treefrog (*Scinax hayii*), and American Snouted Treefrog (*Scinax imbegue*) called from vegetation around artificial lakes and in forest edges, but not within forest areas. Reproductive activity of the Atlantic Forest Treefrog (*Bokermannohyla hylax*), such as calling and egg laying, occurs only in Pirarungáua Stream. Marbled Tropical Bullfrog (*Adenomera marmorata*), Clay Robber Frog (*Haddadus binotatus*), and Big-headed Frogs (genus *Ischnocnema*) inhabit leaf litter.

In scientific collections, we found twelve species, of which we did not detect three during our survey: the Izecksohn's Treefrog (*Bokermannohyla izecksohni*), the Spinythumb Frog (*Crossodactylus boulengeri*), and the Mantagnes Dwarf Frog (*Physalaemus maculiventris*). These species were last recorded from the PEFI in the 1960s. The Mantagnes Dwarf Frog is the most represented with 29 specimens, followed by the Izecksohn's Treefrog (five specimens) and the Spinythumb Frog (four specimens).

Reptiles.—We encountered 24 species of native reptiles in the PEFI, including three species of turtles, seven lizards, two amphisbaenians, and 12 snakes (Appendix Table 3; Fig. 3). We recorded all 24 species by OE, five species by PT (four lizards and one snake), and six by VES (five lizards and one snake). We registered three adults of the South-American Snake-headed Turtle (*Hydromedusa tectifera*) and one young of the Geoffroy's Side-necked Turtle (*Phrynops geoffroanus*) crossing streets inside or outside institutions. Also, we registered six newly hatched of the South-American Snake-headed Turtle leaving the nest located in a garden in the public area of FPZSP, and one adult of the Spine-necked Swamp Turtle (*Acanthochelys spixii*) on a grassy field that borders a forested area. Besides these native species, we recorded two exotic species, the Black-bellied Slider (*Trachemys dorbigni,* native to southern Brazil) and the Red Eared Slider Turtle (*Trachemys scripta elegans,* U.S. native), both living in the artificial lakes of IBOT.

Among lizards, we recorded two species only in the public and service areas of PEFI. Two species show wide distribution and two occurred only within the forest and in its edges (Appendix Table 3). All amphisbaenians and seven snake species were recorded only in service and public areas of FPZSP, found mostly by visitors and employees. We registered most of the snakes crossing streets or as road kills and only two species were recorded in all areas of PEFI (Appendix Table 3). In scientific collections, we found seven species, of which we did not detect one during our survey, the Coastal House Snake (*Thamnodynastes nattereri*). This species was last recorded at the PEFI in 1964 from two specimens collected.

Comparison between forest fragments.—The amphibian assemblage of the PEFI was more similar to nearby small fragments located in periurban (Parque Varginha, Fazenda Castanheiras, and Parque

Figure 2. Amphibian species recorded in Parque Estadual das Fontes do Ipiranga, Brazil: a = *Ischnocnema henselii*; b = *Ischnocnema parva*; c = *Rhinella ictterica*; d = *Rhinella ornata*; e = *Haddadus binotatus*; f = *Aplastodiscus leucopygius*; g = *Boana polytaenia*; h = *Boana bischoffi*; i = *Boana faber*; j = *Boana prasina*; k = *Bokermannohyla hylax*; l = *Bokermannohyla luctuosa;* m = *Scinax hiemalis*; n = *Scinax crospedospilus*; o = *Scinax fuscovarius*; p = *Scinax hayii*; q = *Scinax imbegue*; r = *Adenomera marmorata*; s = *Leptodactylus latrans*; t = *Physalaemus cuvieri*; u = *Physalaemus olfersii.* (Photographs f, g, n and q by Daniel F. Perrella, u by Renata I. Vaz, and all others by Cybele S. Lisboa). Common names are provided in Appendix Table 3.

Jaceguava) and urban surroundings (Parque Ecológico Guarapiranga, Parque do Carmo, and Parque Anhanguera), comprising a group with about 42% similarity (Cophenetic Correlation Coefficient: $r = 0.88$; Fig. 4). Geographical distance was correlated with the similarity in composition of species in each of the fragments ($r = 0.529$; $P < 0.001$).

Discussion

Considering the importance of Atlantic Forest fragments from herpetofauna perspective, we conducted an inventory of amphibians and reptiles of the PEFI. The anuran species that we found or that had been previously recorded in this fragment represented

Figure 3. Reptile species recorded in Parque Estadual das Fontes do Ipiranga, Brazil: a = *Acantochelys spixii;* b = *Hydromedusa tectifera*; c = *Phrynops geoffroanus;* d = *Ophiodes striatus*; e = *Placosoma glabellum*; f = *Enyalius iheringii*; g = *Enyalius perditus*; h = *Urostrophus vautieri*; i = *Salvator merianae*; j = *Tropidurus torquatus*; k = *Amphisbaena dubia*; l = *Leposternon microcephalum*; m = *Chironius bicarinatus*; n = *Chironius exoletus*; o = *Atractus trihedrurus*; p = *Echinanthera undulata*; q = *Helicops modestus*; r = *Oxyrhopus clathratus*; s = *Philodryas patagoniensis*; t = *Taeniophallus affinis*; u = *Tomodon dorsatus*; v = *Tropidodryas striaticeps*; w = *Xenodon neuwiedii*; x = *Bothrops jararaca.* (Photograph a by Daniel F. Perrella, j by Janaína Moraes, and all others by Cybele S. Lisboa). Common names are provided in Appendix Table 3.

approximately 10.5% of the total anuran richness known for the Atlantic Forest of São Paulo State (209 species; Rossa-Feres et al. 2017) and the reptile species represented approximately 12.4% (194 species; Zaher et al. 2011). The PEFI harbors both disturbance-tolerant species and those that require intact natural habitats due to their highly specific environmental requirements. The former includes the Bischoff's Treefrog (*Boana bischoffi*), the Smith Frog (*Boana faber*), the Cuvier's Foam Froglet (*Physalaemus cuvieri*), the toad *Rhinella ornata*, the Black and White Tegu (*Salvator merianae*), and the Jararaca (*Bothrops jararaca*). The latter include the Atlantic Forest Treefrog (*Bokermannohyla hylax*), the frog *Ischnocnema* sp. (gr. *lactea*), the Ihering's

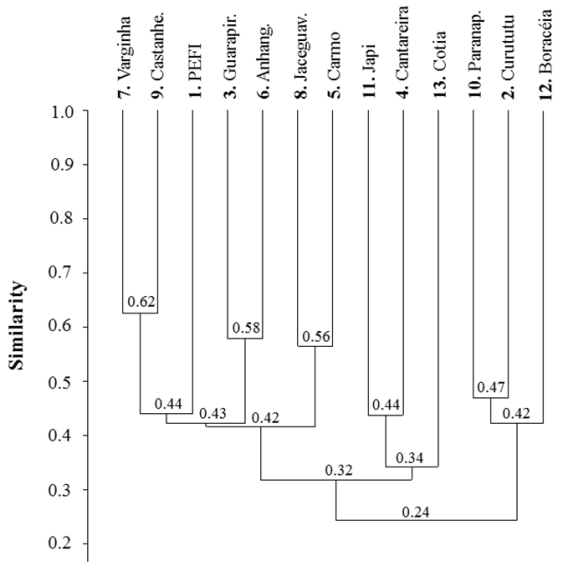

Figure 4. Dendrogram resulting from the Cluster and Similarity analyses based on the Jaccard Index (values presented in the basis of each branch) of amphibian species composition among 13 Atlantic Forest fragments from São Paulo State, Brazil. Fragments are 1. PEFI = Parque Estadual das Fontes do Ipiranga; 2. Curucutu = Parque Estadual da Serra do Mar/Curucutu; 3. Guarapir. = Parque Ecológico Guarapiranga; 4. Cantareira = Parque Estadual da Cantareira; 5. Carmo = Parque do Carmo; 6. Anhang. = Parque Anhanguera; 7. Varginha = Parque Varginha; 8. Jaceguav. = Parque Jaceguava; 9. Castanhe. = Fazenda Castanheiras; 10. Paranap. = Reserva Biológica do Alto da Serra de Paranapiacaba; 11. Japi = Área de Proteção Ambiental Jundiaí /Serra do Japi; 12. Boracéia = Estação Biológica de Boracéia; 13. Cotia = Reserva Florestal de Morro Grande/Cotia.

Fathead Anole (*Enyalius iheringii*), the Southern Ground Snake (*Atractus trihedrurus*) and the Jiboinha (*Tropidodryas striaticeps*; Condez et al. 2009; Marques 2009; Marques et al. 2009; Passos et al. 2010). Taken together, these results argue that the PEFI is an important conservation target to protect herpetofauna.

The PEFI has a history of isolation by urbanization similar to many forest fragments in Brazil (e.g., Mantovani 2005; Souza et al. 2013; Lourenço-de-Moraes et al. 2018) and around the world (e.g., Dawson and Hostetler 2008; Hamer and McDonnell 2008; Li et al. 2018). In the cluster analysis, the PEFI was grouped with proximal small forest fragments in urban areas of São Paulo city. Equivalently, the other clusters point to the similarity between larger fragments and those with greater connection with large forests, similar to other studies in the Atlantic Forest (e.g., Lourenço-de-Moraes et al. 2018) and in the Amazon Forest (e.g., Menin et al. 2019).

Although the composition of amphibian species in the PEFI is similar to proximal urban and periurban forest fragments, its species richness is the highest of these same fragments, even when compared to areas with similar or larger size such as Parque do Carmo and Parque Anhanguera, and also with the nearest areas as Parque Ecológico Guarapiranga, Parque Varginha, Fazenda Castanheiras and Parque Jaceguava (Lourenço-de-Moraes et al. 2018; Appendix Table 2). Parque Anhanguera is the largest of the areas we compared, so we would expect greater species richness there; however, much of that park is covered with non-native vegetation (mostly eucalyptus, *Eucalyptus* spp.), while the other parks maintain a mix of native and exotic vegetation species (Mantovani 2005; Martins 2017). The PEFI, in contrast, even with the small size and disturbances, maintains a mosaic of habitats, as forest habitat, open areas, and water bodies (natural and artificial), which helps to maintain such diversity (Beninde et al. 2015). Other studies of herpetofauna in isolated fragments have indicated that the quality and heterogeneity of microhabitats predict elevated taxonomic richness (Parris 2006; Bickford et al. 2010; Hanson and McElroy 2015; Vanegas-Guerrero et al. 2016; Li et al. 2018).

Conservation implications.—It is important to highlight that, analyzing historical records from the PEFI on scientific collections, we found three species of amphibians and one snake, which we did not detect during our survey. It is possible that the disappearance of the Spinythumb Frog (*Crossodactylus boulengeri*) resulted from the degradation of its breeding habitat. Although the habitat use and reproduction of this species are unknown, we assume that they were similar to other congeners, breeding in streams with calm waters, and placing the eggs in crevices under rocks or stones (Heyer et al. 1990; Nascimento et al. 2005; Almeida-Gomes et al. 2007; Vidigal et al. 2018). Currently, such habitats no longer exist in the PEFI. Causes of decline of the Izecksohn's Treefrog (*Bokermannohyla izecksohni*) and of the Mantagnes Dwarf Frog (*Physalaemus maculiventris*) may be attributable to the synergistic effects of factors such as clearings and/or deforestation, diseases, or even the anthropogenic noise (e.g., Lengagne 2008; Dixo et al. 2009; Francis and Barber 2013; Goutte et al. 2013). The last record of the Coastal House Snake (*Thamnodynastes nattereri*) in the PEFI was from 1964, and this is the only record of this species for São Paulo city. This species usually is found in intact, continuous forests (Domenico 2008; Condez et al. 2009; Araujo et al. 2010; Forlani et al. 2010), which is not the condition of the PEFI.

Parque Estadual das Fontes do Ipiranga is a forest fragment inside a major metropolitan area where the impacts of urban activities, contamination, and anthropogenic noise surely negatively impact resident species (Elmqvist et al. 2016; Lourenço-de-Moraes et al. 2018). Specifically, the intense movement of people and vehicles related to the included institutions there leads to

road mortalities, both within and between institutions, as animals move between plots of forests. During our study, we found 10 specimens road-killed, represented by amphibians, lizards, amphisbaenians, and snakes. Recent studies have emphasized the great significance of this type of impact on fauna (Sássi et al. 2013; De La Ossa-Nadjar and De La Ossa V. 2015; Braz and França 2016), primarily on small vertebrates with reptiles and amphibians the most affected (Centro Brasileiro de Ecologia de Estradas. 2013. Sistema Urubu. Centro Brasileiro de Ecologia de Estradas. Available from http://cbee.ufla.br [Access 04 December 2019]). With regard to the turtles of the PEFI, we consider that populations of the exotics *Trachemys scripta* and *T. dorbigni* living in IBOT lakes could be a problem. These species often have competitive advantages over native species and compete with resident species for environmental resources such as food, places for nesting, and for basking sites (Cadi and Joly 2004).

Citizen science uses.—Opportunistic encounters were essential to complement our surveys of reptile species, specifically for snakes and amphisbaenians, which are usually difficult to sample due to their secretive habits and low densities (Uetanabaro et al. 2007; Sawaya et al. 2008; Araujo et al. 2010). The PEFI, and especially FPZSP, host a large number of visitors, which increased the potential encounters for reptiles, especially snakes. Active public involvement in scientific research (citizen science) has shown great results and is a growing phenomenon (Irwin 2018; Wangyal et al. 2020), and this strategy can be used with the visitors of the institutions of the PEFI and with the surrounding community, mediated and verified by specialists, to improve knowledge of species richness.

Recently, two initiatives were launched by the Education Department of FPZSP to increase the involvement of the neighborhood and visitors with the local fauna and awareness of the conservation value of the PEFI. One of them was the creation of a project in the network iNaturalist called Biodiversidade do PEFI. The other initiative was an e-book about the PEFI to subsidize teachers and educators who work in the region (Formenton-Silva and Rancura 2020). Standardized messaging and portals to collect public sightings and photographs also should be created. We hope with these initiatives that visitors, students, and the surrounding community will feel motivated to protect this fragment and the animals present in it, as well as to continue local sampling.

The Parque Estadual das Fontes do Ipiranga supports a regional representation of Brazilian herpetofauna Atlantic Forest species, which is remarkable given its location within the expansive and densely populated São Paulo megalopolis. Further studies can help improve understanding of the ecology of extant species, the adaptive processes and how they are able to persist in the context of great densities of humans and the result of their activities. The present data reinforce the necessity, and opportunity, for the conservation of this and other urban forest fragments, through strategic management to enhance habitat quality and to enable sustainable use of the area by the community. Urban parks are important for connecting citizens with nature, so valuing the PEFI for this purpose will bring benefits to local biodiversity as people are expected to care about the environment they frequent.

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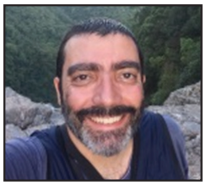
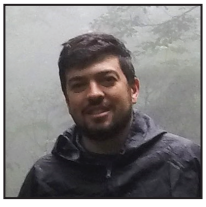


Leo R. Malagoli is a Biologist interested in urban fauna, community ecology, natural history, taxonomy and biogeography. He has been researching frogs in São Paulo municipality, Brazil, since 2001. He obtained his Ph.D. in Zoology from Universidade Estadual Paulista, Rio Claro, São Paulo, Brazil, focused on the diversity and biogeography of anurans of Serra do Mar. (Photographed by Leo R. Malagoli).



Fausto E. Barbo is a Biologist and Associate Researcher at the Instituto Butantan, Brazil, and is interested in the ecology, systematics, taxonomy, and biogeography of snakes. His MSc thesis at Universidade de São Paulo, Brazil, focused the ecology of snakes of São Paulo city, and his Ph.D. at the Universidade Estadual Paulista, São José do Rio Preto, Brazil, was on the biogeography of snakes of the Atlantic Forest. (Photographed by Leo R. Malagoli).

Rachel C. Venturini has worked as a Biology Assistant for 6 y at the Department of Reptiles, Amphibians and Invertebrates of Fundação Parque Zoológico de São Paulo, Brazil, where she performs animal husbandry and contributed to the inventory of herpetofauna. Until 2018, Rachel coordinated the Zoo Design Department at the same institution. She obtained her M.S. degree in Zoo Design from Universidade Estadual de Campinas, Brazil. (Photographed by Francine Luengo).

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Appendices

Appendix Table 1. List of specimens examined and deposited in collections of Museu de Zoologia da Universidade de São Paulo (MZUSP), Museu de Zoologia da Universidade Estadual de Campinas (ZUEC) and Instituto Butantan (IBSP).

Anura: *Adenomera marmorata* (MZUSP 15662, 82443,82444, 82445; ZUEC 19536, 19537); *Aplastodiscus leucopygius* (MZUSP 146248; ZUEC 1879, 19527); *Boana bischoffi* (ZUEC 19512–14); *Boana faber* (ZUEC 19509–11; MZUSP 157515); *Boana polytaenia* (MZUSP 10352, 157110; ZUEC 19517–18); *Boana prasinus* (ZUEC 19515–16); *Bokermannohyla hylax* (MZUSP 157105; ZUEC 19528); *Bokermannohyla izecksohni* (MZUSP 116613–17); *Bokermannohyla luctuosa* (MZUSP 157106); *Crossodactylus boulengeri* (MZUSP 9605, 9619,109436–37); *Haddadus binotatus* (MZUSP 77600, 9604,15661, 157107); *Ischnocnema henselii* (MZUSP 86824–25, 9606–07, 157099, 157109; ZUEC 19531–35); *Ischnocnema parva* (ZUEC 19529–30; MZUSP 157104); *Leptodactylus latrans* (MZUSP 157516); *Physalaemus cuvieri* (MZUSP 82757–59, 157102; ZUEC 19540–42); *Physalaemus maculiventris* (MZUSP 131096–131122; ZUEC 947–48); *Physalaemus olfersii* (MZUSP 77032–35; ZUEC 1359–60, 19538–39); *Rhinella icterica* (ZUEC 19547); *Rhinella ornata* (MZUSP 9603, 15660, 157103, 157108; ZUEC 19543–46); *Scinax crospedospilus* (ZUEC 19521–22; MZUSP 157101); *Scinax fuscovarius* (ZUEC 19519); *Scinax hayii* (ZUEC 19520); *Scinax hiemalis* (ZUEC 19524–26); *Scinax imbegue* (MZUSP 76240, 157100; ZUEC 19523)
Squamata (Lizards): *Enyalius iheringii* (MZUSP 101665, 106025); *Enyalius perditus* (MZUSP 106021, 106022); *Ophiodes striatus* (MZUSP 106028, 22837); *Placosoma glabellum* (MZUSP 101664, 106023, 106024); *Salvator merianae* (MZUSP 101666, 106031, 106032); *Urostrophus vautieri* (MZUSP 106026, 106027)
Squamata (Amphisbaenians): *Amphisbaena dubia* (MZUSP 106030); *Leposternon microcephalum* (MZUSP 106029)
Squamata (Snakes): *Bothrops jararaca* (IBSP - 70045-70048; 70457; 70511; 72410; MZUSP 22801, 22805, 22802, 22804, 22803); *Chironius exoletus* (MZUSP 18963); *Echinanthera undulata* (MZUSP 18964); *Helicops modestus* (MZUSP 22797, 22798, 22799, 22836); *Philodryas patagoniensis* (MZUSP 22800); *Taeniophallus affinis* (IBSP 70245; 70246; MZUSP 22793, 22794); *Thamnodynastes nattereri* (IBSP - 24540; 24541); *Xenodon neuwiedii* (IBSP - 24276; 24959; 25969; 27771; MZUSP 22795, 22796)

Appendix Table 2. Area, distance from Parque Estadual das Fontes do Ipiranga (PEFI) and amphibian species diversity from 12 Atlantic Forest fragments in São Paulo State, Brazil. An asterisk (*) indicates areas relative only to the portion inserted in the municipality of São Paulo.

Atlantic Forest fragment	Category	Area (ha)	Distance from PEFI (km)	Amphibian richness	Reference
Área de Proteção Ambiental Jundiaí / Serra do Japi	Not-urban	35,000	57	31	Haddad and Sazima 1992; Ribeiro et al. 2005
Estação Biológica de Boracéia	Not-urban	16,450	75.2	64	Heyer et al. 1990
Reserva Florestal de Morro Grande/Cotia	Not-urban	10,870	31.8	27	Dixo and Verdade 2006
Parque Estadual da Serra do Mar/ Curucutu	Not-urban	4,500*	39.3	54	Lourenço de Moraes et al. 2018
Parque Estadual da Cantareira	Not-urban	3,984*	24.5	41	Lourenço de Moraes et al. 2018
Parque Anhanguera	Urban	950	31.2	16	Lourenço de Moraes et al. 2018
Parque Natural Municipal Fazenda do Carmo	Urban	450	18.3	22	Lourenço de Moraes et al. 2018
Reserva Biológica do Alto da Serra de Paranapiacaba	Not-urban	426	34.2	69	Verdade et al. 2009
Parque Natural Municipal Varginha	Not-urban	420	19.5	19	Lourenço de Moraes et al. 2018
Parque Natural Municipal Jaceguava	Not-urban	425	20.5	16	Lourenço de Moraes et al. 2018
Parque Ecológico Guarapiranga	Urban	264	16.2	15	Lourenço de Moraes et al. 2018
Fazenda Castanheiras	Not-urban	150	18.5	22	Lourenço de Moraes et al. 2018

Appendix Table 3. Amphibians and reptiles recorded in Parque Estadual das Fontes do Ipiranga, Brazil, and corresponding habitat of occurrence from January 2010 to December 2015. An asterisk (*) indicates an exotic species.

Family/ Species	Forest	Edge forest	Public visitation and service areas
AMPHIBIANS			
Brachycephalidae			
Ischnocnema henselii (no common name)	X	X	
Ischnocnema parva (Girard's Robber Frog)	X		
Ischnocnema sp. (gr. *lactea*)	X		
Bufonidae			
Rhinella icterica (Yellow Cururu Toad)			X
Rhinella ornata (no common name)	X	X	X
Craugastoridae			
Haddadus binotatus (Clay Robber Frog)	X		
Hylidae			
Aplastodiscus leucopygius (Guinle Treefrog)	X	X	
Boana bischoffi (Bischoff's Treefrog)	X	X	X
Boana faber (Smith Frog)	X	X	X
Boana polytaenia (Cope's Eastern Paraguay Treefrog)	X	X	X
Boana prasina (Burmeister's Treefrog)			X
Bokermannohyla hylax (Atlantic Forest Treefrog)	X		
Bokermannohyla luctuosa (Reservoir Treefrog)	X		
Scinax crospedospilus (Campo Belo Snouted Treefrog)		X	X
Scinax fuscovarius (Snouted Treefrog)			X
Scinax hayii (Hay's Snouted Treefrog)		X	X
Scinax hiemalis (Sousas Snouted Treefrog)		X	X
Scinax imbegue (no common name)		X	X
Leptodactylidae			
Adenomera marmorata (Marbled Tropical Bullfrog)	X	X	
Leptodactylus latrans (Butter Frog)			X
Physalaemus cuvieri (Cuvier's Foam Froglet)	X	X	X
Physalaemus olfersii (Atlantic Forest Dwarf Frog)	X	X	X
REPTILES			
Chelidae			
Acantochelys spixii (Spine-necked Swamp Turtle)		X	
Hydromedusa tectifera (South-American Snake-headed Turtle)			X
Phrynops geoffroanus (Geoffroy's Side-necked Turtle)			X
*Trachemys dorbigni** (Black-bellied Slider)			X
*Trachemys scripta** (Red Eared Slider Turtle)			X
Anguidae			
Ophiodes striatus (Striped Worm Lizard)			X
Gekkonidae			
*Hemidactylus mabouia** (House gecko)			X

Appendix Table 3 (continued). Amphibians and reptiles recorded in Parque Estadual das Fontes do Ipiranga, Brazil, and corresponding habitat of occurrence from January 2010 to December 2015. An asterisk (*) indicates an exotic species.

Family/ Species	Forest	Edge forest	Public visitation and service areas
Gymnophtalmidae			
Placosoma glabellum (no common name)	X	X	X
Leiosauridae			
Enyalius iheringii (Ihering's Fathead Anole)	X	X	
Enyalius perditus (no common name)	X	X	
Urostrophus vautieri (Brazilian Steppe Iguana)		X	X
Teiidae			
Salvator merianae (Black and White Tegu)	X	X	X
Tropiduridae			
Tropidurus torquatus (Amazon Lava Lizard)			X
Amphisbaenidae			
Amphisbaena dubia (Uncertain Worm Lizard)			X
Leposternon microcephalum (Smallhead Worm Lizard)			X
Colubridae			
Chironius bicarinatus (Two-headed Sipo)			X
Chironius exoletus (Linnaeus' Sipo)			X
Dipsadidae			
Atractus trihedrurus (Southern Ground Snake)			X
Echinanthera undulata (Wellenstreifige Natter)	X	X	X
Helicops modestus (Olive Keelback)			X
Oxyrhopus clathratus (Duméril's False Coral Snake)			X
Philodryas patagoniensis (Patagonia Green Racer)			X
Taeniophallus affinis (no common name)		X	X
Tomodon dorsatus (Pampas Snake)			X
Tropidodryas striaticeps (Jiboinha)		X	X
Xenodon neuwiedii (Neuwied's False Fer-de-lance)		X	X
Viperidae			
Bothrops jararaca (Jararaca)	X	X	X