



Nesting patterns among Neotropical species assemblages: can reserves in urban areas be failing to protect anurans?

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Abstract

Nestedness among species assemblages implies that sites of lower species richness are subsets of richer sites in a regional species pool. This nestedness is a reflection of a non-random process of species loss as a consequence of factors that promote the disaggregation of assemblages. The impoverishment of assemblage diversity is more often observed in fragmented landscapes. This non-random process has important implications for conservation. We recorded 95 species of anurans across 22 protected areas, of which 11 sites were in an urban matrix and 11 were in a non-urban matrix. We found that sites in the urban matrix had lower richness and high values of nestedness with no spatial autocorrelation among geographic distances and species composition. Thus, species were non-randomly distributed across the landscape and a nested pattern was documented from non-urban matrix sites to urban matrix sites. The impoverishment of assemblages toward the urban matrix sites may suggest that protected areas in an urban matrix are less suitable for anuran conservation than those in a non-urban matrix sites. Both the ecological revitalization of protected areas in urban matrix and protection of non-urban forested sites are needed for the conservation of Neotropical anurans.

Keywords Fragmentation · Atlantic Forest · Biodiversity · Hotspot · Metacommunities

Introduction

Community ecology focuses on the patterns and mechanisms responsible for the distribution of organisms and diversity in space and time (Cadotte et al. 2006; Moore and Swihart 2007). In this sense, a set of communities connected by

dispersion is called a metacommunity (Gilpin and Hanski 1991; Wilson 1992; Leibold et al. 2004), and the distribution of nested species subsets is an ecological component of metacommunity theory (Leibold and Mikkelsen 2002). Nested species assemblages occur when biotas of sites with low species richness are subsets of biotas at richer sites

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(Wright and Reeves 1992; Ulrich and Gotelli 2007; Baselga 2010). The impoverishment of assemblage diversity is more often observed in fragmented landscapes, indicating that species loss is not a random process (Gaston and Blackburn 2000).

Nested distributions may result from differences in species attributes, such as area required, abundance, and tolerance to abiotic variables (Cook and Quinn 1998; Almeida-Neto et al. 2008). Most sites in an urban matrix do not fulfill the requirements of most species, which can promote local extinction (Patterson and Atmar 1986) and/or selective colonization (Cook and Quinn 1995). Although the local dynamics of colonization and extinction can vary over a range of habitats (Taylor and Warren 2001), nestedness analyses have traditionally been conducted on large systems such as islands and mountain ranges (e.g., Patterson and Atmar 1986; Lomolino 1996, 2000; Morrison 2013), which may exhibit patterns indicative of high levels of non-random assemblage organization. The concept of nestedness has been fundamental to understanding the effects of anthropogenic actions in a variety of landscapes (Watling and Donnelly 2007; Watling et al. 2009). Nesting patterns have been reported for fragmented environments (Rocha et al. 2014). The evaluation of nestedness over a gradient from urban to non-urban sites may promote a better understanding of how to manage urban biodiversity.

Brazil has the greatest diversity of amphibians in the world (Segalla et al. 2016) with approximately 50% of its occurring species in the Atlantic Forest (Haddad et al. 2013). Because this biome is considered one of the world's hotspots for biodiversity conservation due its high species diversity and endemism (Mittermeier et al. 2004; Rödder et al. 2007), studying anurans over an urban matrix gradient of Atlantic Forest remnants may offer a good model for conservation policies. Understanding the scale at which impacts occur is critical to the successful conservation of amphibians in urbanized landscapes (e.g., ecological corridors), because it can effectively guide conservation efforts.

Amphibians are sensitive to anthropogenic changes, even inside protected areas (Lambert 1997; Lips and Donnelly 2002; Becker et al. 2007; Francis and Barber 2013). They are the most threatened vertebrate group (Stuart et al. 2004; Wells 2007; Hoffmann et al. 2010) and are considered bioindicators of environmental quality (Wells 2007). Studies investigating amphibian community structure through co-occurrence and nestedness analyses (e.g., Tockner et al. 2006; Watling et al. 2009; Moreira and Maltchik 2012) have shown that anuran distribution patterns are related to area and isolation and their associated processes (Tockner et al. 2006; Watling et al. 2009).

Considering that the effects of urbanization should impose extinction on original assemblages, we hypothesized that anuran communities will exhibit nested patterns of species composition from sites in urban matrix toward sites in non-urban

matrix. To test this hypothesis, we surveyed the frog assemblages of 22 forest fragments in urban and non-urban matrix sites and analyzed the species composition of anurans among them. We aimed to understand: (i) if the distance between sites influences community composition, (ii) how species are distributed among sites (composition and richness), and (iii) if the proximity to urban environments influences anuran species richness. We aim to raise awareness of amphibian sensibility to anthropic environments.

Methods

Study sites

We conducted the study in the Atlantic Forest biome that has latitudinal range extending into the tropical and subtropical regions (Olson et al. 2001; Ribeiro et al. 2009). The longitudinal range of Atlantic Forest favors differences in forest composition due to a diminishing gradient in rainfall from coast (i.e., east, more rainy) to interior (i.e., west, less rainy) (Ribeiro et al. 2009).

To verify that the tested hypothesis are not influenced by forest formation, two areas were studied inside of Atlantic Forest biome both with distinct formation forest types (Fig. 1): 1) Municipality of Maringá, state of Paraná, according to Köppen-Geiger's climate system (Maack 1981; Peel et al. 2007), is classified as Cfb (humid temperate climate with temperate summer) with mean temperatures of 17.7 °C and mean annual rainfall of 1276 mm; it is located in the western part of the biome (Figs. 1 and 2), with formations of warmer and seasonal forests (Olson et al. 2001); and 2) municipality of São Paulo, state of São Paulo is classified as Cwa (humid temperate climate with dry winter and hot summer) with mean temperatures of 18.5 °C and mean annual rainfall of 1340 mm, well distributed throughout the year (Peel et al. 2007); it is located in the eastern region of biome (Figs. 1 and 2), with non-seasonal rainforest formations (Olson et al. 2001).

Spatial species data

Our work was focused on 22 protected areas (PAs) from two municipalities of Brazilian Atlantic Forest (Fig. 1). The protected areas were chosen following three conditions proposed for the occurrence of nesting patterns: i) a common biogeographical history, ii) similarity of composition among habitats, and iii) a hierarchical relationship of niches (e.g., presence of specialist and generalist species, see Patterson and Brown 1991). In the municipality of Maringá (23° 25'S, 51° 55'W) (Fig. 2), we sampled four urban matrix PAs and six non-urban matrix PAs between 2005 and 2016. In the municipality of São Paulo (23°37'S, 46°42'W) (Fig. 2), we sampled

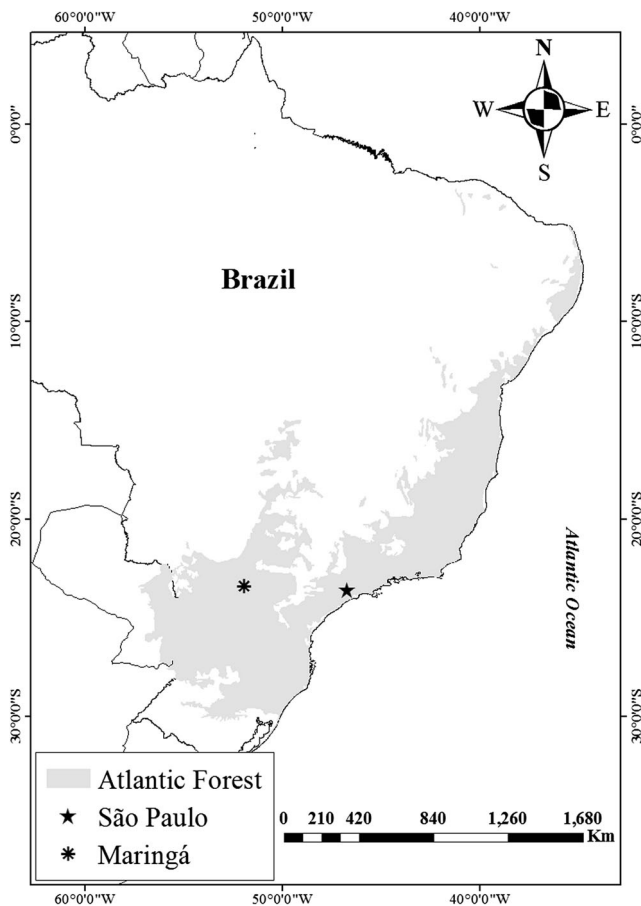


Fig. 1 Location of studied areas in the Brazilian Atlantic Forest (gray)

seven urban matrix PAs and five non-urban matrix PAs between 1996 and 2017.

We evaluated the effect of urbanization on PAs by determining the oldest urbanized areas of both municipalities. The PAs were classified according to “time of urbanization”: i) oldest urbanized area (i.e., >50 years of urbanization); ii) periphery of urban matrix (i.e., <50 years of urbanization); and iii) non-urban matrix (see Fig. 2). The time of urbanization was determined according to data available at official websites from both municipalities (Maringá: <http://www2.maringa.pr.gov.br/site/> and São Paulo: <http://www.capital.sp.gov.br/>). We assumed that anurans from PAs within the oldest urbanized area were more prone to the effects of urbanization (e.g., reduction of gene flow with other populations).

To compile data on species richness for each selected PA, we adopted three procedures: i) fieldwork by the authors, ii) bibliographic records, and iii) search in zoological collections. The anurans were sampled using pitfall traps with drift fences in 14 PAs (Corn 1994), and with acoustic and visual nocturnal and diurnal surveys in all available habitats (e.g., water bodies, leaf-litter and bromeliads) and along 100 m forest transects in 22 PAs (Crump and Scott Jr 1994; Zimmerman 1994). In addition, the data were also complemented from information available in the literature and visits to three zoological collections

(Museu de Zoologia da Universidade de São Paulo – MZUSP, Museu de Zoologia da Universidade Estadual de Campinas – ZUEC, and Coleção “Célio F. B. Haddad” Universidade Estadual Paulista – CFBH).

The urban matrix PAs were more sampled to have the maximum information about the species richness. For the details of the methods and data sources for each area see Supplementary Material 1.

We used the Red List of threatened species of the International Union for Conservation of Nature (IUCN 2016) for assessing the conservation status of species. The taxonomic nomenclature followed Frost (2017).

Data analysis

We used the Mantel test to assess the relationship between geographic distance (i.e., degree of isolation of sites) and species composition among sites (Legendre and Fortin 1989). The Z statistic calculated by the Mantel test indicates the degree of spatial correlation among the data. The test was performed by correlating a dissimilarity matrix (Euclidian distance) with a matrix of species presence or absence (Jaccard). A total of 1000 permutations were performed for null models (Legendre and Anderson 1999).

We used a null model analysis with the *c-score* index to explore the pattern of species co-occurrence and to test whether the distribution is random or due to interspecific interaction mechanisms (i.e., biotic and abiotic interactions) (Gotelli and Graves 1996). An equiprobable-equiprobable null model with 1000 simulations was implemented by randomizing species occurrence and assuming that species occurrences in environments were equally likely, that is, equal probabilities for each species to occur in each environment (Gotelli and Graves 1996).

We calculated a nestedness metric based on overlap and decreasing fill (index NODF) (Almeida-Neto et al. 2008; Ulrich et al. 2009) to determine if the spatial pattern among communities is nested, as well as to verify if there is a nested gradient from the non-urban matrix toward the urban matrix. According to this nestedness metric, two basic properties are required to have the maximum degree of nestedness: (i) complete overlap of 1’s from right to left and from down to up rows, and (ii) marginal decreasing totals between all pairs of columns and all pairs of rows. The nestedness statistic is evaluated separately for columns (N columns), and rows (N rows), and combined for the whole matrix (NODF). The columns of species are ordered according to their presence in sites (species that occurs in all sites is ordered in the first column), rows are ordered according to the species richness in each site. These procedures create a gradient allowing to evaluate the sites that provide species for a subset of species/sites, forming a nested pattern. We used null models to test whether the generated values differ from those expected at random.

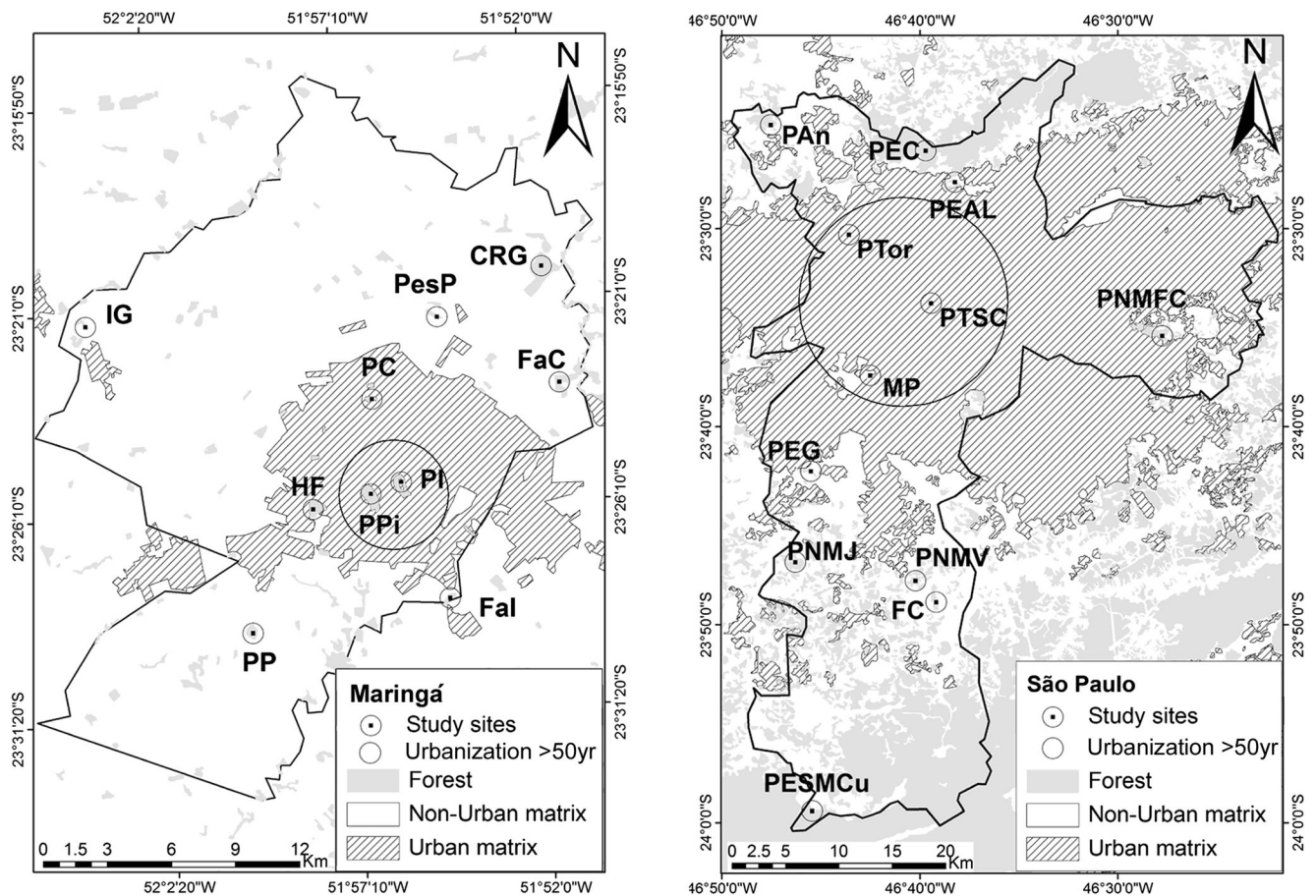


Fig. 2 Location of study sites in the municipality of Maringá and São Paulo (Black line). Study sites: FaC = Fazenda Cesumar; PP = Parque das Perobas; IG = Iguatemi; PC = Parque do Cinquentenário; FaI = Fazenda Ibiteca; CRG = Condomínio Recanto dos Guerreiros; PesP = Pesqueiro do Português; HF = Horto Florestal; PPI = Parque dos Pioneiros; PI = Parque do Ingá. São Paulo study sites: PAn = Parque Anhanguera; PEC = Parque Estadual da Cantareira; PEAL = Parque Estadual Alberto

Löfgren “Horto Florestal”; PTor = Parque Cidade de Toronto; PTSC = Parque Tente Siqueira Campos “Trianon MASP”; PNMFC = Parque Natural Municipal Fazenda do Carmo; MP = Marginal Pinheiros - Área do Projeto Pomar; PEG = Parque Ecológico Guarapiranga; PNMJ = Parque Natural Municipal Jaceguava; PNMV = Parque Natural Municipal Varginha; FC = Fazenda Castanheiras; PESMCu = Parque Estadual da Serra do Mar - Núcleo Curucutu

The null models randomize the occurrence of the taxa between the sites sampled, keeping fixed the sums of the columns (species). To perform this analysis, original matrices were submitted to 1000 simulations.

To evaluate the nesting effects of sites with higher species richness towards the sites with smaller species richness, we partitioned beta diversity into two separate components of species, turnover and nestedness-resultant dissimilarities (Baselga 2010). This method partitions the pairwise Sørensen dissimilarity between two communities (β_{sor}) into two additive components accounting for species spatial turnover (β_{sim}) and nestedness-resultant dissimilarities (β_{sne}). Since β_{sor} and β_{sim} are equal in the absence of nestedness, their difference is a net measure of the nestedness-resultant component of beta diversity, so $\beta_{sne} = \beta_{sor} - \beta_{sim}$ (Baselga 2010). We used the function ‘beta.pair’ that returns three matrices containing the pairwise between-site values of each component of beta diversity (Baselga and Orme 2012).

We followed the gradient provided by NODF index for analysis of beta diversity partitioning. Only the values of β_{sne} are presented (mean, standard deviation, higher and lower value), under the effect of nestedness the first major and second major biota provided by NODF at all sites.

To test whether a negative species gradient with increasing β_{sne} values occurs (increased nesting decreased species richness), we used a simple linear regression between the larger biota provided by index NODF and all sites (subset). To test whether the total area of PAs is significantly different between urban and non-urban matrices, we used Mann-Whitney Test after evaluating data normality using Shapiro test. We also used these statistical tests to evaluate a gradient of species richness between PAs from the urban matrix to the non-urban matrix, in the three urbanization time periods (see above). We performed analyses for both localities separately using the package ‘vegan’ (Oksanen et al. 2007) and ‘betapart’ package (Baselga and Orme 2012) in R (R Development Core Team 2017).

Results

We recorded 95 species of which 27 were from Maringá, 81 from São Paulo, and 13 common to both localities (Supplementary Material 2, 3, and 4). Regarding conservation status, we found the Near Threatened *Crossodactylus schmidti* in Maringá and the Critically Endangered *Bokermannohyla izecksohni* in São Paulo. The other species are listed in either Least Concern (LC) or Data Deficient (DD) categories (see Supplementary Material 3 and 4 for more details).

In Maringá, we found 20 species at urban matrix sites and 26 species at non-urban matrix sites. In São Paulo, we found 30 species in urban matrix sites and 76 species at non-urban matrix sites. In Maringá, 8% of the species were found in forest areas (2 spp), 65% at forest edges (18 spp), and 27% in open areas (7 spp). In São Paulo, 53% of the species were found in forest areas (43 spp), 30% at forest edges (24 spp), and 17% in open areas (14 spp) (see Supplementary Material 2).

The Mantel test showed no spatial autocorrelation among geographic distances and species composition across sites (Maringá: $r = -0.26$, $p = 0.92$; São Paulo: $r = 0.27$, $p = 0.12$). The c -score index was greater than expected by chance (Maringá: C -score = 1.35, $p = 0.0009$; São Paulo: C -score = 1.45, $p = 0.0009$), indicating a pattern of non-random species composition across sites within both localities.

The NODF index indicated that the communities from both localities exhibited nested patterns (Maringá: $p = 0.0009$; São Paulo: $p = 0.0009$), with a ratio of 75 and filling matrix of 51.1% for Maringá and a ratio of 44 and filling matrix of 22.5% for São Paulo (Fig. 3a, b and Table 1). In the species occurrence matrix, we observed a trend to fill the upper left portion, featuring an upper triangular matrix (Fig. 3a, b).

The results of the betapart analysis indicated higher nesting values in urban matrix, and decreasing towards the non-urban matrix. The analysis for Maringá sites indicated β sne mean of 0.26 ± 0.26 (0.02–0.83) for PP (large biota) vs. all sites (subset) and β sne mean of 0.24 ± 0.25 (0.02–0.82) for FaC (large biota) vs. all sites (subset). São Paulo sites indicated β sne mean of 0.48 ± 0.24 (0.10–0.96) for PESMCu (large biota) vs. all sites (subset) and β sne mean 0.24 ± 0.16 (0.00–0.56) for PEC (large biota) vs. all sites (subset). The nesting values between the two largest biotas of both localities are low, for Maringá PP vs. FaC 0.02 and São Paulo PESMCu vs. PEC 0.10 (see Fig. 4a–d).

The linear regression of richness vs. nestedness indicated highly significant values of species richness loss and increase of nesting values towards the urban matrix sites (Maringá $R^2 = 0.85$, $p < 0.001$; São Paulo $R^2 = 0.74$, $p < 0.001$ see Fig. 5). The total area of PAs in urban matrix did not differ from PAs in non-urban matrix (Maringá $W = 71.5$, $p = 0.259$; São Paulo $W = 27.0$, $p = 0.149$). Species richness differed between PAs in urban matrix to PAs in non-urban matrix

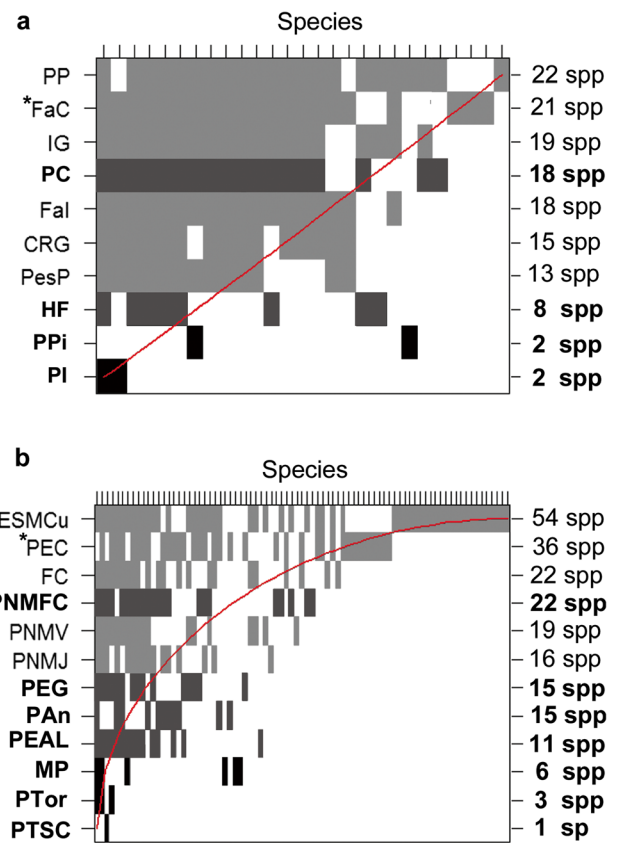


Fig. 3 Matrix of presence (filled cells) and absence (empty cells) of anuran species from sampling sites in Maringá (a) and São Paulo (b). The red line represents the isocline of differences in species richness among PAs. The black bars show the PAs in oldest urbanized area (i.e., >50 years), darkest gray bars the PAs in periphery of urban matrix (i.e., <50 years), and gray bars show the PAs in non-urban matrix. (*) indicates presence of threatened species, PAs in bold indicates presence in urban matrix

(Maringá $W = 86.0$, $p = 0.006$; São Paulo $W = 131.5$, $p < 0.001$ see Fig. 6).

Discussion

Our results revealed a nested pattern of anurans from the non-urban matrix sites toward the urban matrix sites, urban matrix

Table 1 Results generated by the analysis of nestedness metric based on overlap and decreasing fill (NODF) in different study sites. The nestedness statistic is evaluated separately for columns (N columns), for rows (N rows) and combined for the whole matrix (NODF)

NODF Index	Maringá		São Paulo	
	Value	p	Value	p
N columns	75.2	$p = 0.0009$	47.5	$p = 0.0009$
N rows	76.0	$p = 0.0009$	62.1	$p = 0.0009$
NODF	75.3	$p = 0.0009$	47.7	$p = 0.0009$
Matrix fill	51.1%		22.5%	

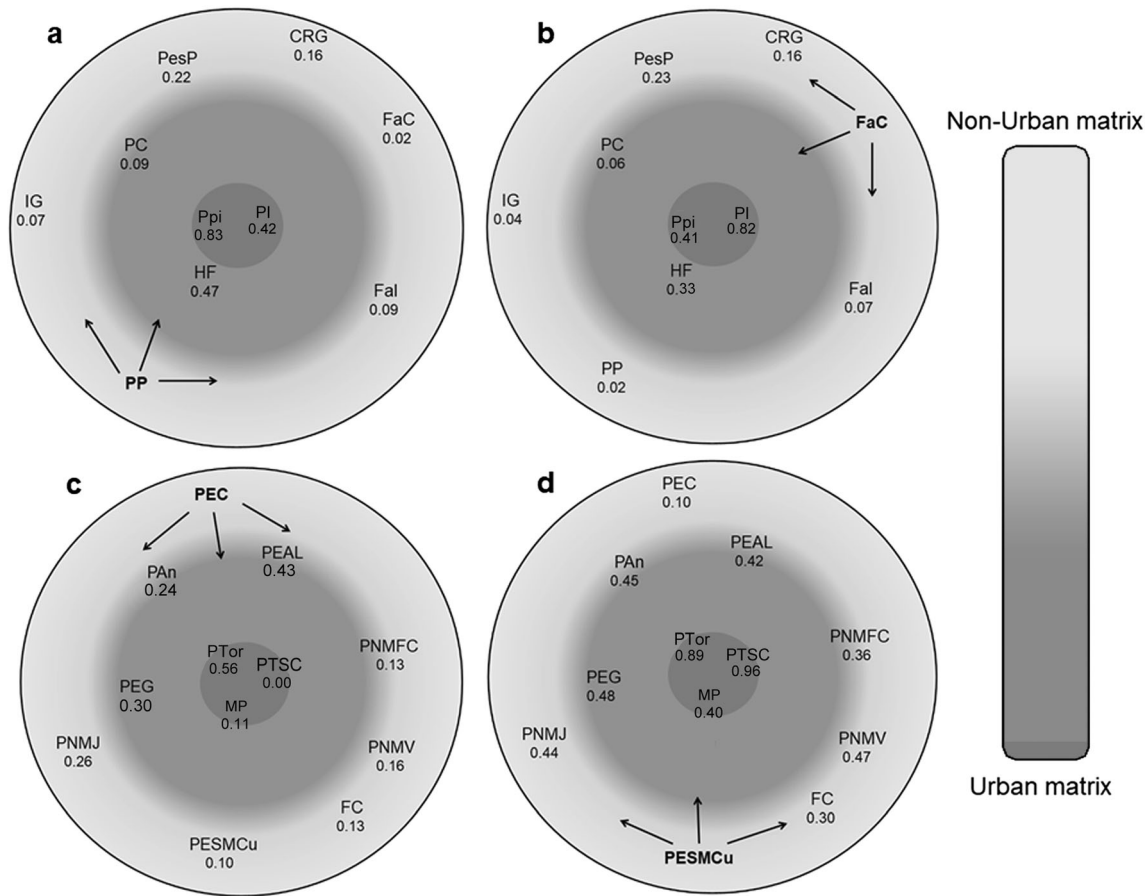


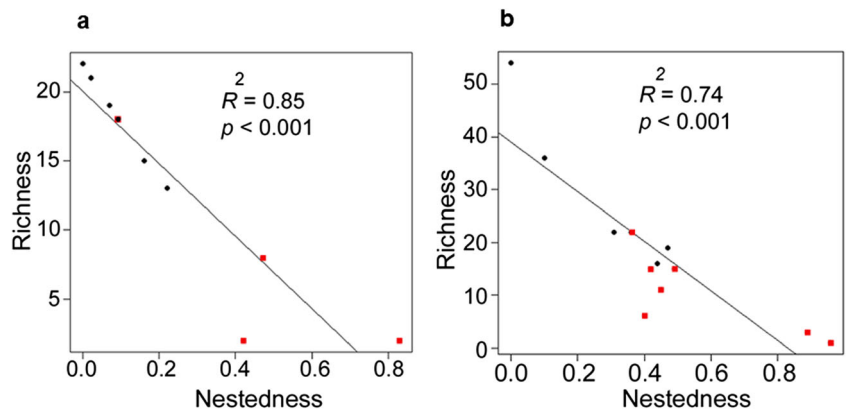
Fig. 4 Scheme in which the layout of the parks is based on their location on the map (Fig. 2). Betapart values (β_{sne}) of studied sites at Maringá (a, b) and São Paulo (c, d). The betapart analyzes regards the NODF ordering. (a) show the nesting values of PP and (d) PESMCu (in bold) for the

other sites (arrows); (b) show the nesting values of FaC and (c) PEC (in bold) in relation to the other areas (arrows). The urbanization time is in the legend indicated by the coloration of light gray (no effect) for the darkest gray (>50 years)

sites are subsets of non-urban matrix sites. This pattern is similar in both types of forest formations (Maringá: warmer and seasonal forest; São Paulo: non-seasonal forest). The NODF values for Maringá indicated by the isoclines of differences in species richness (Fig. 3), showed that nestedness is better distributed and species richness gradually decrease. In São Paulo the NODF values indicated by isoclines that nestedness is influenced by high values of PESMCu, because

of high species richness in relation to the others PAs. The urban matrix sites had poorer species richness toward the non-urban matrix sites. However, two areas located in the periphery of the urban matrix (PC and PNMFC) showed species richness similar to smaller areas in non-urban matrix. These areas seem to be less affected by urbanization, which allows more species to remain. The Mantel test indicated that the distance between sites does not influence

Fig. 5 Simple linear regressions between (a) species richness and nesting values (PP) and (b) species richness and nesting values (PESMCu). The black points show the PAs in non-urban matrix; red squares show PAs in urban matrix



distribution, and the analysis of the C-score indicated that the species composition pattern was non-random. However, our contrasting results among NODF (nestedness significant) and C-score indices (isolation significant) may be attributed to the long isolation of sites, the effect of human activities, and the likely resistance of the matrix surrounding the urban sites. It is possible that external factors, such as habitat quality and species attributes are influencing the pattern of nestedness (Butaye et al. 2001). An association between nestedness and isolation has been found in other studies (see Meyer and Kalko 2008), possibly because is related to habitat quality (Kadmon 1995).

Our results from C-scores index showed that species composition is different from those generated randomly. This result suggests that this nested pattern is related to the regional pool of species, and species are isolated in PAs within urban matrix. However, the small PAs in urban matrix may not safeguard some species for long time due to small population size, high predation rate, and high pollution level (Lengagne 2008; Herrera-Montes and Aide 2011; Francis and Barber 2013). Moreover, it is likely that corridors are ineffective as dispersal routes for many species, mainly those in urban matrix. Therefore, we suggest that the observed pattern among the anuran communities of this study may also reflect environmental filters that restrict the distribution of species due to anthropogenic changes.

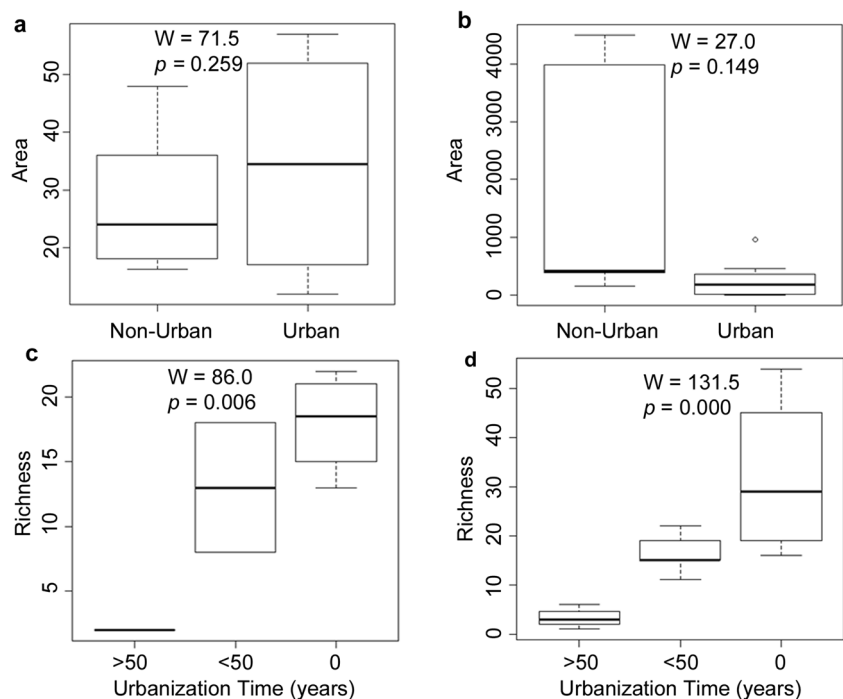
It is important to emphasize the presence of the forest-specialist *Haddadus binotatus* in an urban matrix site of Maringá (i.e., Parque dos Pioneiros - PPI). This species was considered rare in this municipality and differs from most other species by having direct development on the forest

leaf-litter (Hedges et al. 2008). In both study localities *Haddadus binotatus* was only found in PAs that had been only partially altered (i.e., selective logging, earth-moving). Regarding Maringá, most forest areas were substantially altered.

In São Paulo, *Adenomera marmorata* was the only species recorded in an urban matrix site (i.e., Parque Tentente Siqueira Campos “Trianon MASP”- PTSC). This species does not use water bodies for breeding but lays its eggs in subterranean chambers where endotrophic tadpoles develop until >metamorphosis (Heyer et al. 1990). Although this area is a remnant of native vegetation, it is located in the center of São Paulo city and there are no connections to fragments, and thus it has been completely isolated for over a century (Malagoli 2008).

The betapart results indicated that the sites with greater species richness (inserted in non-urban matrix) act similarly and positively in the nesting pattern in both regions. This suggested that the global network of points between sites have greater importance in the structure of communities and not only the point of greatest species richness. Most species from the urban matrix sites are likely to be more resistant to environmental changes because they are considered open area dwellers. For instance, species dependent on forest environments and preserved sites, such as *Crossodactylus schmidti* and *Bokermannohyla astartea*, were not recorded in urban matrix sites. The absence of these species in urban matrix sites may indicate their dependence on forest for maintaining viable population. Moreover, other habitat-specialist species were only found in non-urban matrix sites (Malagoli 2008, 2013; present study), such as *Vitreorana uranoscopa* and *Hylodes*

Fig. 6 Box plot showing the mean area of PAs (size in Ha) from Urban to Non-Urban matrix for (a) Maringá and (b) São Paulo with Mann-Whitney test; (c) Maringá and (d) São Paulo, showing the mean richness of PAs located in the oldest urbanized areas, periphery of urban matrix and non-urban areas



phylloides that require clean freshwater in streams for larval development, and *Dendrophryniscus brevipollicatus* and *Bokermannohyla astartea*, that lay eggs in large bromeliads (Malagoli 2008; Haddad et al. 2013).

Large PAs within the urban matrix of the municipality of Maringá have lower species richness when compared to PAs of all sizes in the non-urban matrix (PI 47.4 ha and PPI 57.3 ha). This pattern suggests that the location and the conservation status of these sites are possibly more important for the occurrence of most species than the size of the fragment. In São Paulo, PESMCu and PEC are non-urban matrix sites that are much larger than other PAs. Additionally, these areas are connected to other forest remnants (e.g., PESMCu is part of Serra do Mar State Park, the largest PA in the Atlantic Forest of São Paulo State with ca. 327,000 ha) that may have high habitat quality that facilitates greater species persistence. However, populations remaining isolated in the urban matrix (i.e., *Adenomera marmorata* in PTSC) may be suffering from reproductive isolation and subjected to factors that reduce their long-term persistence due to increasing inbreeding and genetic drift (see Dixo et al. 2009). In addition, species with terrestrial development (i.e., *H. binotatus* and *A. marmorata*, respectively) are more susceptible to the negative effects of the chytridiomycosis (Mesquita et al. 2017). Considering that these species seem to persist in urban matrix (e.g., PPI and PTSC), they may be more susceptible to both isolation and chytrid fungus. Even anurans from PAs in the periphery of urban matrix may be affected by urbanization. We recommend further study in these areas, analyzing if those species are suffering from genetic isolation.

Patterns of nested assemblages of anurans are strongly influenced by the sensitivity of individual species to altered habitat (Cook et al. 2004). Most anurans are sensitive to environmental changes, and especially to changes in their breeding site, which may result in their extinction from a particular location (Gerson 2012). For example, acoustic communication is an important aspect of anuran social interactions, including reproduction (Wells 2007). Proximity to urban environments can result in noise pollution, which can affect the acoustical context of anuran social interactions and thus their persistence in an environment (Bee and Swanson 2007; Hoskin and Goosem 2010; Goutte et al. 2013).

Some studies have related the type of matrix habitat to the susceptibility for extinction (Henle et al. 2004; Watling and Donnelly 2007). Amphibians generally have low rates of colonization and association to matrix (Watling et al. 2009; Almeida-Gomes and Rocha 2014; Lourenço-de-Moraes et al. 2014; Ferreira et al. 2016). Factors, such as susceptibility to water loss by evaporation can affect amphibian dispersion among habitat patches (Young et al. 2005, 2006; Becker et al. 2007; Tracy et al. 2008; Watling et al. 2009). Additionally, some PAs are disconnected from water bodies (i.e., habitat split), which increases the negative effect on anurans with

biphasic life cycles (Becker et al. 2007; Ferreira et al. 2010, 2012, 2016) and are more susceptible to invasive and domestic species (e.g., *Lithobates catesbeianus* and cats) that prey on native anurans (Silva et al. 2011; RLM pers. obs.).

Information related to habitat quality and how environmental characteristics (e.g., predation and pollution) may affect anurans are vital to making decisions that maximize their protection. Our results contribute to the understanding of the distribution of anurans among urban and non-urban matrix sites in the Neotropics and provide some relevant considerations for the management of protected areas, especially those in urban environments. The urbanization time had a dramatic negative effect on the anurans. The Revitalization strategies, adjustment and maintenance (as quality of reproductive environments and effective corridors) of protected areas in urban matrix are necessary for the conservation of Neotropical anurans.

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