SPECIES COMPOSITION AND SIMILARITIES AMONG ANURAN ASSEMBLAGES OF FOREST SITES IN SOUTHEASTERN BRAZIL

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ABSTRACT: Neotropical forests show high anuran species richness, but some Brazilian forest formations, like cerradão, semideciduous forests and restingas, remain poorly known. The composition of anuran species were determined for four forest sites belonging to different biomes in southeastern Brazil, based on two complementary techniques (visual encounter survey and survey on breeding sites), both applied simultaneously. A total of 60 anuran species belonging to eight families was recorded. Species richness and levels of endemism were higher in the Atlantic rainforest site. Sites located in the Cerrado domain were more alike than those located in the Atlantic Forest Domain. Similarity in anuran species composition was negatively correlated to the geographical distance among sites, which explains part of similarities in species composition. Factors affecting these occurrence patterns are discussed. One species (if its identity is confirmed) is considered Data Deficient by IUCN (The World Conservation Union), though it is not included in the Brazilian list of threatened amphibians. The presence of certain species with special habitats and microclimate requirements (bioindicators) suggests well-preserved ecosystems.
Key words: anurans, species richness, species composition, conservation

COMPOSIÇÃO DE ESPÉCIES E SIMILARIDADES ENTRE TAXOCENOSES DE ANUROS DE ÁREAS FLORESTAIS DO SUDESTE DO BRASIL

RESUMO: As florestas neotropicais apresentam altas riquezas de espécies de anuros, mas algumas formações florestais brasileiras, como o cerradão, as florestas semidecíduas e as restingas, permanecem pouco conhecidas. A composição de espécies de anuros de quatro áreas florestais pertencentes a diferentes biomas do sudeste do Brasil foi determinada com base em duas técnicas complementares (procura visual e investigação nos sítios reprodutivos), aplicadas de forma simultânea. Registramos um total de 60 espécies de anuros, incluídas em oito famílias. A riqueza de espécies e o nível de endemismo foram maiores na área coberta por floresta pluvial atlântica. As áreas localizadas no domínio do Cerrado foram mais similares entre si do que as áreas localizadas no domínio da Mata Atlântica. Os índices de similaridade mostraram-se negativamente relacionados com a distância geográfica entre as áreas, explicando parte das similaridades observadas. Os fatores que influenciam os padrões de ocorrência são discutidos. Uma das espécies (caso sua identidade seja confirmada) é considerada como Deficiente em Dados pela IUCN (The World Conservation Union), mas não está incluída na lista da fauna brasileira ameaçada de extinção. A presença de certas espécies com requisitos especiais de hábitat e microclima (bioindicadores) sugerem que os ecossistemas estão bem-preservados.
Palavras-chave: anfíbios, riqueza de espécies, ambientes de floresta, biodiversidade, conservação

INTRODUCTION

Despite its extreme diversity (Whitmore, 1990), anuran fauna of Brazilian forests is still poorly known. In recent decades, Brazilian forests were cleared for cattle farming and sugarcane, coffee and cocoa plantations, and less than 9% of the original Atlantic coast forest remains (Myers, 1986; Fearnside, 1990; 1996). This scenario of increasing habitat loss and degradation is associated to anuran declines and local extinctions (Heyer et al., 1988; 1990; Weygoldt, 1989; Haddad & Sazima, 1992; Bertoluci & Heyer, 1995; Bertoluci et al., 2005; Eterovick et al., 2005). Status of all Brazilian anurans was updated by the Global Amphibian Assessment workshop (GAA) (IUCN, Conservation International & NatureServe, 2006).

In Brazil, studies dealing with anuran communities of forest environments were concentrated in Amazonia (Crump, 1971; Hero, 1990; Gascon, 1991), in semideciduous forests of southeastern and southern regions (e.g. Haddad & Sazima, 1992; Rossa-Feres & Jim, 1994; Bernarde & Kokubum, 1999; Toledo et al., 2003; Ribeiro et al., 2005; Bernarde & Anjos, 1999; Machado et al., 1999; Bernarde & Machado, 2001), and in the Atlantic rainforest (Heyer et al., 1990; Guix et al., 1994; Bertoluci, 1998; Bertoluci & Rodrigues, 2002a; 2002b). The anuran fauna of other Brazilian forest formations like "cerradão" (the forest physiognomy of Cerrado) and the Restinga, however, remains virtually unknown. Pombal Jr. & Gordo (2004) provided a list of anurans from the Estação Ecológica Juréia-Itatins (Rio Verde) that includes species of both Restinga and Atlantic rainforest habitats, and Narvaes (1993) developed a year-round study on anurans from Estação Ecológica Juréia-Itatins (Guarauzinho).

Species inventories and long-term monitoring of both population and community levels are essential to assess the conservation status of Brazilian anurans and to delineate actions for their conservation. Only continuous and long-term studies are able to separate human impacts from natural population fluctuations (Pechman et al., 1991).

The main goals of the present study included the determination of the species composition of anuran assemblages of four forest sites in different biomes in the state of São Paulo based on two complementary techniques applied simultaneously to the sites; the evaluation of the levels of similarity among the assemblages; the comparisons of these levels of similarity with the similarities among the same areas based on tree species composition; and the comparison of the composition of the assemblages with those of other Brazilian anuran communities.

MATERIAL AND METHODS

Study Sites

From September 2005 to August 2006, anuran species inventories were conducted in the following preservation reserves of the State of São Paulo, southeastern Brazil:

Assis Ecological Station (Estação Ecológica de Assis; EEA). With an area of 1,312.28 ha, EEA is located in the municipality of Assis (22º33' - 22º36'S, 50º23' - 50º22'W), at altitudes varying from 520 to 590 m above sea level. The climate is of the Cwa type of Köppen's classification, megathermic, tropical with a dry season in winter and rains concentrate in summer; mean annual temperature is 22.4°C and mean rainfall is 1255 mm. The vegetation in EEA is of the Cerrado *latu sensu* type, called "cerradão", with a continuous canopy 15 m high and absence of grasses. This site lies in the Cerrado-Caatinga-Chaco Domain (mixed savanna and open forest formation) as described by Duellman (1999) based on the morphoclimatic domains of Ab'Saber (1977).

Caetetus Ecological Station (Estação Ecológica de Caetetus; EEC). This reserve belongs to the municipalities of Gália and Alvilândia (22º41' - 22º46'S, 49º10' - 49º16'W) and has an area of 2,178.84 ha, inside the Médio Paranapanema river basin. The local climate is Cwa (Köppen's classification), mesothermic, subtropical, with dry winter; mean annual temperature is 21.4°C and mean annual raifall is 1313 mm. The primary vegetation consists of a Semideciduous Seasonal Forest associated to the Planalto Ocidental do Estado de São Paulo. The altitude varies from 520 to 680 m. This forest has some extremely well-preserved portions, housing many threatened plant and animal species (Tabanez et al., 2005), and also lies in the Cerrado-Caatinga-Chaco Domain.

Carlos Botelho State Park (Parque Estadual Carlos Botelho; PECB). Located in the southern part of the São Paulo state, in the municipalities of São Miguel Arcanjo, Capão Bonito and Sete Barras (24º00' - 24º15'S, 47º45' - 48º10'W), PECB has a total area of 37,793.63 ha, in altitudes varying from 30 to 1003 m (Domingues & Silva, 1988). The present study was carried out in an area at about 500 m, inside the Núcleo Sete Barras. The climate is Cfa (Köppen's classification), mesothermic, subtropical, wet and hot, without a dry season; mean annual temperature is 21.8°C and mean annual rainfall is 1582 mm. This site is included in the Brazilian Highlands (coastal ranges and interior highlands), which belongs to the Atlantic Forest Domain (Ab'Saber, 1977; Duellman, 1999).

Ilha do Cardoso State Park (Parque Estadual da Ilha do Cardoso; PEIC). Situated in the southern coast of the state of São Paulo, in the municipality of Cananéia (25º03' - 25º18'S, 47º53' - 48º05'W), this island has an area of 22,500 ha. The climate is Af (Köppen's classification), megathermic, tropical, without a dry season; mean annual temperature is 22.4°C and mean annual raifall is 2261 mm. Relief is predominantly mountainous, with altitudes up to 800 m. Distinct plant formations occur associated to diferent substrate characteristics: montane fields in shallow soils and rocky outcrops in mountain tops, Atlantic rainforest in sharp declivities, sand dune vegetation, Restinga forest in the coastal plain, and mangroves. The study was conducted in areas covered by Restinga forest at an altitude of 10

m. This site is included in the Atlantic Coastal Forest, which also belongs to the Atlantic Forest Domain (Ab'Saber, 1977; Duellman, 1999).

Each site has a 10 ha permanent plot, consisting of a 320 m-sided square subdivided into 256 subplots (20 m-sided squares). Species inventories at the four sites were carried out inside the permanent plot, in a variable number of selected aquatic breeding sites (swamps, temporary pools, ponds, streams, and lake margins), and in trails and roads that give access to these sites and to the plots.

Methods

Each site was visited by two reasearchers every month for two days and two nights. Inside the permanent plot frogs were searched actively in the microhabitats commonly used by them, like leaf litter, underneath fallen logs, and in rock crevices. This visual encounter survey technique (Crump & Scott, 1994) was applied by day along a 5,000 m transect (about 2,500 m at the PECB site due to its highly irregular relief) on the lines separating subplots. The monthly sampling effort was 20 hours/person and the total effort at each site was 240 hours/person. Each individual frog was captured and photographed, and had its snout-to-vent length (SVL) measured with a caliper to the nearest 0.5 mm. All specimens but one voucher to each species were released after measurement.

At each site, the inventory was complemented by surveys in previously selected aquatic breeding sites (four in PECB and PEIC, five in EEA, and 10 in EEC). In these aquatic sites the number of calling males was recorded for each active species from 19h00 to midnight. The list was completed by species that called during the day or outside the monitored sites.

At least one specimen by species was collected under IBAMA license n° 430/05, killed by asphyxy in an atmosphere of CO_2, fixed in formalin 10% and preserved in alcohol 70% (Heyer et al., 1994).

Data Analysis

Alpha diversity was used here as a synonym of species richness (Primack, 1998). Hence, alpha diversity of each site was the number of species found there. In order to compare large areas gamma diversity was calculated for each pair of sites belonging to different domains (sites EEA+EEC, Cerrado-Caatinga-Chaco Domain; PECB+PEIC, Atlantic Forest Domain) as the number of species recorded at the two sites minus the number of species shared by the sites. Beta diversity (variability of species composition along a geographical or environmental gradient; Primack, 1998) was calculated as gamma diversity divided by mean alpha diversity.

To estimate the similarity between the pairs of sites in terms of anuran species composition, two indexes of similarity were used, both varying from zero (no similarity between both sites) to 1 (species composition identical in both sites): i) the Jaccard index of similarity, given by $J = Ns / N_A + N_B - Ns$, where *Ns* is the number of species shared by sites A and B, N_A is the number of species in site A and N_B is the number of species in site B (Zar, 1999), and ii) the Coefficient of Geographical Resemblance, defined by Duellman (1990) as $CGR = 2\ Ns / N_A + N_B$ (symbols as above). This index is identical to the index of Sorensen (Wolda, 1981), which duplicates the number of shared species, increasing similarity values. Jaccard's index was calculated in order to compare it with values obtained by Rodrigues (2003) based on tree species composition for the same sites.

A cluster analysis of the sites using *CGR* values was then performed, using the WPGMA linkage method (Sneath & Sokal, 1973) because of the different number of species at each site (Dixo & Verdade, 2006).

These four study sites were compared with other ten Brazilian sites (Figure 1) in terms of anuran species composition by means of cluster analy-

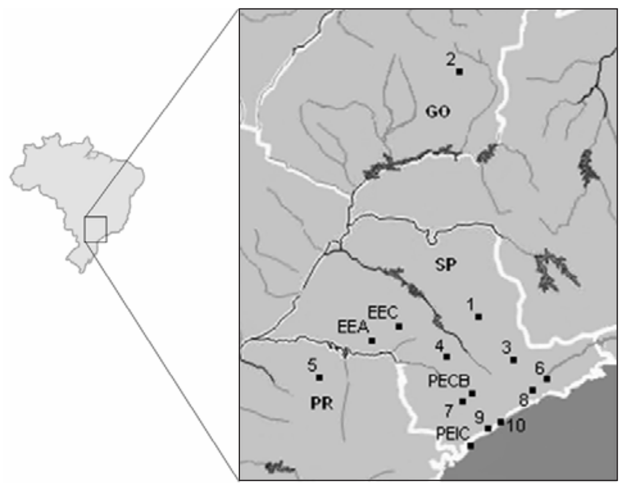

Figure 1 - Location of the study sites and ten other Brazilian sites used in comparisons of anuran species composition. Legend: EEA, Estação Ecológica de Assis; EEC, Estação Ecológica de Caetetus; PECB, Parque Estadual de Carlos Botelho; PEIC, Parque Estadual da Ilha do Cardoso; 1. Estação Ecológica de Itirapina (Brasileiro et al., 2005); 2. Floresta Nacional de Silvânia (Bastos et al., 2003); 3. Serra do Japi (Haddad & Sazima, 1992; Ribeiro et al., 2005); 4. Botucatu (Rossa-Feres & Jim, 1994); 5. Parque Estadual Mata dos Godoy, Londrina (Bernarde & Anjos, 1999); 6. Estação Biológica de Boracéia (Heyer et al., 1990; Bertoluci et al., 2005); 7. Parque Estadual de Intervales (Bertoluci, 1998); 8. Reserva Biológica de Paranapiacaba (Vanessa K. Verdade, pers. commun.); 9. Estação Biológica Juréia-Itatins, Rio Verde (Pombal Jr. & Gordo, 2004); 10. Estação Biológica Juréia-Itatins, Guarauzinho (Narvaes, 1993).

sis using *CGR* and the WPGMA linkage method. To avoid taxonomic problems, this analysis excluded all undetermined species cited in the original papers as sp., gr. (species group) and aff. (*affinis*), but included in the analysis species cited as cf. (*confer*).

The relationship between the geographical distance (in km) between pairs of sites and their respective indexes of similarity (*CGR*) was estimated by two independent simple regression analyses: the first included only the four sites of this study; in the second, the ten selected sites mentioned above were added. Regression analyses were performed with the software BioEstat 3.0 (Ayres et al., 2003). Cluster analyses were performed with the software FITOPAC (Shepherd, 1996).

RESULTS AND DISCUSSION

Throughout the four study sites a total of 60 anuran species belonging to the families Brachycephalidae (2 species), Bufonidae (6), Cycloramphidae (3), Hylidae (28), Hylodidae (2), Leiuperidae (6), Leptodactylidae (8), and Microhylidae (5) was recorded (Table 1). The phylogenetic arrangement recently proposed by Frost et al. (2006) was adopted here, except for species of the subfamily Hylodinae (included in Cycloramphidae) which was elevated to the level of family (Hylodidae), and for species of *Physalaemus*, currently of the newly proposed family Leiuperidae (Grant et al., 2006). Anuran fauna of all sites is largely dominated by family Hylidae. This pattern is common in South American areas belonging to different biomes (Heyer et al., 1990; Rossa-Feres & Jim, 1994; Bertoluci & Rodrigues, 2002b; Pombal Jr. & Gordo, 2004; Brasileiro et al., 2005). In fact, this family of specialized arboreal anurans constitutes 25% of the South American anuran fauna (Duellman, 1999).

The most species-rich site was PECB (28 species), followed by EEC (24), EEA (19), and PEIC (16) (Table 1). These numbers must be considered partial, since no inventory techniques were applied able to detect rare species. For example, Guix et al. (1994) found 40 species in PECB area; their study, however, was developed along an altitudinal transect (22 to 1003m). This richness is similar to that recorded in Parque Estadual Intervales (47), an Atlantic rainforest reserve located in the same region (Bertoluci & Rodrigues, 2002b).

Nineteen species were found only in PECB and nine species were collected only in PEIC. In EEA and EEC only five exclusive species each were found. Only the hylid *Hypsiboas faber* was recorded in the four sites. Proportion of shared species was higher in EEC (19 species, 79.2%), followed by EEA (14, 73.7%), PEIC (7, 44%), and PECB (9 species, 32.1%). The similarity in anuran species composition between each pair of sites are shown in Table 2. The most similar sites were EEC and EEA (*CGR* = 0.6512; 14 shared species in a total of 29 species), followed by the pair PEIC and PECB (*CGR* = 0.2927; 6 in 35). The most different sites were EEA and PEIC (*CGR* = 0.0606; 1 in 32) followed by the pair EEA and PECB (*CGR* = 0.0870; 2 in 44). These values contrast to similarities (Jaccard) among the same sites based on tree species (Rodrigues, 2003) (Table 2). The most similar sites in terms of anuran composition (EEA-EEC, *J* = 0.4828) were very dissimilar (*J* = 0.0535) in tree species composition. Other factors can explain these similarities, as can be seen below.

Figure 2 shows the dendrogram obtained for the four sites. Geographical distance among sites has no influence on tree species similarities (f = 0.8599, R^2 = -2.88%, *P* = 0.5911), but geographical distance explains at least part of the greater similarities in anuran species composition occurring between pairs of

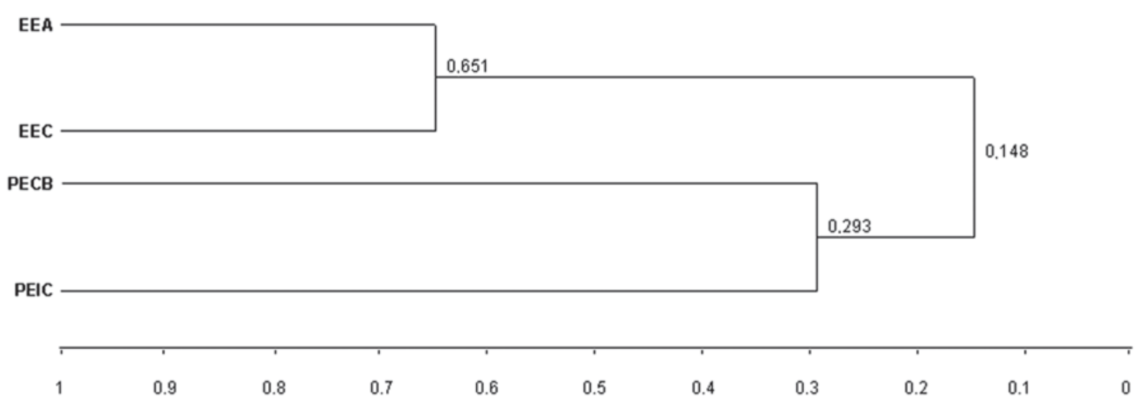

Figure 2 - Cluster analysis of four sites based on their similarities (*CGR*) in anuran species composition (cophenetic correlation coefficient = 0.9482). Legend: EEA, Estação Ecológica de Assis; EEC, Estação Ecológica de Caetetus; PECB, Parque Estadual de Carlos Botelho; PEIC, Parque Estadual da Ilha do Cardoso.

Table 1 - Anuran species collected in four forest sites of southeastern Brazil between September 2005 and September 2006. EEA, Estação Ecológica de Assis; EEC, Estação Ecológica de Caetetus; PECB, Parque Estadual de Carlos Botelho; PEIC, Parque Estadual da Ilha do Cardoso.

	EEA	EEC	PECB	PEIC
BRACHYCEPHALIDAE				
Eleutherodactylus binotatus (Spix, 1824)		X	X	X
Eleutherodactylus guentheri (Steindachner, 1864)			X	
BUFONIDAE				
Chaunus ictericus (Spix, 1824)			X	
Chaunus ornatus (Spix, 1824)		X	X	X
Chaunus schneideri (Werner, 1894)	X	X		
Dendrophryniscus brevipollicatus Jiménez de la Espada, 1871			X	
Dendrophryniscus leucomystax Izecksohn, 1968				X
Rhinella margaritifer (Laurenti, 1768)			X	
CYCLORAMPHIDAE				
Cycloramphus sp.			X	
Odontophrynus americanus (Duméril & Bibron, 1841)	X	X		
Proceratophrys boiei (Wied-Neuwied, 1824)			X	
HYLIDAE				
Aparasphenodon bokermanni Pombal, 1993				X
Bokermannohyla hylax (Heyer, 1985)			X	
Dendropsophus berthalutzae (Bokermann, 1962)				X
Dendropsophus decipiens (A. Lutz, 1925)				X
Dendropsophus elegans (Wied-Neuwied, 1824)			X	
Dendropsophus minutus (Peters, 1872)	X	X	X	
Dendropsophus nanus (Boulenger, 1889)	X	X		
Dendropsophus seniculus (Cope, 1868)			X	
Hypsiboas albomarginatus (Spix, 1824)			X	X
Hypsiboas albopunctatus (Spix, 1824)	X	X		
Hypsiboas bischoffi (Boulenger, 1887)			X	
Hypsiboas caingua (Carrizo, 1991 "1990")		X		
Hypsiboas faber (Wied-Neuwied, 1821)	X	X	X	X
Hypsiboas lundii (Burmeister, 1856)	X	X		
Hypsiboas semilineatus (Spix, 1824)			X	
Itapotihyla langsdorffii (Duméril & Bibron, 1841)		X		X
Phyllomedusa distincta A. Lutz in B. Lutz, 1950			X	
Phyllomedusa tetraploidea Pombal & Haddad, 1992	X	X		
Scinax alter (B. Lutz, 1973)			X	
Scinax argyreornatus (Miranda-Ribeiro, 1926)				X
Scinax cuspidatus (A. Lutz, 1925)				X
Scinax fuscomarginatus (A. Lutz, 1925)	X			
Scinax fuscovarius (A. Lutz, 1925)	X	X		
Scinax hayii (Barbour, 1909)			X	
Scinax littoralis (Pombal & Gordo, 1991)			X	
Scinax rizibilis (Bokermann, 1964)		X	X	
Scinax x-signatus (Spix, 1824)		X		

Continue...

Table 1 - Continuation.

Scinax sp.				X
HYLODIDAE				
Hylodes sp. (gr. *lateristrigatus*)		X		
Hylodes phyllodes Heyer & Cocroft, 1986			X	
LEIUPERIDAE				
Eupemphix nattereri (Steindachner, 1863)	X	X		
Physalaemus moreirae (Miranda-Ribeiro, 1937)			X	
Physalaemus cuvieri Fitzinger, 1826	X	X		
Physalaemus fuscomaculatus (Steindachner, 1864)	X			
Physalaemus olfersii (Lichtenstein & Martens, 1856)		X	X	
Physalaemus spiniger (Miranda-Ribeiro, 1926)				X
LEPTODACTYLIDAE				
Leptodactylus fuscus (Schneider, 1799)	X	X		
Leptodactylus labyrinthicus (Spix, 1824)	X	X		
Leptodactylus marmoratus (Steindachner, 1867)			X	X
Leptodactylus mystaceus (Spix, 1824)		X		
Leptodactylus mystacinus (Burmeister, 1861)	X	X		
Leptodactylus notoaktites Heyer, 1978			X	
Leptodactylus ocellatus (Linnaeus, 1758)			X	X
Leptodactylus podicipinus (Cope, 1862)	X			
MICROHYLIDAE				
Chiasmocleis albopunctata (Boettger, 1885)	X			
Chiasmocleis leucosticta (Boulenger, 1888)				X
Elachistocleis bicolor (Valenciennes in Guérin-Menéville, 1838)	X			
Elachistocleis ovalis Schneider, 1799		X		
Myersiella microps (Duméril & Bibron, 1841)			X	
Number of species	19	24	28	16

Table 2 - Similarities in anuran composition among sites expressed by the index of similarity of Jaccard (italics) and the Coefficient of Geographical Resemblance (Duellman 1990) (bold). Numbers in brackets are indexes of Jaccard calculated for similarities among sites in tree species (Rodrigues, 2003).

	EEA	EEC	PECB	PEIC
EEA		**0.6512**	**0.0870**	**0.0606**
EEC	*0.4828* (0.0535)		**0.2353**	**0.2105**
PECB	*0.0455* (0.0352)	*0.1333* (0.0951)		**0.2927**
PEIC	*0.0312* (0.0654)	*0.1176* (0.0537)	*0.1714* (0.1289)	

sites belonging to the same domain (f = 9.9025, R^2 = 64.04%, P = 0.0351) (Figure 3). Gamma diversity was higher in the Atlantic Forest Domain sites (PECB+PEIC, 38 species) than in Cerrado-Caatinga-Chaco Domain sites (EEA+EEC, 29 species) (Table 1). Beta diversity was also higher in the Atlantic Forest Domain sites (1.72) than in Cerrado-Caatinga-Chaco Domain sites (1.35).

The dendrogram obtained from cluster analysis of all Brazilian sites used here for comparisons (Figure 4) evidences three major groups: (A) sites located in the Atlantic coastal ranges and interior highlands (PECB and sites 3, 6, 7 and 8), (B) sites in the lowlands of the Atlantic Coastal Forest (PEIC and sites 9 and 10), and (C) sites belonging to the Cerrado domain or the transition Cerrado-Atlantic Forest (EEA, EEC, and sites 1, 2, 4, and 5). The Serra do Japi grouped with Atlantic rainforest localities despite being considered a semideciduous forest. This fact reveals the transitional character of the area (Leitão-

Filho, 1992). Distance among sites explains a small part of similarities between pairs of sites belonging to the same domain (f = 27.8783, R^2 = 23.00%, P = 0.0000) (Figure 5). The pattern of similarity among sites included in group A is exactly the same as the one obtained by Dixo & Verdade (2006) when comparing the leaf litter anurans. Dixo & Verdade (2006) suggested that similarities among sites reflect differences inherent to distinct geomorphological formations: Serra do Mar (sites 6 and 8), interior Atlantic highlands (site 7 and PECB), and Serra da Mantiqueira (site 3).

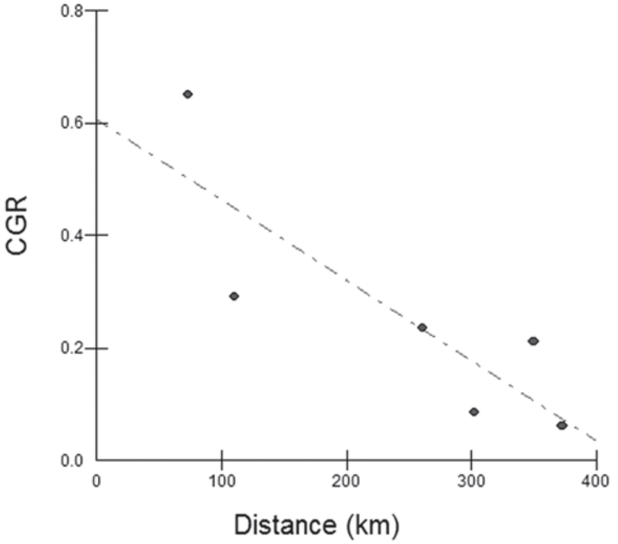

Figure 3 - Relationship between similarities in anuran species composition (*CGR*) and geographical distance for four forest sites of southeastern Brazil (f = 9.9025, R^2 = 0.64, P = 0.0351; Y' = 0.6069 - 0.0014X).

Species shared by sites belonging to different domains are wide-ranging species, like *Dendropsophus minutus* and *Leptodactylus ocellatus* (IUCN, Conservation International & NatureServe, 2006). Wide-ranging species recorded only at sites belonging to the Cerrado domain (EEA and EEC) – the hylids *Hypsiboas albopunctatus* and *S. fuscovarius*, the leptodactylids *L. fuscus, L. labyrinthicus, L. mystacinus*, the leiuperid *P. cuvieri*, and the cycloramphid *Odontophrynus americanus* – are expected to occur also in PECB, since they were found in other studies carried out in Atlantic Forest sites (Heyer et al., 1990; Guix et al., 1994; 2000; Bertoluci, 1998; Bertoluci & Rodrigues, 2002a; 2002b; Pombal Jr. & Gordo, 2004). The presence of some of these species may represent recent colonization due to human interference, as postulated to Estação Biológica de Boracéia (Heyer et al., 1988; 1990; Bertoluci & Heyer, 1995) and PECB (Guix et al., 1994; 2000). These species were not recorded in

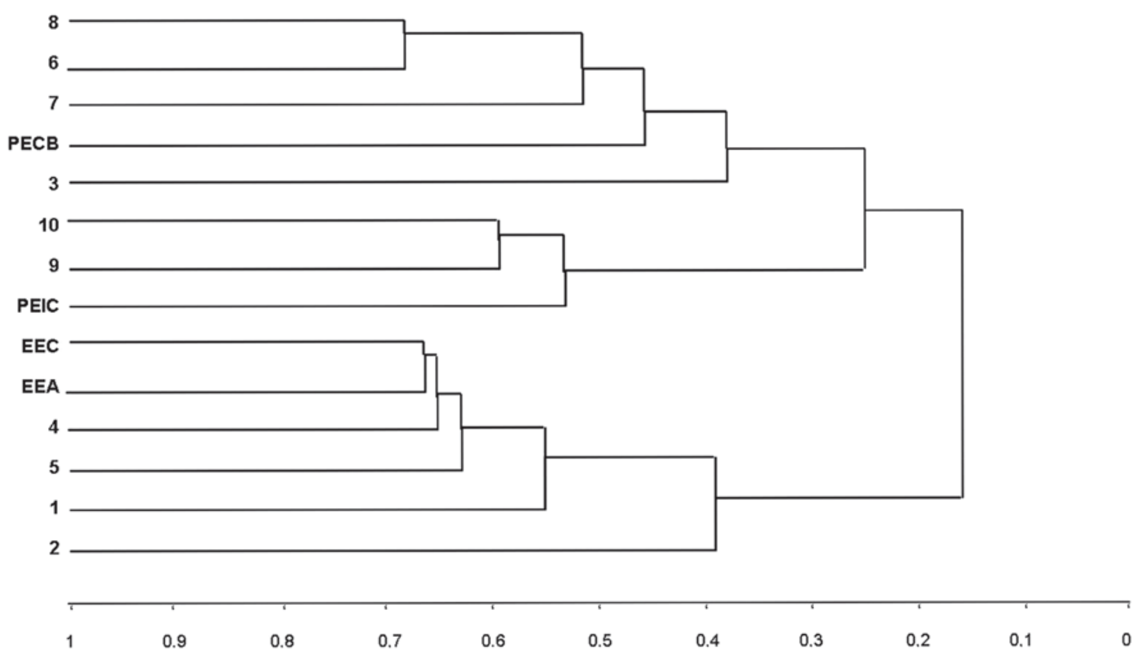

Figure 4 - Cluster analysis of 14 Brazilian sites based on their similarities (*CGR*) in anuran species composition (cophenetic correlation coefficient = 0.8880). Legend: EEA, Estação Ecológica de Assis; EEC, Estação Ecológica de Caetetus; PECB, Parque Estadual de Carlos Botelho; PEIC, Parque Estadual da Ilha do Cardoso; 1. Estação Ecológica de Itirapina (Brasileiro et al., 2005); 2. Floresta Nacional de Silvânia (Bastos et al., 2003); 3. Serra do Japi (Haddad & Sazima, 1992; Ribeiro et al., 2005); 4. Botucatu (Rossa-Feres & Jim, 1994); 5. Parque Estadual Mata dos Godoy, Londrina (Bernarde & Anjos, 1999); 6. Estação Biológica de Boracéia (Heyer et al., 1990; Bertoluci et al., 2005); 7. Parque Estadual de Intervales (Bertoluci, 1998); 8. Reserva Biológica de Paranapiacaba (Vanessa K. Verdade, pers. commun.); 9. Estação Biológica Juréia-Itatins, Rio Verde (Pombal Jr. & Gordo, 2004); 10. Estação Biológica Juréia-Itatins, Guarauzinho (Narvaes, 1993).

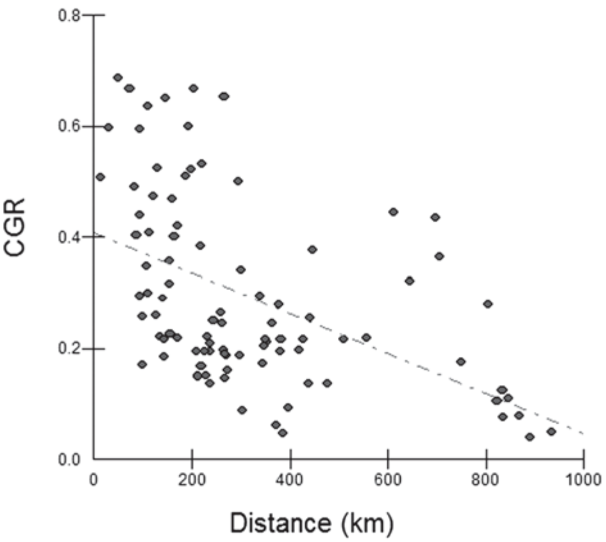

Figure 5 - Relationship between similarity in anuran species composition (*CGR*) and geographical distance for 14 sites of southeastern Brazil (f = 27.8783, R^2 = 0.23, *P* = 0.0000; Y' = 0.4089 - 0.0004X).

that site probably due to the fact that the field work conducted in PECB focused mainly in forest areas rather than open ones or forest edges.

The presence of typical Atlantic forest species (*Physalaemus olfersii*, *Scinax rizibilis*, *Itapotihyla langsdorffii*, *Chaunus ornatus*, and *Eleutherodactylus binotatus*) in EEC suggests that this site is zoogeographically under influence of the Atlantic Forest Domain. The Atlantic Forest Domain is a hotspot of species richness and endemism, with more than 322 anuran species, whereas 300 of them (93%) are endemic (Duellman, 1999). This pattern is typical of several Atlantic rainforest sites of southeastern Brazil (e.g. Heyer et al., 1990; Guix et al., 1994; Bertoluci & Rodrigues, 2002b) and it seems to be associated to topography, climate, and structural complexity of vegetation.

Topography is a major factor determining high degrees of species richness and endemism: 53.4% of all South American anurans (985 species, 930 endemics) live in highland regions which correspond to only 15.5% of the area of the continent (Duellman, 1999). A narrow climatic variability determines the selection of a narrower range of altitudes by anurans, which leads to higher endemism (Lynch, 1986; Duellman, 1999). In the mountain ranges of southeastern Brazil the complex relief of Serra do Mar and Serra da Mantiqueira promoted geographical isolation of populations and favored speciation and endemism (Haddad, 1998).

The diversity of amphibians is highly correlated with moisture due to their permeable skin and their shell-less eggs, and anuran species with reproductive modes dependent on high atmosphere humidity are most abundant at sites with heavy rainfall (Duellman & Trueb, 1986; Duellman & Thomas, 1996; Duellman, 1999). Data here collected corroborate this pattern. Mean annual temperature is high in all sites and mean annual rainfall in PECB and PEIC is higher than in EEA and EEC. Mean air relative humidity is 72.2 and 74.1% in EEA and EEC and 89.1 and 84.4% in PECB and PEIC, respectively. The lower number of species recorded in PEIC when compared to EEC and EEA could be attributed to a combination of flat relief and physical and chemicals factors, including high temperatures and salinity (Ormond, 1960; Franco et al., 1984).

The great structural diversity of tropical forests could explain their high levels of frog richness and endemism. Different strata (e.g. understory, canopy, epiphytes, vines) house a great diversity of potential prey, which determines a more diverse fauna of arboreal frogs (Pough et al., 1998) and provide a great variety of microhabitats associated with specialized reproductive modes (Haddad & Prado, 2005). Additionally, mountain streams of Atlantic forest house several endemic hylodids of genera *Hylodes*, *Crossodactylus* and *Megaelosia* (Duellman, 1999), whose activities are restricted to these habitats.

No species in the areas is included in the IBAMA ("Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis", the Brazilian governmental agency for the environment and natural resources) list of Brazilian threatened amphibians (Machado et al., 2005), but it must be considered that there are two Brazilian lists containing two very different sets of threatened species: the IBAMA list with 24 species and the GAA list including 110 species (Baillie et al., 2004; Stuart et al., 2005). If its identity is confirmed, *Physalaemus* cf. *moreirae* recorded at PECB will be included in GAA list as Data Deficient but it might be considered of Least Concern by the IBAMA list. Discrepancy between both lists reflects two different attitudes towards conservation status assessment, an evidentiary (IBAMA) and a precautionary point of view (GAA) (Baillie et al., 2004, Pimenta et al., 2005, Stuart et al., 2005). The GAA attitude is here preferred because this species is endemic to Atlantic rainforest, which is severely divided into small (< 7,000 km^2) isolated fragments, with only 3,000 km^2 of forest included in protected areas (Brooks & Balmford, 1996). Additionaly, the remnants of Atlantic forest of southeastern Brazil are under high levels of UVB incidence and have highly projected future effects of climatic change, and some species were infected by the fungus *Batrachochytrium dendrobatidis* (Carnaval et al., 2005; 2006; Toledo et al., 2006).

Some species are excellent bioindicators of habitat quality due to their dependence on special microhabitats and microclimatic conditions. *Eleutherodactylus binotatus* and *E. guentheri* lay eggs that undergo direct development on the leaf litter (Lynn & Lutz, 1946; Thibaudeau & Altig, 1999), tadpoles of *Leptodactylus marmoratus* develop out of water in a terrestrial foam nest (Heyer, 1973), and some species of *Cycloramphus* lay eggs in terrestrial situations (Haddad & Sazima, 1989; Verdade & Rodrigues, 2003). Richness of species of the genus *Eleutherodactylus* in Equatorian Amazonia decreased in deforested areas, probably due to microclimate changes (Pearman, 1997). Many anurans use bromeliads as refuge and for forrage and reproduction (Britto-Pereira et al., 1988; Peixoto, 1995; Oliveira & Rocha, 1997; Schineider & Teixeira, 2001), and some species depend on water accumulated in these plants for oviposition and tadpole development. In our sites species associated with bromeliads include *Dendrophryniscus brevipollicatus* (Carvalho, 1949), registered in PECB, and *Scinax argyreornatus* and *Aparasphenodon bokermanni* from PEIC.

The presence of anurans with specific ecological and reproductive requirements in the study sites suggests the presence of healthy ecosystems that must be preserved.

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