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Anuran community of a coastal Atlantic Forest fragment in the state of Rio de Janeiro, southeastern Brazil

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Abstract. We conducted an anuran survey in a forest fragment of approximately 800 ha situated in the municipalities of Maricá, Saquarema, and Tanguá (22°52' S; 42°40' W; 20–450 m a.s.l., SAD69), in Rio de Janeiro state, Brazil, comprising matrices of dense ombrophilous forest and disturbed areas. This study aimed to render an inventory of the anuran species present in the area and provide data on spatial and temporal distribution, as well as natural history information on the species. Fieldwork was performed monthly between January 2011 and December 2012, during which anurans were sampled by means of Visual Encounter Surveys (VES) and 1 m^2 plots. Total sampling effort was 411 man/hours (for VES) and 180 m^2 of surveyed leaf litter (for plots). We recorded 44 species of frogs, with Hylidae being the most representative family. The VES method recorded an abundance of 2.8 individuals/hour, and plot sampling yielded an estimated density of 4 individuals/100 m^2. The species rarefaction curve did not reach an asymptote, indicating that an increase of sampling effort could still expand the number of recorded species. Our results reflect the relevance of the maintenance of this important and so far unprotected forest remnant in the state of Rio de Janeiro. The species richness found here indicates that the studied area, despite its small size, should be considered a priority area for amphibian conservation.

Key words. Conservation, diversity, Espraiado, Mato Grosso Mountain Range, microhabitat use, richness, similarity, spatial and seasonal distribution, vocalization sites.

Introduction

The number of studies on amphibian communities in the Atlantic Forest has grown considerably over the past decade (e.g., Moraes et al. 2007, Carvalho-e-Silva et al. 2008, Bertoluci et al. 2009, Wachlevski & Rocha 2010, Vilela et al. 2011, Martins et al. 2012). However, despite the variety of such studies, they have been unbalanced in their approaches, field methods, and research designs (e.g., Bernarde et al. 1999, Giaretta et al. 1999, Eterovick & Sazima 2000) and therefore, more long-term studies using intensive approaches are still necessary in order to provide enough knowledge about this group (Silvano & Segalla 2005).

Previous studies on anuran communities conducted in Rio de Janeiro state (e.g., Carvalho-e-Silva et al. 2008, Rocha et al. 2008, Silva et al. 2008, Almeida-Gomes et al. 2008, 2010, Salles et al. 2009, Martins et al. 2012, Pontes et al. in press) have demonstrated that although the original Atlantic Forest habitat has been highly disturbed, it still harbours important forest fragments with a relatively high degree of connectivity (Rocha et al. 2003), which facilitates the occurrence of a diverse anuran community. These forest remnants in Rio de Janeiro state are included in the Serra do Mar corridor (MMA 2006) and play an important role in the conservation of endemic and/or threatened anuran species (Rocha et al. 2004) and thus should be considered priority areas for anuran species conservation in the state.

Herein we present the results of two years of monitoring the anuran community in a secondary ombrophilous forest fragment within the Atlantic Forest biome in Rio de Janeiro state, providing data on the local composition, natural history and ecology of anuran species.

Material and methods

Study area

The study area consists of a secondary forest fragment of approximately 800 ha in size, known as Espraiado

(22°52'56" S, 42°41'04" W). This area lies in the Mato Grosso mountain range and its surroundings, covering areas in the municipalities of Maricá, Saquarema, and Tanguá, in the state of Rio de Janeiro, Brazil (Fig. 1). The vegetation is composed by lowland ombrophilous formations (*sensu* Veloso et al. 1991) at different levels of degeneration and regeneration due to urban growth and agriculture in the last decades (Pontes et al. 2012). This area has not yet been the target of botanical studies and therefore, analyses were performed to characterise the vegetation found in the area. Trunk diameters and heights of trees of more than 5 cm in diameter at chest height (DBH) were measured at three random sites within a 100 m^2 area with a measuring tape to the nearest 1 cm. The total circumferences of these trees were converted into diameter applying the formula of $D = C/\pi$, where D is the diameter, C the circumference and $\pi = 3{,}14$. We measured a total of 100 trees for their diameters. Tree height was estimated by the trigonometric method (Soares et al. 2006), where the distance between the observer and the tree was measured with a measuring tape to the nearest 0.1 m, and the angle between the tree and the observer (at the eye level) was measured with a manual clinometer. We analysed a total of 70 trees at three randomly chosen sites. Canopy cover was estimated in nine areas, using photos of 20 × 25 cm taken 1 m above ground level. The pictures were divided into 2,925 quadrants and the number of quadrants covered by vegetation was considered to be equal to the percentage of vegetation cover.

According to the Köppen classification, the climate of the area is *Aw*, being hot and humid with average temperatures ranging from 22–23°C (Kottek et al. 2006, Barbiére & Coe-Neto 1999). The dry season extends from May to June and the rainy season comprises the months from September to March (Kottek et al. 2006, Barbiére & Coe-Neto 1999) although most of the rainfall (around 60%) is concentrated in the months of December and January (Barros et al. 2007).

Data collection

Twenty-four field expeditions were conducted once a month from January 2011 through December 2012; however, data collected from January through December 2011 was only computed for species richness, considering that we did not have a pattern in fieldwork techniques during this period (e.g., VES times not limited and no plots used; see below) in order to achieve comparable results. In the period from January through December 2011, a team of three to five researchers performed random searches for unlimited periods of time in the study area, investigating the forest and temporary ponds in its surroundings, totalling 321 man hours of sampling effort. For statistical analysis, only data obtained from January through December 2012 were used, which was when forest and riverside areas were investigated with VES and plot sampling methods. The sampling method of Visual Encounter Survey (VES) (*sensu* Crump & Scott 1994) conducted from January through December 2012 consisted of a team of five researchers each randomly searching microhabitats (e.g.,

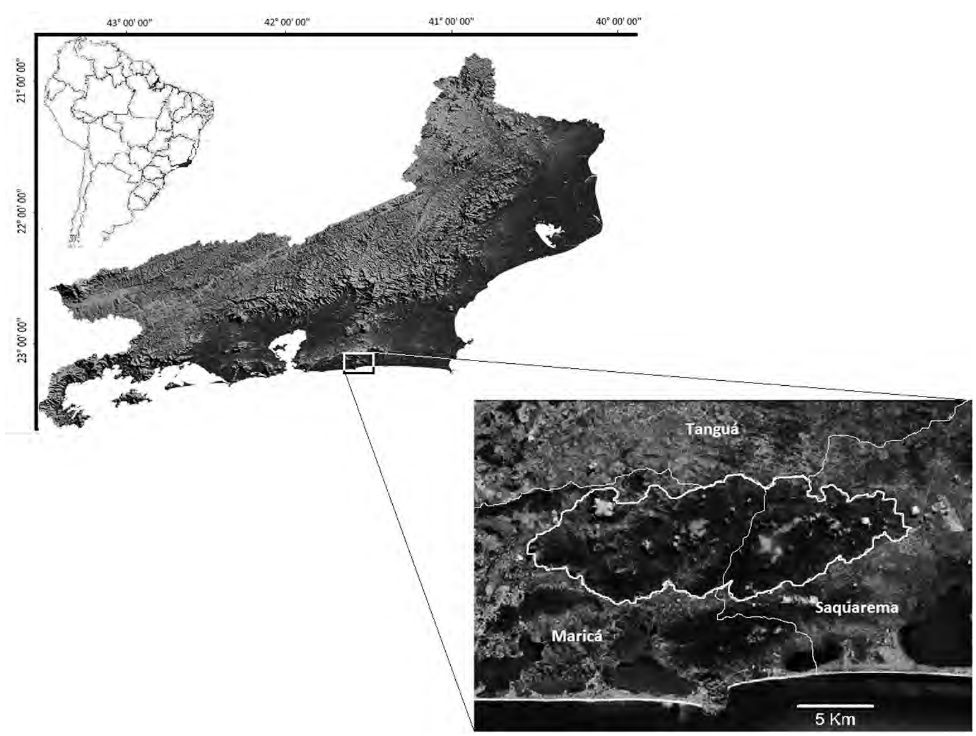

Figure 1. Delimitation of the study area of Espraiado (solid white line), encompassing parts of the municipalities of Maricá, Saquarema, and Tanguá, Rio de Janeiro state, southeastern Brazil.

leaves, burrows in rocky outcrops and logs) for amphibians during a period of 30 minutes each, three times per night, totalling 7.5 man hours/night of sampling effort and therefore totalling 90 man hours from January through December 2012. In addition, each researcher randomly searched three square plots of 1 m^2 per night, which were demarcated on the forest floor, totalling 15 m^2 of leaf litter area investigated per field expedition, and a total of 180 m^2 for the whole period. Plot areas were delimited by fences in order to prevent frogs inside from escaping, and set randomly on the forest floor, with a minimum distance of 5 m between each researcher. For each plot, we estimated the mean leaf-litter depth by measuring its depth with a ruler to the nearest 0.01 cm at the corners of the plot and calculating the mean value.

Data were gathered on some abiotic variables deemed important to amphibian activity (Heyer et al. 1994). Temperature and humidity were obtained by means of a digital thermo-hygrometer (to the nearest 0.2°C and 0.2% humidity) at the beginning and end of conducting a VES, where only the average between these two measurements was considered for further comparisons. Rainfall data were obtained from the closest meteorological station of the Instituto Nacional de Meteorologia – INMET located at Forte de Copacabana, municipality of Rio de Janeiro. This station (22° 57' 06.9" S, 43° 11' 55.8" W; SAD 69) is about 45 km distant from the study area, and thus we assume for our data analysis that it is exposed to similar climatic conditions.

Voucher specimens were euthanised and fixed according the standard procedures of McDiarmid (1994) and deposited in the collection of amphibians at the Museu Nacional/Universidade Federal do Rio de Janeiro (MNRJ). Those captured specimens that were not euthanised were released in the same area at the end of a searching stint. Specimens were classified following the nomenclature of Frost (2013) and identified through direct comparisons with literature data and specimens in the collection of amphibians at the Museu Nacional/Universidade Federal do Rio de Janeiro (MNRJ).

Data analysis

To evaluate the efficiency of our sampling methods, a rarefaction curve of species captured with the VES method was generated (Krebs 1999) with 1,000 randomisations from a data matrix of abundance, totalling 12 samples, where each sample corresponded to a month, from January through December 2012. Species richness in the study area was estimated by the extrapolation of the accumulation curve, using Jackknife1 as the estimator in EstimateS 7.0 software. An estimate of anuran diversity was obtained via the Shannon-Wiener index (Magurran 1988) using DivEs 2.0 software.

We conducted chi-square tests to check if different types of microhabitats used by frogs differed statistically. A Spearman Correlation analysis was performed to compare climatic conditions during the sampling period with available data from previous decades (1961 through 2010, available from the INMET database). To check the influence of environmental data on amphibian abundance, multiple regression analyses were conducted, including data on rainfall, temperature and humidity as independent variables. The normality of the data was tested with the Kolmogorov-Smirnov analysis (Zar 1999). Statistical analyses were performed with Statistica 7 software, using a significance index of $p < 0.05$ for all analyses.

To compare the anuran species composition in our study area with different communities reported for other sites within the Atlantic Forest domain, Jaccard similarity analyses were performed with PRIMER 6 software, clustering groups with the group-average method. To ensure the comparability of data, only those anuran surveys that were undertaken over periods of one to two annual cycles were selected. The localities that were considered for our similarity analysis are listed in Table 1. To avoid possible misidentifications, only species reliably identified at species level were used, excluding species that could be identified only as "cf.", "gr.", "sp." or "aff.".

Results

Vegetation of the study area

Our data indicate that the studied area is composed of heterogeneous secondary forest, although some sub-areas still harbour well-preserved primary vegetation, frequently around the tops of mountains. We also observed the presence of several exotic species, such as the ornamental plant *Tradescantia zebrina* Heynh ex. Bosse, banana trees (species of *Musa* Linnaeus) and jackfruit trees (*Artocarpus heterophyllus* Lam.). The vegetation includes arboreal elements (20–39 individuals/100 m^2; 32 ± 10.4 individuals/100 m^2) with bromeliads and other epiphytes. The arboreal elements had DBH values ranging from 2.2–84.3 cm (17.3 ± 16.1 cm). Tree height ranged from 2–22 m (10 ± 5.2 m). Canopy cover was a minimum of 96.2 and a maximum of 99.7% (97.9 ± 1.1%). Marginal areas were marked by the removal of original vegetation for utilisation as pastures, with the vegetation being characterized mostly by grass and shrubs. Furthermore, some core areas were found to be affected by the removal of original vegetation, mostly along the banks of rivers through banana plantations.

Anuran species composition

We recorded a total of 44 anuran species, with the Hylidae being the most speciose family (24 spp.), followed by Leptodactylidae (7 spp.) (Tab. 2). According to the IUCN Red List (IUCN, 2013), all species except for *Scinax trapicheiroi* – which is considered "Near Threatened (NT)" – are classified as "Least Concern" (LC) regarding their conservation status (Tab. 3).

We recorded an abundance of 2.8 individuals/hour with the VES method, with higher abundance levels in the rainy

Table 1. Localities, municipalities, states and sources of data for different amphibian communities reported from the Atlantic Forest domain used in Jaccard similarity analyses for comparison with the study area.

Locality	Municipality	State	Source
–	João Pessoa	Paraíba	Santana et al. 2007
Reserva Sapiranga	Mata de São João	Bahia	Juncá 2006
Camamu	Itapebi and Prado	Bahia	Silvano & Pimenta 2003
Reserva Biológica de Duas Bocas	Cariacica	Espírito Santo state	Prado & Pombal 2005
Parque Estadual dos Três Picos	Nova Friburgo	Rio de Janeiro	Siqueira et al. 2011
Parque Estadual Serra do Brigadeiro	Araponga, Divino, Ervália, Fervedouro, Miradouro, Muriaé, Pedrão Bonita, and Sericita	Minas Gerais	Moura et al. 2012
–	Rio Novo	Minas Gerais	Feio & Ferreira 2005
Reserva Particular do Patrimônio Natural Santuário do Caraça	Santa Bárbara and Catas Altas	Minas Gerais	Canelas et al. 2007
	Ribeirão Branco and Apiaí	São Paulo	Pombal 1997
Parque Estadual Mata do Godoy	Guararape	São Paulo	Bernarde & Kokubum 1999
Parque Estadual de Intervales	of Guapira, Ribeira Branco, Sete Barras, El Dorado, and Iporanga	São Paulo	Bertoluci & Rodrigues 2002
Parque Estadual Carlos Botelho	São Miguel Arcanjo, Capão Bonito, and Sete Barras	São Paulo	Bertoluci et al. 2007
Parque Estadual da Ilha do Cardoso	Cananéia	São Paulo	Bertoluci et al. 2007
	Londrina	Paraná	Bernarde & Anjos 1999
Parque Estadual do Rio Guarani	Três Barras	Paraná	Bernarde & Machado 2001
Área de Proteção Ambiental Guaratuba	São José dos Pinhais	Paraná	Cunha et al. 2010

Table 2. Anuran species recorded from different environments (forested areas and ponds) in Espraiado, Rio de Janeiro state, southeastern Brazil. Legend: Ll: leaf litter; F: forest; Wa: water; Ro: rock; Bl: bromeliad; Br: branch; Ca; canopy; P: pond; Vo: vocalization record; Le: leaf; Sa: sand.

Taxonomic category	Forest	Pond	Vocalization site
Brachycephalidae Günther, 1858			
Ischnocnema guentheri (Steindachner, 1864)	Ll (12)	–	F/Ll
Ischnocnema octavioi (Bokermann, 1965)	Ll (3)	–	–
Ischnocnema parva (Girard, 1853)	Ll (1), Vo	–	–
Bufonidae Gray, 1825			
Rhinella icterica (Spix, 1824)	Ll, Wa (13)	–	P/Ll
Rhinella ornata (Spix, 1824)	Ll, Wa (17)	–	P/Ll
Craugastoridae Hedges, Duellman & Heinicke, 2008			
Haddadus binotatus (Spix, 1824)	Ll (74)	–	F/Ll
Cycloramphidae Bonaparte, 1850		–	
Thoropa miliaris (Spix, 1824)	Ro, Ll, Wa (61)	–	F/Ro
Zachaenus parvulus (Girard, 1853)	Ll (1)	–	–
Hemiphractidae Peters, 1862			
Fritziana goeldii (Boulenger, 1895 "1894")	Bl (1)	–	F/Bl, Banana
Gastrotheca albolineata (Lutz & Lutz, 1939)	Br (2)	–	F/Br
Hylidae Rafinesque, 1815			
Aplastodiscus eugenioi (Carvalho-e-Silva & Carvalho-e-Silva, 2005)	Le, Br (6)	–	F/Le

Taxonomic category	Forest	Pond	Vocalization site
Dendropsophus anceps (Lutz, 1929)	–	Br, Le (6)	P/Br
Dendropsophus bipunctatus (Spix, 1824)	–	Le, Br (13)	P/Br
Dendropsophus decipiens (Lutz, 1925)	–	Le (1)	P/Br
Dendropsophus elegans (Wied-Neuwied, 1824)	–	Le (8)	P/Br
Dendropsophus meridianus (Lutz, 1954)	–	Le (49)	P/Br
Dendropsophus minutus (Peters, 1872)	–	Vo	P/(?)
Dendropsophus aff. *oliveirai*	–	Le, Br (21)	P/Br
Dendropsophus pseudomeridianus (Cruz, Caramaschi & Dias, 2000)	–	Le, Br (9)	P/Br
Dendropsophus seniculus (Cope, 1868)	–	Vo	P/(?)
Hypsiboas albomarginatus (Spix, 1824)	Le (5)	Le (34)	P/Br
Hypsiboas faber (Wied-Neuwied, 1821)	Br (12)	–	F/Br
Hypsiboas semilineatus (Spix, 1824)	Br (9)	–	F/Br
Itapotihyla langsdorffii (Duméril & Bibron, 1841)	Br (1)	–	–
Phasmahyla guttata (Lutz, 1924)	Ll, Ro, Br, Le (87)	–	F/Br,Le
Phyllomedusa burmeisteri Boulenger, 1882	–	Vo	–
Phyllomedusa rohdei Mertens, 1926	Le (8)	–	P/Br,Le
Scinax alter (Lutz, 1973)	–	Br (20)	P/Br
Scinax humilis (Lutz, 1954)	Br (7)	–	F/Br
Scinax trapicheiroi (Lutz, 1954)	Le, Ro,Br (109)	–	F/Br
Scinax aff. *v-signatus* (Lutz, 1968)	Bl (2)	–	F/Bl
Scinax aff. *x-signatus*	–	Br (Vo)	P/Br (Vo)
Sphaenorhynchus planicola (Lutz & Lutz, 1938)	–	Le, Wa (8)	P/Wa
Hylodidae Günther, 1858			
Crossodactylus gaudichaudii Duméril & Bibron, 1841	Ro, Sa, Ll, Wa (72)	–	F/Wa,Ro
Hylodes cf. *pipilans*	Wa, Ro, Ll, As (20)	–	–
Leptodactylidae Werner, 1898			
Adenomera aff. *marmorata*	Ll (1)	–	F/Ll
Adenomera marmorata Steindachner, 1867	Ll, Le (22)	–	F/Ll
Adenomera thomei (Almeida & Angulo, 2006)	Ll (5)	–	F/Ll
Leptodactylus fuscus (Schneider, 1799)	–	Vo	P/(?)
Leptodactylus latrans (Steffen, 1815)	Ll (2)	Ll, Wa (9)	P/Wa
Leptodactylus mystacinus (Burmeister, 1861)	Ll (1)	–	–
Physalaemus signifer (Girard, 1853)	Ll, Wa (47)	–	F/Wa,Ll
Microhylidae Günther, 1858			
Myersiella microps (Duméril & Bibron, 1841)	Ll (2)	–	–
Odontophrynidae Lynch, 1971			
Proceratophrys boiei (Wied-Neuwied, 1824)	Ll (2)	–	F/Ll

season (3.3 individual/hour) compared to the dry season (2.3 individuals/hour) (Fig. 3). *Scinax trapicheiroi* and *Phasmahyla guttata* were the most abundant species, with 13.6 and 10.9% of the total records, respectively. The high abundances found for *S. trapicheiroi* did not occur homogeneously throughout all areas surveyed with the VES method, but in specific backwater areas along riversides. On the other hand, high abundances for *P. guttata* were recorded more homogeneously throughout riverside areas. The estimated overall density of frogs living in leaf litter was 4 individuals/100 m^2, represented by the species *Crossodactylus gaudichaudii, Haddadus binotatus, Ischnocnema guentheri*, *Adenomera marmorata*, and *Phasmahyla guttata*. The most abundant species recorded by means of plot-sampling were *H. binotatus* and *C. gaudichaudii*, which together represented 28.6% of all anurans sampled. Higher capture rates (85.8% of the individuals captured; n = 6 plots in which anurans were found) in plot-sampling were obtained during the rainy season, compared to 14.2 % of individuals captured (n = 1 plot in which anurans were found) during the dry season. Leaf litter depths varied from 3.4 to 4.8 cm, showing little difference throughout the year (Fig. 4).

Table 3. Distances of anuran microhabitats above the ground and from the nearest water body recorded in Espraiado, municipalities of Maricá, Saquarema, and Tanguá, Rio de Janeiro state, southeastern Brazil, and their conservation status. Numbers represent classes of distance from ground and water: (I) 0–0.1 cm; (II) 0.1–200 cm; (III) > 200 cm; ALL: above leaf litter; WLL: within leaf litter; Riv: river; Pon: Pond; LC: Least concern; DD: data deficient; NT: near threatened.

Taxonomic category	Ground distance (m)	Distance from water body (m)	Conservation Status
Anura Fischer von Waldheim, 1813			
Brachycephalidae Günther, 1858			
Ischnocnema guentheri (Steindachner, 1864)	ALL	III	LC
Ischnocnema octavioi (Bokermann, 1965)	ALL	II	LC
Ischnocnema parva (Girard, 1853)	ALL	III	LC
Bufonidae Gray, 1825			
Rhinella icterica (Spix, 1824)	ALL	III	LC
Rhinella ornata (Spix, 1824)	ALL	III	LC
Craugastoridae Hedges, Duellman & Heinicke, 2008			
Haddadus binotatus (Spix, 1824)	ALL	III	LC
Cycloramphidae Bonaparte, 1850			
Thoropa miliaris (Spix, 1824)	ALL	(Riv) I	LC
Zachaenus parvulus (Girard, 1853)	ALL	I	LC
Hylidae Rafinesque, 1815			
Hypsiboas faber (Wied-Neuwied, 1821)	II	III	LC
Hypsiboas semilineatus (Spix, 1824)	II	II	LC
Phasmahyla guttata (Lutz, 1924)	II	(Riv) II	LC
Scinax trapicheiroi (Lutz, 1954)	II	(Riv) II	NT
Hylodidae Günther, 1858			
Crossodactylus gaudichaudii Duméril & Bibron, 1841	ALL	(Riv) I	LC
Hylodes cf. pipilans	ALL, I	I	–
Leptodactylidae Werner, 1898			
Adenomera aff. *marmorata*	ALL, WLL	III	–
Adenomera marmorata Steindachner, 1867	ALL, WLL	III	LC
Adenomera thomei (Almeida & Angulo, 2006)	ALL	III	LC
Leptodactylus latrans (Steffen, 1815)	ALL	(Pon) I	LC
Leptodactylus mystacinus (Burmeister, 1861)	ALL	III	LC
Physalaemus signifer (Girard, 1853)	ALL	(Pon) I	LC
Microhylidae Günther, 1858			
Myersiella microps (Duméril & Bibron, 1841)	ALL, WLL	(Riv) III	LC
Odontophrynidae Lynch, 1971			
Proceratophrys boiei (Wied-Neuwied, 1824)	ALL, WLL	(Pon) II	LC

Spatial and temporal distribution

Species of the families Brachycephalidae, Bufonidae, Craugastoridae, Cycloramphidae, Hylodidae, Leptodactylidae, Microhylidae, and Odontophrynidae were more commonly associated with microhabitats on ground level, whereas Hylodidae and Cycloramphidae seemed to prefer riverside microhabitats (e.g., sand, rocks, and water). However, *Hylodes* cf. *pipilans* was sporadically recorded inactive on leaves or branches close to streams, mostly at night, at between 0.2 and 0.6 m above the ground. Most of the species belonging to the families Hylidae and Hemiphractidae were observed in arboreal microhabitats, such as branches and leaves. Notwithstanding, some species were found merely transiting through ground microhabitats (e.g., leaf litter) such as *Phasmahyla guttata* and *Scinax trapicheiroi* (Tab. 2). Hylidae species perched at similar average distances from the ground, ranging from 1 to 2 m above ground, except for *Aplastodiscus eugenioi*, which was seen at heights of 3 to 4 m above the ground (Tab. 3). In addition, some species were encountered exclusively in bromeliads, such as *Scinax* aff. *v-signatus*, or exclusively on canopy branches, such as *Gastrotheca albolineata*.

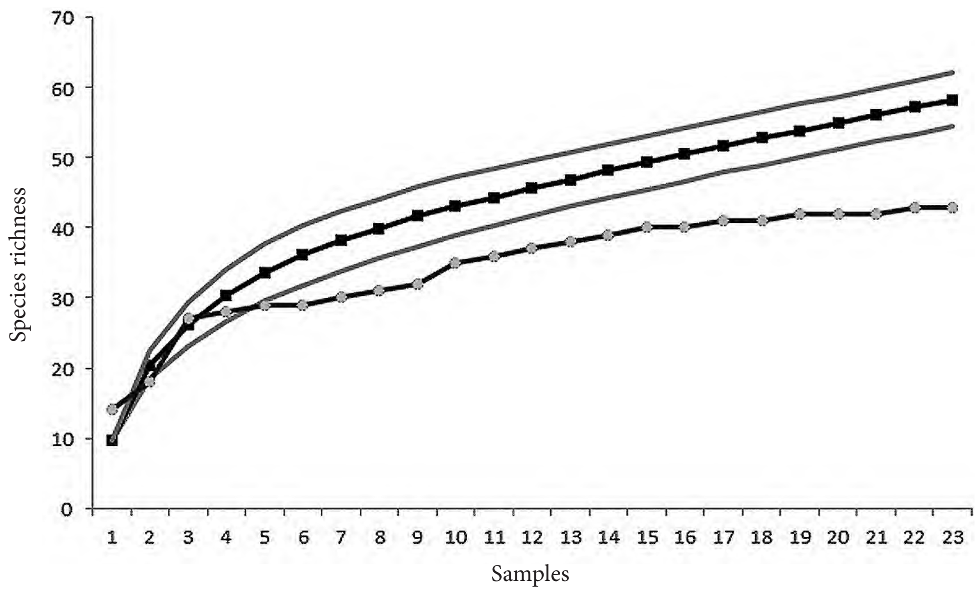

Figure 2. Rarefaction curve estimated for anuran species with the *Jackknife1* estimator (black squares), estimated confidence interval of 0.95 % (grey lines), and accumulation curve (grey circles) for Espraiado, municipalities of Maricá, Saquarema, and Tanguá, Rio de Janeiro state, southeastern Brazil, from January through December 2012.

For most of the species recorded in the area, vocalization site records coincided with the microhabitat used by a species while foraging or inactive. Only *Aplastodiscus eugenioi* vocalized from branches/bromeliads in the canopy during the dry season, and was recorded on branches close to the ground during the rainy season (Tab. 3).

Data analysis

The rarefaction curve of species found during visual encounters showed a rapid increase in the number of species when the sampling effort was increased. Although the curve tended to move towards the asymptote, it did not reach a plateau. Based on the Jackknife1 estimator, the species richness for the area was estimated at 58.3 ± 3.77 species (Fig. 2).

According to the Shannon-Wiener index, the frog diversity in the study area was H' = 1.32. Chi-square tests revealed that anurans preferred to use terrestrial microhabitats (n = 261, χ^2 = 44.7), such as leaf-litter or bare soil, rather than rocks (n = 44, χ^2 = 1.2), water (n = 25, χ^2 = 4.05, df = 6), sand (n = 4, χ^2 = 29.7, df = 6), or arboreal habitats such as leaves (n = 82, χ^2 = 53.7, df = 6), branches (n = 56, χ^2 = 9.38, df = 6), or bromeliads (n = 4, χ^2 = 29.7, df = 6).

Spearman correlation obtained through the comparison of previous decades with the studied period were not significant for rainfall data (R = 0.230, p = 0.470), whereas temperature was significant (R = 0.627, p = 0.028). According to multiple regressions, amphibian abundance does not seem to be related to any of the abiotic factors considered ($F_{3,8}$ = 0.219; p = 0.880; r = 0.275 for the entire analysis; $F_{3,8}$ = 0.219; p = 0.938 for rainfall; $F_{3,8}$ = 0.219; p = 0.456 for temperature; and $F_{3,8}$ = 0.219; p = 0.580 for relative humidity) (Fig. 3). With regard to total frog abundance, higher values were computed in rainy seasons compared to dry seasons.

The similarity analysis that compared Atlantic Forest compositions between different areas showed two well-defined groups: one comprising the more northern localities (Rio de Janeiro to Bahia state) and the other the localities from farther south (São Paulo and Paraná states) (Fig. 5). The frog assemblage of Espraiado was part of the northern group and, within it, it was closest to the frog assemblages of Parque Estadual dos Três Picos (Rio de Janeiro state), Parque Estadual da Serra do Brigadeiro (Minas Gerais state), and Reserva Particular do Patrimônio Natural Santuário do Caraça (Minas Gerais state).

Discussion

Anuran composition, diversity and similarity

The amphibian species composition in the study area resembles those reported in other studies that were carried out in ombrophilous forest areas in the state of Rio de Janeiro (e.g., Carvalho-e-Silva et al. 2008, Almeida-Gomes et al. 2010, Siqueira et al. 2011a, Pontes et al. unpubl. data), with the Hylidae family likewise being predominant in the community recorded herein. This pattern has been traditionally associated with the capability of these species to occupy vertical strata due to the presence of adhesive discs on their digits (Cardoso et al. 1989, Pombal 1997, Prado & Pombal 2005).). Therefore, this characteristic facilitates a simultaneous presence of a higher number of Hylidae species within an area because they are able to segregate vertically in addition to horizontal-

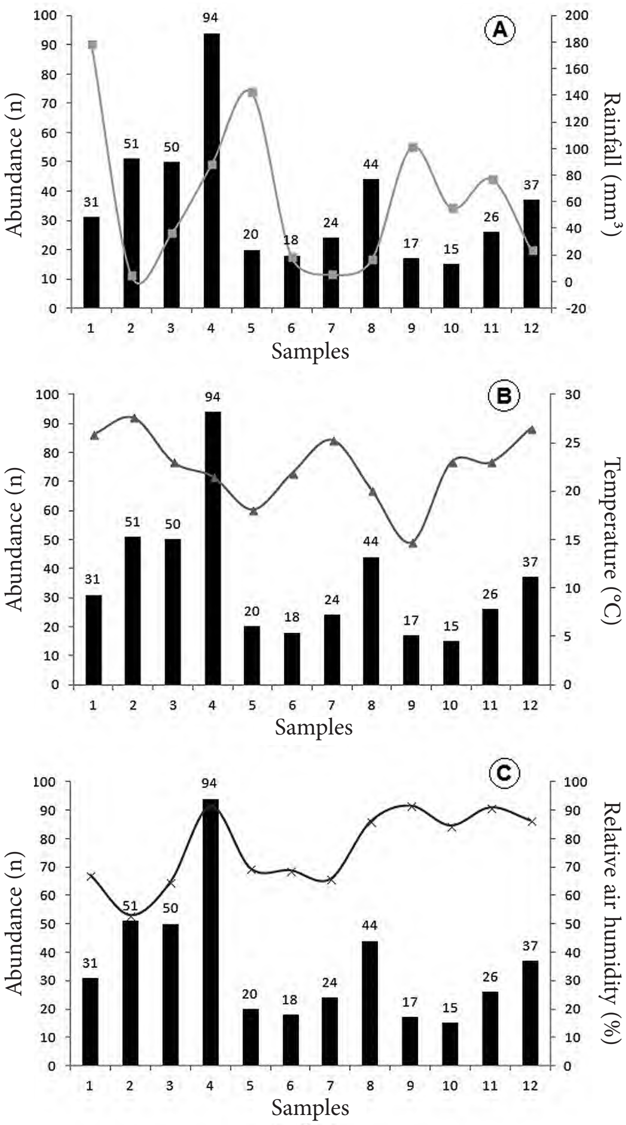

Figure 3. Correlation of recorded anuran abundance and abiotic factors in Espraiado, municipalities of Maricá, Saquarema, and Tanguá, Rio de Janeiro state, southeastern Brazil from January through December 2012. (A) Anuran abundance (black bars) and rainfall (grey squares and line); (B) anuran abundance (black bars) and temperature (grey triangles and line); (C) anuran abundance (black bars) and relative humidity (grey "x" and line)

ly (Cardoso et al. 1989, Pombal 1997, Prado & Pombal 2005). Differentiated specialised diets of hylids might have furthered the successful colonisation of a wider variety of microhabitats, thus increasing the diversity of the family in anuran communities (Parmelee 1999).

Magurran (1988) suggested that species diversity was high when Shannon-Wiener values were higher than 3.5, moderate at values between 1.5 and 3.5 and low at an index lower than 1.5, which possibly indicates areas impacted by human activities. Although our study area harbours

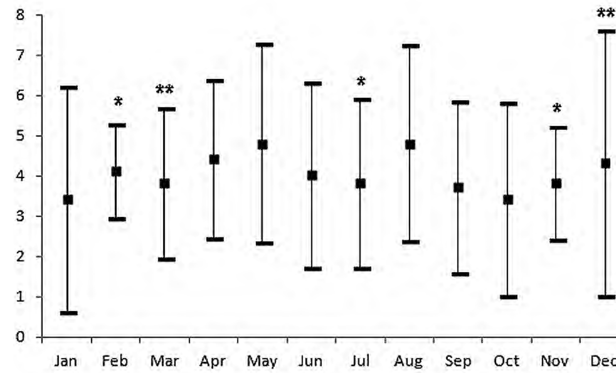

Figure 4. Depth of the leaf litter layer (mm) recorded in Espraiado, municipalities of Maricá, Saquarema, and Tanguá, Rio de Janeiro state, southeastern Brazil, from January through December 2012. Black squares mark the mean depths and vertical traces indicate standard deviations. Asterisks represent the number of species captured in each month.

high species richness, we found a low diversity index in the present study (H' = 1.32).

The results of similarity analyses showed two well-defined areas in the Atlantic Forest domain. This difference between the anuran compositions from areas in Paraná and São Paulo state to those from areas in Rio de Janeiro to Bahia state, agrees with other studies that also found a north-south division in the Atlantic Forest (Costa 2003, Grazziotin et al. 2006, Carnaval et al. 2009, Fitzpatrick et al. 2009, Martins 2011). Within the northern group, the higher level of similarity between Espraiado and areas in Rio de Janeiro (Parque Estadual dos Três Picos) and Minas Gerais (Parque Estadual Serra do Brigadeiro and RPPN Santuário do Caraça) states, all located in the Atlantic Forest domain or transition areas between the Cerrado and the Atlantic Forest domain, is probably due to the phytophysiognomic similarities among them, with less disturbed and denser vegetation areas composed of secondary forest. Moreover, similarity patterns could also be influenced by historical factors, such as the climatic changes that occurred during the Pliocene and/or the formation of refuge areas during the Pleistocene, which could have led to differences in the faunistic composition among different Atlantic Forest areas nowadays (Vasconcelos et al. 1992, Grazziotin et al. 2006, Carnaval & Moritz 2008).

Microhabitat usage and spatial distribution

According to our Chi-square results, we found that "leaf litter/ground" was by far the most commonly preferred microhabitat of anurans, which is probably due to the high abundance of species with terrestrial life habits (families Leptodactylidae, Microhylidae, Bufonidae, Craugastoridae, Brachycephalidae, Cycloramphidae, and Hylodidae) as compared to arboreal and/or aquatic habits (Hylidae

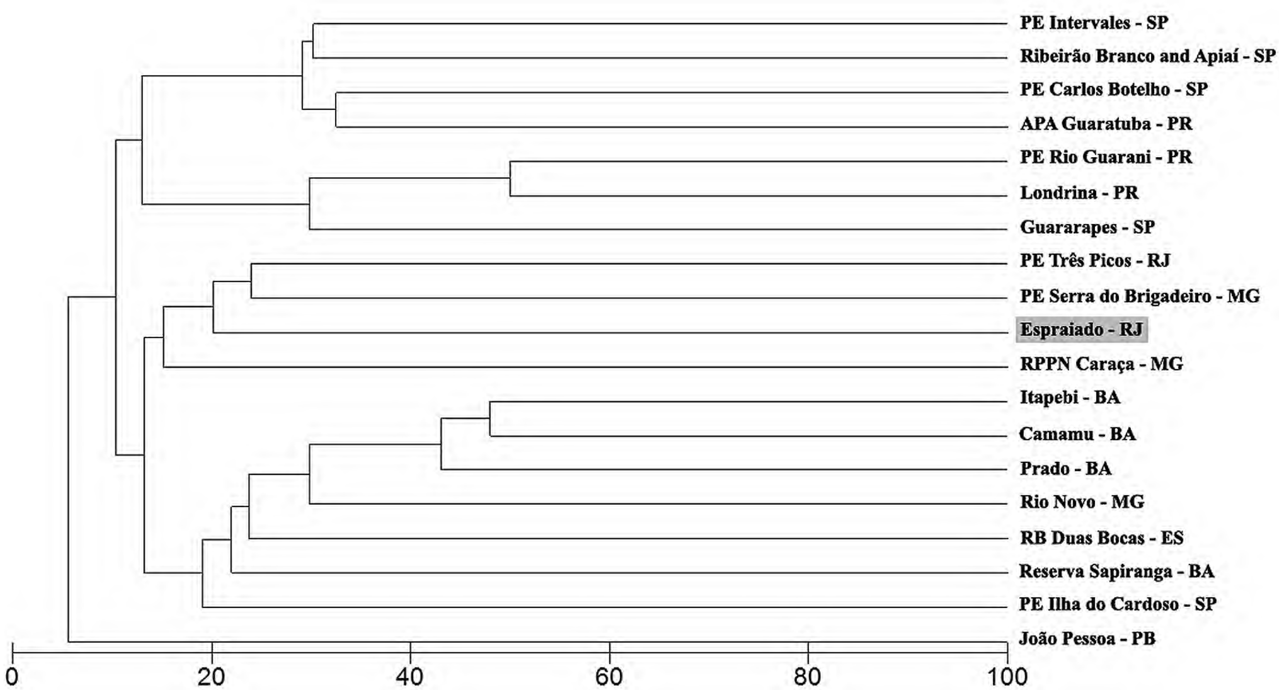

Figure 5. Dendrogram of a cluster similarity analysis among Brazilian Atlantic Forest areas, using the Jaccard index and group-average method.

and Hemiphractidae). Spatial partitioning of ecological resources enables species to coexist in a small area (Crump 1974). Thus, the great number of microhabitats at ground level found herein, such as water, rocks, sand and different levels in the leaf litter, facilitates the simultaneous presence of several species from different families (Brachycephalidae, Bufonidae, Craugastoridae, Cycloramphidae, Hylodidae, Leptodactylidae, Microhylidae, and Odontophrynidae) in the area as well as their high abundances. For instance, water, sand and rock microhabitats (all located on river banks) were mainly used by Cycloramphidae, Hylodidae and Leptodactylidae species, while leaf litter was preferred by Brachycephalidae, Bufonidae, Microhylidae, and Odontophrynidae species. Among the species found on or in the leaf litter, *Ischnocnema* spp. and *Haddadus binotatus* exhibit adaptations to water-independent reproduction, such as the direct development of terrestrial eggs (Haddad et al. 2008, Hedges et al. 2008). *Hylodes* cf. *pipilans* was always found near streams and specimens were occasionally encountered on leaves or branches above ground. The occupation of leaves or branches by *H.* cf. *pipilans* could possibly be a result of a defensive strategy, as was found by Almeida-Gomes et al. (2007) who previously observed a spatial segregation among the members of Hylodidae, with *Hylodes phyllodes* retreating to more vertical microhabitats when disturbed or scared by an observer.

Concerning arboreal species, some Hylidae and Hemiphractidae species strictly associated with bromeliads were recorded in the study area, such as *Scinax* aff. *v-signatus* and *Fritziana goeldii*. According to Peixoto (1995), members of the *Scinax perpusillus* group (such as *S.* aff. *v-signatus*), *Gastrotheca albolineata* and *F. goeldii* are categorized as bromeligenic species, due to their biological dependence on bromeliads, although we failed to record *G. albolineata* from bromeliads (for more information, see Pontes et al. 2012)

Abundance rates and different methodologies

Regarding amphibian abundance, our results are similar to previous studies undertaken in coastal lowlands and other areas in Rio de Janeiro state (Almeida-Gomes et al. 2008, 2010, Martins et al. 2012, Pontes et al. unpubl. data). Differences between abundance rates may be a result of applied methods and/or habitats investigated. Higher abundances recorded with the VES method (Pontes et al. unpubl. data: 4.2 individuals/hour, Siqueira et al. 2011a: 3 individuals/hour) are probably caused by a greater sampling effort in different habitats by previous authors, such as temporary and permanent ponds. The higher abundance found in these diverse habitats might be related to the lek system found in almost all anuran communities, which consequently leads to a high aggregation of species and individuals around these areas (Wells 2007). Hence, the mostly riverine sampling carried out in this study, where anuran individuals are sparsely distributed with some small aggregations, could yield a lower abundance rate as compared to Pontes et al. (unpubl. data) simply because fewer individuals are captured in this manner. On the other hand, Pontes et al. (in press), Martins et al. (2012) and Siqueira et al. (2011b) recorded a lower abundance of anuran species (1.7 individuals/hour, 0.9 individuals/hour and 0.3 individuals/hour, respectively), which might be a consequence of their sampling in less diverse habitats (such as restinga and rocky seashore ecosystems) or disturbed remnants that may have a low abundance of anuran species to begin with.

Regarding plot sampling, we believe that the leaf litter frog density values obtained in our study (4 individuals/100 m^2) could be underestimated, because the low abundances recorded herein by means of plot-sampling might have been due to the inefficiency of sampling plots of 1 m^2 rather than 2 × 1 m (2 m^2), as previously judged more effective by Rocha et al. (2001). Nevertheless, a comparison of the few accessible data on the density of leaf-litter frogs obtained through plot-sampling indicates that the density recorded here is higher than in disturbed areas (e.g., Almeida-Gomes et al. 2010: 3.1 individuals/100 m^2, Cambuci) and lower than in well-preserved areas such as Três Picos and Cachoeiras de Macacu (Siqueira et al. 2011b: 13.2 individuals/100 m^2) and Reserva Rio das Pedras (Rocha et al. 2013: 10.1 individuals/m^2) both in the state of Rio de Janeiro, and Serra das Torres mountains, in Espírito Santo state (Oliveira et al. 2013: 6.6 individuals/100 m^2).

The results obtained from the rarefaction curve and the Jaccknife1 estimator suggest that the species composition is still underestimated, and more long-term studies may reveal the presence of additional species in the area. Future studies should be complemented with combined and/or different approaches in fieldwork, such as the use of pitfall traps for leaf-litter species, increased visual search times, and the use of larger plots (e.g., 2 m^2). Although the use of pitfall traps has not proven to be an efficient method for short herpetofaunal surveys in Atlantic Forest areas (Siqueira et al. 2011a, Almeida-Gomes et al. 2008, 2010), a few studies have proven the importance of this methodology for enhancing the capture potential of leaf-litter frogs in some Atlantic forest areas (e.g., Martins et al. 2012). Therefore, the use of pitfall traps in a future long-term study may prove to be important to increase leaf-litter frog capture rates. Moreover, increasing visual search times during dusk and night will surely maximize encounter rates, considering that the VES method has been demonstrated to be the most efficient method for capturing frogs in Brazilian rainforest areas (e.g., Almeida-Gomes et al. 2010, Siqueira et al. 2011a, Martins et al. 2012).

Study area and the importance of forest fragment conservation

Several studies conducted within disturbed and small (ca. 500–600 ha) Atlantic Forest fragments (e.g., Almeida Gomes et al. 2008, Santana et al. 2008) reported a low number (usually < 20 spp.) of species that are most commonly associated with disturbed environments. According to Almeida-Gomes et al. (2010), such fragments may suffer an irreversible loss of diversity and species richness that will directly affect anuran communities. However, the high species richness in a small fragment (ca. 800 ha.) obtained herein might be historically explained with to the emerging of vegetation matrices in the past decades. In other words, the studied area has been subjected to intense disturbances, such as the removal of original vegetation for the use of land as pastures and plantations, and, therefore, only some small forest fragments remained unaltered over time – mostly on top of the mountains. These remnants might have played an important role for the continued existence of anuran assemblages in "forest islands" that now serve as refuges. Where agricultural activities were abandoned later, these fragments could reconnect, allowing amphibian populations to recolonise previously hostile areas. Therefore, the low number of species previously reported by other authors (e.g., Almeida-Gomes et al. 2008, Feio & Ferreira 2005, Santana et al. 2008, Lucas & Fortes 2008) in small remnants may be a direct effect of a lack of "forest islands" as a source of subsequent recolonisation. Thus, although some studies affirm that secondary forests and remnants may not represent potential refuges for many threatened species (Gardner et al. 2006), the results here observed suggest that disjunctive small remnants that currently do not harbour substantial species richness can – with the effort of conservation initiatives – become relevant areas for the maintenance of anuran assemblages in the future.

Species conservation status and perspectives

According to the IUCN Red List, *Scinax trapicheiroi* is classified Near Threatened (NT) due to its small distribution range (less than 20,000 km^2), even though it occurs in a habitat that is not immediately threatened, and therefore, its population is probably not in decline. However, according to Luna-Dias et al. (2009) and the results from our study (not only concerning distribution, as well as abundance), the new localities from which the species was recorded expands its known distribution range (this study = ~50.000 m^2), and chances are that the populations of this species are merely unknown and poorly studied rather than in decline. However, considering the results of our study, detailed studies should be conducted to elucidate its population status. The small distribution range of the species, in conjunction with intense habitat loss and fragmentation might call for urgent measures to be taken in order to preserve the fragments where these frogs are still found.

Male specimens of *Hylodes* cf. *pipilans* were all juvenile, which did not allow to identify this species with the required certainty. If our specimens are confirmed to represent *Hylodes pipilans*, the species will be included in the list of "Data Deficient" species, and, therefore, the conservation of forest fragments where it is found will not only increase the chances for its population to survive, but also allow future studies on the systematics and natural history, and assisting with a proper definition of the conservation status of the species.

Our data presented herein may be useful for suggesting the implementation of a legally protected area comprising the fragments studied. This measure is necessary considering the ongoing anthropogenic disturbances caused by harmful tourist activities in the area, which might directly affect species such as *Scinax trapicheiroi*, and species about which little ecological and natural history information exists. Only the urgent implementation of protection measures will ensure effective and direct results for the species conservation in this area.

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References

Abrunhosa, P. A., H. Wogel & J. P. Pombal(2006): Anuran temporal occupancy in a temporary pond from the Atlantic Rain Forest, South-Eastern Brazil. – Herpetological Journal, **16**: 115–122.

Almeida-Gomes, M., M. Almeida-Santos, P. Goyannes-Araújo, V. N. T. Borges-Júnior, D. Vrcibradic, C. C. Siqueira, C. V. Ariani, A. S. Dias, V. V. Souza, R. R. Pinto, M. Van Sluys & C. F. D. Rocha (2010): Anurofauna of an Atlantic Rainforest fragment and its surroundings in Northern Rio de Janeiro State, Brazil. – Brazilian Journal of Biology, **70**: 871–877.

Almeida-Gomes, M, F. H. Hatano, M. Van Sluys & C. F. D. Rocha (2007): Diet and microhabitat use by two Hylodinae species (Anura, Cycloramphidae) living in sympatry and syntopy in a Brazilian Atlantic Rainforest area. – Iheringia, Série Zoológica, Porto Alegre, **97**: 27–30.

Almeida-Gomes, M., D. Vrcibradic, C. C. Siqueira, M. C. Kiefer, T. Klaion, P. Almeida-Santos, D. Nascimento, C. V. Ariani, V. N. T. Borges-Junior, R. F. Freitas-Filho, M. Van Sluys & C. F. D. Rocha (2008): Herpetofauna of an Atlantic rainforest area (Morro São João) in Rio de Janeiro State, Brazil. – Anais da Academia Brasileira de Ciências, **80**: 291–300.

Barbiére, E. B. & P. S. Coe-Neto (1999): Spatial and temporal variation of the east fluminense coast and atlantic Serra do Mar, State of Rio de Janeiro, Brazil. – pp. 47–56 in: Knoppers, B.; E. D. Bidone & J. J. Abrão (eds): Environmental Geochemistry of Coastal System, Rio de Janeiro, Brazil. – Série Geoquímica Ambiental, **5**.

Bernarde, P. S. & L. Anjos (1999): Distribuição espacial e temporal da Anurofauna no Parque Estadual Mata dos Godoy, Londrina, Paraná, Brasil (Amphibia: Anura). – Comunicações do Museu de Ciências e Tecnologia da Pontifícia Universidade Católica do Rio Grande do Sul Série Zoologia, **12**: 127–140.

Bernarde, O. S. & M. N. C. Kokubum (1999): Anurofauna do município de Guararapes, Estado de São Paulo, Brasil (Amphibia: Anura). – Acta Biologica Leopoldensia, **21**: 89–97.

Bernarde, P. S., M. N. C. Kokubum, R. S. Machado & L. Anjos (1999): Uso de habitats naturais e antrópicos pelos anuros em uma localidade no Estado de Rondônia, Brasil (Amphibia: Anura). – Acta Amazônica, **29**: 555–562.

Bernarde, P. S. & R. A. Machado (2001): Riqueza de espécies, ambientes de reprodução e temporada de vocalização da anurofauna em Três Barras do Paraná, Brasil (Amphibia: Anura). – Cuaderno de Herpetologia, **14**: 93–104.

Bertoluci, J. (1998): Annual patterns of breeding activity in Atlantic Rainforest anurans. – Journal of Herpetology **32**: 607–611.

Bertoluci, J., R. A. Brassaloti, R. W. Ribeiro Júnior, V. M. F. Nasser & H. O. Sawakuchi (2007): Species composition and similarities among anuran assemblages of Forest sites in southeastern Brazil. – Scientia Agrícola, **64**: 364–374.

Bertoluci, J., M. A. S. Canelas, C. C. Eisemberg, C. F. S. Palmuti & G. G. Montingelli (2009): Herpetofauna da Estação Ambiental de Peti, um fragmento de Mata Atlântica do estado de Minas Gerais, sudeste do Brasil. – Biota Neotropica, **9**: 147–155.

Bertoluci, J. & M. T. Rodrigues (2002): Utilização de habitats reprodutivos e micro-habitats de vocalização em uma taxocenose de anuros (Amphibia) na Mata Atlântica do sudeste do Brasil. – Papéis Avulsos de Zoologia, **42**: 287–297.

Canelas, M. C. S. & J. Bertoluci (2007): Anurans of the Serra do Caraça, southeastern Brazil: species composition and phenological patterns of calling activity. – Iheringia, Série Zoologia, **97**: 21–26.

Cardoso, A. J. , G. V. Andrade & C. F. B. Haddad (1989): Distribuição espacial em comunidades de anfíbios (Anura) no sudeste do Brasil. – Revista Brasileira de Biologia, **49**: 241–249.

Carnaval, A. C. & C. Moritz (2008): Historical climate modelling predicts patterns of current biodiversity in the Brazilian Atlantic forest. – Journal of Biogeography, **35**: 1187–1201.

Carnaval, A., M. J. Hickerson, C. F. B. Haddad, M. T. Rodrigues & C. Moritz (2009): Stability predicts genetic diversity in the Brazilian Atlantic Forest Hostpot. – Science, **323**: 785–789.

Carvalho-E-Silva, A. M. P. T., G. R. Silva & S. P. Carvalho-E-Silva (2008): Anuros da Reserva Rio das Pedras, Mangaratiba, RJ, Brasil. – Biota Neotropica, **8**: 199–209.

Costa, L. P. (2003): The historical bridge between Amazon and the Atlantic Forest of Brazil: a study of molecular phylogeography with small mammals. – Journal of Biogeography, **30**: 71–86.

Crump, M. L. (1974): Reproductive strategies in a tropical anuran community. – Miscellaneous Publications of the Museum of Natural History of the University of Kansas **61**: 1–68.

Crump, M. L. & N. J. Scott-Jr (1994): Visual encounter surveys. – pp. 84–92 in: Heyer, W. R. et al. (eds): Measuring and Monitoring Biological Diversity. Standard Methods for Amphibians. – Smithsonian Institution Press, Washington.

Cunha, A. K., I. S. Oliveira & M. T. Hartmann (2010): Anurofauna da Colônia Castelhanos, na Área de Proteção Ambiental de Guaratuba, Serra do Mar paranaense, Brasil. – Biotemas, **23**: 123–134.

Eterovick, P. C. & I. Sazima (2000): Structure of an anuran community in a montane meadow in southeastern Brazil: effects of seasonality, habitat and predation. – Amphibia-Reptilia, **21**: 439–461.

Feio, R. N. & P. L. Ferreira (2005): Anfíbios de dois fragmentos de Mata Atlântica no município de Rio Novo, Minas Gerais. – Revista Brasileira de Zoociências, **7**: 121–128.

Fitzpatrick, S. W., C. A. Brasileiro, C. F. B. Haddad & K. R. Zamudio (2009): Geographical variation in genetic structure of Atlantical Coastal Forest frog revels regional differences in habitat stability. – Molecular Ecology, **18**: 2877–2896.

Frost, D. R. (2013): Amphibian Species of the World: an Online Reference. Version 5.6 (Acces in October 24^{th}). – American Museum of Natural History, New York.

Haddad, C. F. B., L. F. Toledo & C. P. A. Prado (2008): Anfíbios da Mata Atlântica, Vol. 1. – Editora Neotropica, São Paulo.

Hedges, S. B., W. E. Duellman & M. P. Heinicke (2008): New World direct-developing frogs (Anura: Terrarana): Molecular phylogeny, classification, biogeography, and conservation. – Zootaxa, **1737**: 1–182.

Heyer, W. R., M. A. Donnelly, R. W. Mcdiarmid, L. A. C. Hayek & M. S. Foster (1994): Measuring and Monitoring Biological Diversity. Standard Methods for Amphibians. – Smithsonian Institution, Washington. 364 p.

Giaretta, A. A., K. G. Facure, R. J. Sawaya, J. H. M. Meyer & N. Chemin (1999): Diversity and abundance of litter frogs in a montane forest of Southeastern Brazil: seasonal and altitudinal changes. –Biotropica, **31**: 669–674.

Grazziotin, F. G., M. Monzel, S. Echeverrigaray & S. L. Bonatto (2006): Phylogeography of *Bothrops jararaca* complex (Serpentes: Viperidae): past fragmentation and island colonization in the Brazilian Atlantic Forest. – Molecular Ecology, **15**: 3969–3982.

IUCN 2013: The IUCN Red List of Threatened Species. Version 2013.1. http://www.iucnredlist.org. Downloaded on 02 July 2013.

Juncá, F. A. (2006): Diversidade e uso de hábitats por anfíbios anuros em duas localidades de Mata Atlântica, no norte do estado da Bahia. – Biota Neotropica **6**: 1–17.

Kottek, M., J. Grieser, C. Beck, B. Rudolf & F. Rubelf (2006): World map of the Köppen-Geiger climate classification updated. – Meteorologische Zeitschrift, **15**: 259–263.

Lucas, E. M. & V. B. Fortes (2008): Frog diversity in the Floresta Nacional de Chapecó, Atlantic Forest of southern Brazil. – Biota Neotropica, **8**: 50–61.

Luna-Dias, C., S. P. Carvalho-E-Silva & A. M. P. T Carvalho-E-Silva (2009): Amphibia, Anura, Hylidae, *Scinax trapicheiroi*: Distribution extension – Checklist, **5**: 251–253.

Magurran, A. (1988): Ecological diversity and its measurement. – Croom Helm Ltd., London, p. 179.

Martins, F. M. (2011): Historical biogeography of the Brazilian Atlantic forest and the Carnaval-Moritz model of Pleistocene refugia: what do phylogeography studies tell us? – Biological Journal of the Linnean Society, **104**: 499–509.

Martins, A. R., S. F. Bruno & A. Q. Navegantes (2012): Herpetofauna of Núcleo Experimental de Iguaba Grande, Rio de Janeiro state, Brazil. – Brazilian Journal of Biology, **72**: 553–562.

Mcdiarmid, R. W. (1994): Preparing amphibians as scientific specimens. – pp. 289–297 in: Heyer W. R. et al. (eds): Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Washington, D.C. – Smithsonian Institution Press.

Moraes, R. A., R. J. Sawaya & W. Barrela (2007): Composição e diversidade de anfíbios anuros em dois ambientes de Mata Atlântica no Parque Estadual Carlos Botelho, São Paulo, sudeste do Brasil. – Biota Neotropica, **7**: 26–36.

Moura, M. R., A. P. Motta, F. D. Fernandes & R. N. Feio (2012): Herpetofauna da Serra do Brigadeiro, um remanescente de Mata Atlântica em Minas Gerais, Sudeste do Brasil. – Biota Neotropica, **12**: 209–235.

Oliveira, J. C. F., E. Pralon, L. Coco, R. N. V. Pagotto & C. F. D. Rocha (2013): Environmental humidity and leaf-litter depth affecting ecological parameters of a leaf-litter frog community in an Atlantic Rainforest area. – Journal of Natural History, **47**: 2115–2124.

Parmelee, J. R. (1999): Trophic ecology of a tropical anuran assemblage. – Natural History Museum, University of Kansas, Kansas.

Peixoto, O. L. (1995): Associação de anuros a bromeliáceas na Mata Atlântica. – Revista da Universidade Rural, Série Ciência da Vida, **17**: 75–83.

Pombal, J. P. (1997): Distribuição espacial e temporal de anuros (Amphibia) em uma poça permanente na Serra de Paranapiacaba, Sudeste do Brasil. – Revista Brasileira de Biologia, **57**: 583–594.

Pontes, R. C., R. A. Murta-Fonseca, A. C. C. Lourenço, D. B. Maciel, A. R. Martins & L. O. Ramos (2012): New record and update distribution map of *Gastrotheca albolineata* (Lutz & Lutz, 1939) (Amphibia: Anura: Hemiphractidae). – Check List, **8**: 158–160.

Prado, G. M. & J. P. Pombal (2005): Distribuição espacial e temporal dos anuros em um brejo da Reserva Biológica de Duas Bocas, Sudeste do Brasil. – Arquivos do Museu Nacional, **63**: 685–705.

Rocha, C. F. D., F. H. Hatano, D. Vrcibradic & M. Van Sluys (2008): Frog species richness, composition and β-diversity in costal Brazilian restinga habitats. – Brazilian Journal of Biology, **68**: 101–107.

Rocha, C. F. D., L. Cogliatti-Carvalho, A. F. Nunes-Freitas, T. C. Rocha-Pessoa, A. S. Dias, C. V. Ariani & L. N. Morgado (2004): Conservando uma larga porção da diversidade biológica através da conservação de Bromeliaceae. – Vidalia, **2**: 52–72.

Rocha, C. F. D., M. Van Sluys, M. A. S. Alves, H. G. Bergallo & D. Vrcibradic (2001): Estimates of forest floor litter frog communities: A comparison of two methods. – Austral Ecology, **26**: 14–21.

Rocha C. F. D., D. Vrcibradic, M. C. Kiefer, M. Almeida-Gomes, V. N. T. Borges-Junior, V. A. Menezes, C. V. Ariani, J. A. L. Pontes, P. Goyannes-Araújo, R. V. Marra, D. M. Guedes, C. C. Siqueira & M. Van Sluys (2013): The leaf-litter frog community from Reserva Rio das Pedras, Mangaratiba, Rio de Janeiro State, Southeastern Brazil: species richness, composition and densities. – North-Western Journal of Zoology, **9**: 151–156.

Salles, R. O., L. N. Weber & T. Silva-Soares (2009): Amphibia, Anura, Parque Natural Municipal da Taquara, municipality of Duque de Caxias, state of Rio de Janeiro, southeastern Brazil. – Checklist, **5**: 840–854.

Santana, G. G., W. L. S. Vieira, A. Pereira-Filho, F. R. Delfim, Y. C. C. Lima & K. S. Vieira (2008): Herpetofauna em um fragmento de Floresta Atlântica no Estado da Paraíba, Região Nordeste do Brasil. – Revista Biotemas, **21**: 75–84.

Silva, H. R., A. L. G. Carvalho & G. B. Bittencourt-Silva (2008): Frogs of Marambaia: a naturally isolated Restinga and Atlantic Forest remnant of southeastern Brazil. – Biota Neotropica, **8**: 166–174.

Silvano, D. L. & B. V. S. Pimenta (2003): Diversidade e distribuição de anfíbios anuros na Mata Atlântica do sul da Bahia. – pp. 46–98 in: Prado, P., H. Landau, R. Moura, L. Pinto, G. Fonseca & K. Alger (eds): Corredor de Biodiversidade da Mata Atlântica do Sul da Bahia. – IESB/CI/CABS/UFMG/UNICAMP, Ilhéus.

Silvano, D. L. & M. V. Segalla (2005): Conservação de anfíbios no Brasil. – Megadiversidade, **1**: 79–86.

Siqueira, C. C., D. Vrcibradic, M. Almeida-Gomes, V. A. Menezes, V. N. Borges-Junior, F. H. Hatano, J. A. Pontes, P. Goyanes-Araújo, M. Van Sluys & C. F. D. Rocha (2011a): Species composition and density estimates of the anurofauna of a site within the northernmost large Atlantic Forest remnant (Parque Estadual do Desengano) in the state of Rio de Janeiro, Brazil. – Biota Neotropica, **11**: 131–137.

Siqueira, C. C., D. Vrcibradic, T. A. Dorigo & C. F. D. Rocha (2011b): Anurans from two high-elevation areas of Atlantic Forest in the state of Rio de Janeiro, Brazil. – Zoologia, **24**: 457–464.

Vasconcelos, P. M., T. A. Becker, P. R. Renne & G. H. Brimhall (1992): Age and duration of weathering by ^{40}K-^{40}Ar and ^{40}Ar/^{39}Ar analyses of potassium-manganese oxides. – Science, **258**: 306–365.

Veloso, H. P., A. L. R. R. Filho & J. C. A. Lima (1991): Classificação da vegetação brasileira adaptada a um sistema universal. Rio de Janeiro. – IBGE, 124 p.

Vilela, V. M. F. N., R. A. Brassaloti & J. Bertoluci (2011): Anurofauna da floresta de restinga do Parque Estadual da Ilha do Cardoso, Sudeste do Brasil: composição de espécies e uso de sítios reprodutivos. – Biota Neotropica, **11**: 1–11.

Wachlevski, M. & C. F. D. Rocha (2010): Amphibia, Anura, restinga of Baixada do Maciambu, municipality of Palhoça, state of Santa Catarina, southern Brazil. – Check List, **6**: 602–604.

Zar, J. H. (1999): Biostatistical analysis, 4nd. – Prentice Hall, New Jersey. 663 p.

Appendix 1
Specimens examined (all from Brazil)

Adenomera aff. *marmorata* (*n* = 1). RIO DE JANEIRO: *Saquarema* (MNRJ 76763); *Adenomera marmorata* (n = 5). RIO DE JANEIRO: *Saquarema* (MNRJ 74765, 76775, 76778-79, 84003); *Adenomera thomei* (n = 3). RIO DE JANEIRO: *Saquarema* (MNRJ 76776-77, 76780); *Aplastodiscus eugenioi* (n = 5). RIO DE JANEIRO: *Maricá* (MNRJ 76267-81); *Crossodactylus gaudichaudii* (n = 5). RIO DE JANEIRO: *Maricá* (MNRJ 76761, 76764, 76768-70); *Dendropsophus anceps* (n = 5). RIO DE JANEIRO: *Maricá* (MNRJ 74519-23); *Dendropsophus* aff. *oliveirai* (n = 5). RIO DE JANEIRO: *Maricá* (MNRJ 74502-04); *Saquarema* (MNRJ 74753-54); *Dendropsophus bipunctatus* (n = 5). RIO DE JANEIRO: *Maricá* (MNRJ 74550-52); *Saquarema* (MNRJ 74756, 74768; *Dendropsophus decipiens* (n = 4). RIO DE JANEIRO: *Maricá* (MNRJ 74501, 74532); *Saquarema* (MNRJ 74745, 79393); *Dendropsophus elegans* (n = 5). RIO DE JANEIRO: *Maricá* (MNRJ 74533, 77981, 77989-91); *Dendropsophus meridianus* (n = 5). RIO DE JANEIRO: *Maricá* (MNRJ 74514, 77821-22); *Saquarema* (MNRJ 74746, 74752); *Dendropsophus pseudomeridianus* (n = 1). RIO DE JANEIRO: *Saquarema* (MNRJ 74757); *Fritziana goeldii* (n = 4). RIO DE JANEIRO: *Saquarema* (MNRJ 79395, 81568-70); *Gastrotheca albolineata* (n = 2). RIO DE JANEIRO: *Saquarema* (MNRJ 75915, 75917); *Haddadus binotatus* (n = 5). RIO DE JANEIRO: *Maricá* (MNRJ 77816-17, 83149); *Saquarema* (MNRJ 76767, 84005); *Hylodes cf. pipilans* (n = 5). RIO DE JANEIRO: *Saquarema* (MNRJ 79362-63, 79554-55, 81561);

Hypsiboas albomarginatus (n = 5). RIO DE JANEIRO: *Maricá* (MNRJ 74505-08, 77815); *Hypsiboas faber* (n = 5). RIO DE JANEIRO: *Saquarema* (MNRJ 74701, 74760, 79130, 79365, 84653); *Hypsiboas seminilineatus* (n = 5). RIO DE JANEIRO: *Saquarema* (MNRJ 74703-04, 77179, 83690-91); *Ischnocnema guentheri* (n = 5). RIO DE JANEIRO: *Maricá* (MNRJ 81540); *Saquarema* (MNRJ 74764, 79551-52, 81563); *Ischnocnema octavioi* (n = 2). RIO DE JANEIRO: *Maricá* (MNRJ 81541, 83142); *Itapotihyla langsdorfii* (n = 1). RIO DE JANEIRO: *Maricá* (MNRJ 82507); *Leptodactylus latrans* (n = 4). RIO DE JANEIRO: *Maricá* (MNRJ 74500, 74556-57); *Saquarema* (MNRJ 83689); *Leptodactylus mystacinus* (n = 1). RIO DE JANEIRO: *Maricá* (MNRJ 77818); *Myersiella microps* (n = 2) RIO DE JANEIRO: *Maricá* (MNRJ 73105–106); *Phasmahyla guttata* (n = 5). RIO DE JANEIRO: *Maricá* (MNRJ 77819, 83141); *Saquarema* (MNRJ 74712, 74715, 76757); *Phyllomedusa rohdei* (n = 5). RIO DE JANEIRO: *Maricá* (MNRJ 74573); *Saquarema* (MNRJ 74769-71, 83688); *Physalaemus signifer* (n = 5). RIO DE JANEIRO: *Maricá* (MNRJ 77823-26, 77828); *Proceratophrys boiei* (n = 2). RIO DE JANEIRO: *Maricá* (MNRJ 76274-75); *Rhinella icterica* (n = 5). RIO DE JANEIRO: *Maricá* (MNRJ 74585); *Saquarema* (MNRJ 74702, 74705, 74716, 74719); *Rhinella ornata* (n = 5). RIO DE JANEIRO: *Maricá* (MNRJ 77812, 83151-53); *Saquarema* (MNRJ 74707); *Scinax alter* (n = 5). RIO DE JANEIRO: *Maricá* (MNRJ 74524-26, 74534-35); *Scinax humilis* (n = 5). RIO DE JANEIRO: *Maricá* (74570-72); *Saquarema* (MNRJ 77159-60); *Scinax trapicheiroi* (n = 5). RIO DE JANEIRO: *Maricá* (MNRJ 83147, 83148); *Saquarema* (MNRJ 74709, 76762, 76766);

Scinax v-signatus (n = 1). RIO DE JANEIRO: *Maricá* (MNRJ 81781); *Sphaenorhynchus planticola* (n = 5). RIO DE JANEIRO: *Maricá* (MNRJ 74493-97);

Thoropa miliaris (n = 5). RIO DE JANEIRO: *Saquarema* (MNRJ 74711, 76758-60, 76765); *Zachaenus parvulus* (n = 1). RIO DE JANEIRO: *Maricá* (MNRJ 80882).