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Parameters from the community of leaf-litter frogs from Estação Ecológica Estadual Paraíso, Guapimirim, Rio de Janeiro State, southeastern Brazil

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ABSTRACT

We studied the leaf-litter frog community of Estação Ecológica Estadual Paraíso, in Guapimirim, Rio de Janeiro State, southeastern Brazil. Herein we combined three sampling methods (large plots, visual encounter surveys and pit-fall traps) to present data on species composition, richness, relative abundance and densities. The local assemblage of frogs associated to the leaf-litter was composed by 14 species, belonging to nine families. *Haddadus binotatus*, a direct-developing frog, was the most abundant species in the community. The estimated density of the local leaf-litter frog assemblage based on plot sampling was 4.3 frogs/100 m^2. *Haddadus binotatus* had the highest density (1.1 ind/100 m^2). Frogs were predominantly found at night. *Thoropa miliaris* had the largest values of SVL (39.0 $\pm$ 10.3 mm), whereas the smallest species were *Euparkerella brasiliensis* (16.7 $\pm$ 2.2 mm) and *E. cochranae* (16.0 $\pm$ 2.7 mm). *Rhinella ornata* had the highest mean body mass (12.1 $\pm$ 7.5 g), and *E. cochranae* the lowest (0.4 $\pm$ 0.2 g). The overall frog mass was 938.6 g/ha. Our data support that higher densities of leaf-litter frogs tend to occur in the Neotropical region compared to the Old World tropics, tending to be higher in Central America than in South America.

Key words: Amphibia, Atlantic Forest, Brazil, community parameters, density, leaf-litter.

INTRODUCTION

Amphibians constitute important components of leaf-litter communities in tropical forests (e.g. Fauth et al. 1989, Allmon 1991, Vitt and Caldwell 1994). Many studies in the past 45 years have investigated the richness and diversity of forest floor leaf-litter amphibian communities in tropical regions (e.g. Lloyd et al. 1968, Scott Jr 1976, 1982, Inger 1980, Toft 1980a, b, 1982, Lieberman 1986, Fauth et al. 1989, Allmon 1991, Rodriguez 1992, Gascon 1996, Giaretta et al. 1997, 1999, Rocha et al. 2000, 2001, 2007, Watling and Donnelly 2002, Huang and Hou 2004, Hillers et al. 2008, Vasudevan et al. 2008, Siqueira et al. 2009). Many of these studies have included density estimates, which allow

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quantitative comparisons to be made among anuran faunas. Such comparisons may lead to the recognition of significant between-site differences in parameters of litter frog communities, such as the general trend for tropical leaf-litter amphibians to have higher densities and abundances in the New World than in the Old World (Scott Jr 1976, Inger 1980, May 1980, Allmon 1991).

Contrasting with the relatively abundant information available on leaf-litter frog communities from other tropical regions, in the Brazilian Atlantic Rainforest, one of the most species-rich and endangered biomes on Earth (Myers et al. 2000), data on community parameters of such organisms are currently limited to studies on a few areas (Giaretta et al. 1997, 1999, Rocha et al. 2000, 2001, 2007, Van Sluys et al. 2007, Almeida-Gomes et al. 2008, Siqueira et al. 2009). The scarcity of information on this vertebrate group imposes serious limitations for the understanding of its ecology, and ultimately for management and conservation of the extremely threatened Atlantic Rainforest biome.

Herein, we studied the leaf-litter frog community of an important continental Atlantic Rainforest area – Estação Ecológica Estadual Paraíso, in Rio de Janeiro State, Brazil. We present data primarily on community parameters such as species composition, richness, relative abundance and densities, and secondarily on activity period, body size, estimates of frog mass per hectare and the occurrence of endemic species in the studied area.

MATERIALS AND METHODS

Study Area

The study was carried out at Estação Ecológica Estadual Paraíso (22°29′S, 42°55′W; hereafter EEEP), which encloses an area of 4290 ha in Guapimirim and Cachoeiras de Macacu municipalities in the central portion of Rio de Janeiro State, southeastern Brazil. Most of the reserve is covered by the Atlantic Forest in different stages of conservation, including large portions of relatively undisturbed forest. Climate of the region is wet and warm, total annual rainfall ranges between 2000 and 3000 mm, and mean annual temperature is *ca.* 23°C (Kurtz and Araújo 2000). Altitude in the reserve varies from 20 to 1350 m above sea level. Vegetation in the area is predominantly of evergreen forest.

Sampling Methods and Analysis

Samplings were carried out during late September and early October 2004 at altitudes between 60 and 300 m using three sampling methods: plot sampling (Jaeger and Inger 1994), visual encounter surveys (Crump and Scott Jr 1994) and pit-fall traps with drift fences (Corn 1994).

For plot sampling we set 28 quadrats of 5 × 5m on the forest floor at altitudes between 150 and 300 m during seven days (four quadrats per day), totaling 700 m^2 of forest floor sampled. Each 25 m^2 quadrat was delimited by a flexible plastic fence *ca.* 50 cm high whose corners were fixed with wooden stakes and whose bottom was pinned to the ground with stones and sticks to prevent frogs from escaping. After sunset, five searchers using head lamps moved within each plot on hands and knees, side-by-side, carefully searching for frogs (usually with the aid of hand rakes) for about 30 minutes.

For the visual encounter surveys (hereafter VES), searchers walked along random transects at a slow walking pace along the forest, looking for frogs in all potential microhabitats available. Surveys were carried out during the diurnal (44.5 hours), crepuscular (25 h) and nocturnal periods (36 h), totaling 105.5 hours of sampling effort.

We also established three pit-fall trap systems that consisted of ten 30-liter buckets buried on the ground, each one set *ca.* 5 m apart from the next, with soft plastic drift fences about 50 cm high extended between them. Six of the buckets were set in line, and the remaining four were placed at opposite ends of the fence (two at each side), perpendicularly to the main axis. Pitfalls remained open for a total of 20 days and were checked once per day, always in the morning.

All frogs found were collected and identified. Furthermore, frogs found during casual encounters were also recorded. After preservation in 10% formaline (and posteriorly in 70% alcohol), all frogs collected during the study had their snout-vent length (SVL, in mm) measured with digital calipers, and their preserved body mass (in grams) taken with an electronic balance. For an estimate of species composition and richness of the leaf-litter frog community, as well as for calculation of mean values for SVL and body mass per species, we considered individuals recorded by all three sampling methods plus those collected during casual encounters.

For estimates of density (expressed as frogs/100 m^2) we considered only data obtained during plot sampling, as this method has been widely used for frog density estimates in tropical forests worldwide (e.g. Allmon 1991, Watanabe et al. 2005, Vasudevan et al. 2008), thus allowing for comparisons among areas. We estimated density and overall mass of leaf-litter frogs per hectare (g/ha) by dividing, respectively, the total number and the pooled body mass of frogs found in the plots by the total area sampled. Individuals that were seen, but eventually escaped collection during plot sampling, were also considered for the estimates of frog density and (when the species could be determined) overall mass per hectare; in the latter case, mass of the uncollected frog was established as the mean mass for its species calculated from all individuals collected during the study (regardless of methodology).

Voucher specimens of all species recorded during the study were deposited at the Museu Nacional, Rio de Janeiro.

RESULTS

We found 14 frog species associated to the leaf-litter habitat at EEEP (Table I): *Ischnocnema guentheri* (Steindachner 1864), *I. octavioi* (Bokermann 1965) (Brachycephalidae), *Haddadus binotatus* (Spix 1824) (Craugastoridae), *Euparkerella brasiliensis* (Izecksohn 1988), *E. cochranae* Izecksohn 1988 (Strabomantidae), *Crossodactylus aeneus* Müller 1924 (Hylodidae), *Proceratophrys boiei* (Wied-Neuwied 1824), *Thoropa miliaris* (Spix 1824), *Zachaenus parvulus* (Girard 1853) (Cycloramphidae), *Leptodactylus marmoratus* (Steindachner 1867) (Leptodactylidae), *Rhinella hoogmoedi* Caramaschi and Pombal 2006, *R. ornata* (Spix 1824) (Bufonidae), *Physalaemus signifer* (Girard 1853) (Leiuperidae) and *Scinax argyreornatus* (Miranda-Ribeiro 1926) (Hylidae).

We recorded 14 frog species during VES sampling, with *Haddadus binotatus* (N = 17, or 32.7 % of individuals found) being the most frequently recorded one (Table I). Most of the species sampled by VES method were found at night (N = 10 species, or 71%) (Table II). Seven species (50%) were found during crepuscular samplings, and only four (29%) were found in the diurnal period (Table II). Similarly, most individuals were found during the nocturnal (N = 27, or 52% of sampled individuals) and crepuscular (N = 16, or 31%) samplings, whereas the proportion of frogs found during the diurnal ones (N = 9, or 17%) was comparatively low.

We recorded 30 individuals of eight anuran species during plot sampling (Table I), which gives an estimated overall density of 4.3 frogs/100 m^2. The number of frogs per plot ranged from zero (10/28 or 35.7% of all plots) to three (3/28 or 10.7%), with a mean of 1.1 $\pm$ 0.3 frogs per plot. Of the plots in which frogs were found, 55.5% yielded a single individual. Considering each species individually, *Haddadus binotatus* had the highest density (1.1 ind/100 m^2) and comprised 26.7% of all frogs found in plots, followed by *Physalaemus signifer* (1.0 ind/100 m^2) and *Leptodactylus marmoratus* (1.0 ind/100 m^2). During the plot samplings, four individuals (13.3% of the total) evaded capture: one *H. binotatus*, one *I. octavioi*, one indeterminate *Euparkerella* (identification to species, was not possible) and one unidentified frog.

Thirty frogs in seven species were captured in the pit-fall traps (Table I). The species most frequently captured were *Physalaemus signifer* (33.3% of all specimens captured) and *Proceratophrys boiei* (26.7%).

Considering the combined methods, the most abundant species in the community was *Haddadus binotatus* (25.0% of all individuals sampled), followed by *Physalaemus signifer* (19.6%) and *Leptodactylus marmoratus* (15.2%) (Table I).

Body size of frogs varied widely among species in the leaf-litter community. *Rhinella ornata* had the highest mean body mass (12.1 $\pm$ 7.5 g) followed by *Thoropa miliaris* (7.0 $\pm$ 5.7 g), whereas *Euparkerella brasiliensis* (0.5 $\pm$ 0.1 g) and *E. cochranae* (0.4 $\pm$ 0.2 g) had the lowest mean body mass (Table I). In terms of SVL (considering only species represented by three or more specimens), the largest values were for *T. miliaris* (39.0 $\pm$ 10.3 mm), followed by *P. boiei* (33.8 $\pm$ 8.6 mm) whereas the smallest species were the two *Euparkerella* (*E. brasiliensis* = 16.7 $\pm$ 2.2 mm, and *E. cochranae* = 16.0 $\pm$ 2.7mm). The species with the highest estimated mass per hectare at EEEP was *H. binotatus* (573.4 g/ha), whereas *E. brasiliensis* (16.6 g/ha) and *E. cochranae* (22.9 g/ha) had the lowest estimated mass per hectare

TABLE I

Number of frogs of each species found by three sampling methods at EEEP in southeastern Brazil. Mean values (± one standard deviation) of snout-vent length (SVL, in mm) and body mass (in g) are given for each species (with sample sizes in parentheses). Overall mass (g/ha) and density (frogs/100m^2) estimated for each species are based only on data from plot sampling. (∗) juvenile specimens (probably of *R. ornata*); (∗∗) mass was stipulated as the mean mass of the two *Euparkerella* species pooled, and considered only for the total (overall) mass per ha estimate; (∗ ∗ ∗) includes one unidentified frog that evaded capture during plot sampling.

Species	Plots	Transects	Pitfalls	SVL (N)	Body mass (N)	Overall mass (g/ha)	Density (ind/100 m^2)
BRACHYCEPHALIDAE							
Ischnocnema guentheri	1	5	1	22.3 ± 2.5 (19)	1.1 ± 0.3 (19)	32.3	0.1
I. octavioi	1	2	–	24.3 ± 0.3 (2)	1.3 ± 0.3 (2)	–	0.1
BUFONIDAE							
Rhinella hoogmoedi	–	–	1	42.0 (1)	7.1 (1)	–	–
R. ornata	–	2	6	29.6 ± 14.0 (11)	12.1 ± 7.5 (11)	–	–
Rhinella indet. (*)	–	2	–	8.7 ± 1.1 (3)	0.05 ± 0.02 (3)	–	–
CRAUGASTORIDAE							
Haddadus binotatus	8	17	3	31.3 ± 7.4 (31)	3.9 ± 3.0 (31)	573.4	1.1
CYCLORAMPHIDAE							
Proceratophrys boiei	1	2	8	33.8 ± 8.6 (15)	5.2 ± 5.5 (15)	83.0	0.1
Thoropa miliaris	–	2	–	39.0 ± 10.3 (16)	7.0 ± 5.7 (16)	–	–
Zachaenus parvulus	–	1	–	21.7 (1)	1.7 (1)	–	–
HYLIDAE							
Scinax argyreornatus	–	1	–	20.7 (1)	1.0 (1)	–	–
HYLODIDAE							
Crossodactylus aeneus	–	1	–	22.5 ± 5.0 (39)	1.4 ± 0.7 (39)	–	–
LEIUPERIDAE							
Physalaemus signifer	6	6	10	23.2 ± 2.5 (26)	1.4 ± 0.5 (26)	105.8	0.9
LEPTODACTYLIDAE							
Leptodactylus marmoratus marmoratus	6	10	1	20.8 ± 2.6 (14)	0.9 ± 0.2 (14)	79.7	0.9
STRABOMANTIDAE							
Euparkerella brasiliensis	2	1	–	16.7 ± 2.2 (3)	0.5 ± 0.1 (3)	16.6	0.3
E. cochranae	4	1	–	16.4 ± 2.0 (5)	0.4 ± 0.1 (5)	22.9	0.6
Euparkerella indet. (**)	1	–	–	–	–	–	–
Total (***)	30	52	30	–	–	938.6	4.3

(Table I). The overall frog mass (pooled species) at the leaf litter of EEEP was 938.6 g/ha (Table I).

DISCUSSION

Compared to previous studies providing density estimates for Atlantic Rainforest leaf-litter frog assemblages, our estimated density value for EEEP was higher than that of Serra do Japi, state of São Paulo (1.4 ind/100 m^2; Giaretta et al. 1997) and similar to those of three other areas (4.6 ind/100 m^2 at Atibaia, in São Paulo State – Giaretta et al. 1999; 5.9 ind/100 m^2 at Ilha Grande, in Rio de Janeiro State – Rocha et al. 2001; and 4.5 ind/100 m^2 at Morro São João, in Rio de Janeiro State – Almeida-Gomes et al. 2008). However, higher density estimates were reported at two other areas located, like EEEP, at the lower portion of the Serra dos Órgãos mountain range, in Rio de Janeiro State: 8.4 ind/100m^2 at the Reserva Ecológica de Guapiaçu (altitudes 100-400 m; Rocha et al. 2007) and 17.1 ind/100 m^2 at a site within the Três Picos State Park (altitudes 500-800 m; Siqueira et al. 2009). These areas lie, respectively, just

TABLE II

Number of frogs of each species sampled during visual encounter surveys (VES) for each period of the day (diurnal, crepuscular and nocturnal) at EEEP in southeastern Brazil. (*)

Species	Diurnal	Crepuscular	Nocturnal
BRACHYCEPHALIDAE			
Ischnocnema guentheri	–	1	4
I. octavioi	–	1	1
BUFONIDAE			
Rhinella ornata	1	–	1
Rhinella indet. (*)	2	–	–
CRAUGASTORIDAE			
Haddadus binotatus	2	5	10
CYCLORAMPHIDAE			
Proceratophrys boiei	–	–	2
Thoropa miliaris	–	1	1
Zachaenus parvulus	–	–	1
HYLIDAE			
Scinax argyreornatus	1	–	–
HYLODIDAE			
Crossodactylus aeneus	–	–	1
LEIUPERIDAE			
Physalaemus signifer	3	–	2
LEPTODACTYLIDAE			
Leptodactylus marmoratus	–	6	4
STRABOMANTIDAE			
Euparkerella brasiliensis	–	1	–
E. cochranae	–	1	–
Total	9	16	27

20 km and 35 km to the east of EEEP, and all three are located within the same continuous forest block. Thus, the variation in frog densities may partly result from differences in altitude among the sampled sites (seasonal variation is presumably negligible, as all three sites have been sampled during the September-October period).

Comparing our data with other studies in different tropical forest regions in South America that report estimates of leaf-litter frog density, the results were similar to those obtained in Amazon rainforest areas in Brazil (3.0 ind/100 m^2; Allmon 1991) and in Peru (4.4 ind/100 m^2; Toft 1980a) during the dry season, but lower than those reported for the wet season in the same localities (6.0 ind/100 m^2 – Allmon 1991; 15.5 ind/100 m^2 – Toft 1980a). Our density estimates were also lower than those reported for rainforest sites in Central America (Costa Rica: 13.4–62.3 ind/100 m^2 – Scott Jr 1976; 15.7 ind/100 m^2 – Lieberman 1986; 11.5 ind/100 m^2 – Heinen 1992; Panama: 30.2 ind/100 m^2 – Heatwole and Sexton 1966; 7.5 – 19.4 ind/100 m^2 – Toft 1980b). On the other hand, estimated leaf-litter frog density at EEEP was higher than those reported for most studied Old World tropical forests (e.g. 0.5–2.6 ind/100 m^2 in Thailand – Inger and Colwell 1977; 1.2 ind/100 m^2 in Borneo – Lloyd et al. 1968; 1.5–2.2 ind/100 m^2 in Uganda – Vonesh 2001; 1.5 ind/100 m^2 in the southern Western Ghats, India – Vasudevan et al. 2008), with three exceptions (e.g. 9.4 ind/100 m^2 in Cameroon – Scott Jr 1982; 3.5–10.2 ind/100 m^2 in Taiwan – Huang and Hou 2004; 41.8 ind/100 m^2 in Iriomote island, Japan – Watanabe et al. 2005). Hence, our data generally support the idea that higher densi-

ties of leaf-litter frogs tend to occur in the Neotropical region compared to the Old World tropics, although in the Neotropics they tend to be consistently higher in Central America than in South America (Allmon 1991, Huang and Hou 2004, Siqueira et al. 2009).

Haddadus binotatus, a species with direct development, was the most abundant species at the leaf-litter frog community at EEEP, representing about one fourth of all individuals sampled. Considering the pooled abundances of all direct developers belonging to families Brachycephalidae, Craugastoridae and Strabomantidae, we can see that the leaf-litter anuran community at EEEP was numerically dominated by individuals from species with this reproductive mode. In most litter frog communities in the Neotropics (e.g. Heyer and Berven 1973, Scott Jr 1976, Lieberman 1986, Fauth et al. 1989, Giaretta et al. 1997, 1999, Rocha et al. 2001, 2007, Almeida-Gomes et al. 2008, Siqueira et al. 2009), anurans with direct development are relatively dominant. Frogs with direct development and terrestrial eggs may benefit from the relative independence of free water to reproduce. Their froglets are able to disperse within the forest after hatching from eggs laid in moist substrates, because they are not limited by the availability of water bodies (Heyer and Berven 1973, Scott Jr 1976, 1982, Allmon 1991).

Ischnocnema octavioi, currently considered endemic to the state of Rio de Janeiro, was among the least frequently recorded species in the area, as also occurred in previous studies on other Atlantic forest anuran assemblages (Rocha et al. 2007, Almeida-Gomes et al. 2008, Siqueira et al. 2009). By comparison, other infrequently recorded species at EEEP such as *Zachaenus parvulus* and *Euparkerella brasiliensis* are locally abundant in other areas studied in the state (Rocha et al. 2001, Siqueira et al. 2009). This suggests that *I. octavioi* tends to be locally rare in Atlantic forest areas where it occurs.

Izecksohn (1988) suspected that *Euparkerella brasiliensis* and *E. cochranae* could occur syntopically at the Serra dos Órgãos mountains, particularly in the Teresópolis-Guapimirim region. Our study confirms this. Also, our data, albeit limited, suggest that the two species may occur with similar abundances locally neither being clearly numerically dominant over the other (despite their great similarity in size and general appearance, which could hint at a potential for strong interspecific competition).

Among the anuran species associated with the leaf-litter we found one individual of the treefrog *Scinax argyreornatus*. Treefrogs are not common inhabitants of the leaf-litter because they have arboreal habits. However, hylids are occasionally found on the leaf-litter or perched close to the ground during plot sampling (e.g. Rodriguez 1992, Giaretta et al. 1997, 1999, Rocha et al. 2007), and have been referred to as casual species in the leaf-litter frog community (Giaretta et al. 1999). The occurrence of *S. argyreornatus* on the leaf-litter at EEEP is not totally unexpected, as this treefrog may occasionally forage on the ground (Teixeira and Vrcibradic 2004). Two other species that were poorly represented in our samples, *Crossodactylus aeneus* and *Thoropa miliaris*, are known to be abundant at EEEP, but are strongly associated to rocky streams (Jordão-Nogueira et al. 2006, Siqueira et al. 2006). These two species are habitat-specialists and, like *S. argyreornatus*, may be found only occasionally on the leaf-litter (and likely always in the proximity of streams).

Most of the frogs recorded during transects (about 86%) were found during the crepuscular and nocturnal periods, reflecting the predominance of crepuscular-nocturnal habits among anurans in general. The predominance of active frogs at dusk and at night has also been reported in our previous studies at other Atlantic forest areas of southeastern Brazil (Rocha et al. 2000, 2007, Almeida-Gomes et al. 2008, Siqueira et al. 2009). For the Amazonian region a similar trend has been found, with comparisons among diurnal and nocturnal samplings showing that the latter yielded about 73% of the frogs (Menin et al. 2008 in central Brazilian Amazonia) or about 80% of the reptiles and amphibians (Doan 2003 in Amazonian Peru) recorded. Our data reinforce the importance of sampling tropical leaf-litter frogs preferentially during the crepuscular-nocturnal period to maximize sampling efficiency.

There are relatively few studies providing estimates of leaf-litter frog mass per hectare for tropical forests in the world. The estimated frog biomass per unit of area at EEEP (938.4 g/ha) was similar to those reported for another Atlantic forest area by Rocha et al.

(2001) (1150 g/ha) and for an area in Amazonian Peru (1088 g/ha) by Toft (1980a), but somewhat higher than those of two other Atlantic forest sites (476.6 g/ha – Giaretta et al. 1999; 684.2 g/ha – Siqueira et al. 2009). Although clearly we still need a more consistent dataset on leaf-litter frog biomass per unit of area for tropical forests, the available data suggest that differences among areas do not tend to be too large and may be influenced by species composition and relative abundance at each locality, as well as by elevation and time of the year when samplings were realized.

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RESUMO

Estudamos a comunidade de anuros de folhiço da Estação Ecológica Estadual Paraíso, em Guapimirim, estado do Rio de Janeiro, no sudeste do Brasil. Combinamos três métodos de amostragem (plots, transectos e armadilhas de queda) para apresentar dados sobre a composição de espécies, riqueza, abundância relativa e densidade. A assembleia local foi composta por 14 espécies de anuros, pertencentes a nove famílias. *Haddadus binotatus*, espécie de desenvolvimento direto, foi a mais abundante durante o estudo. A densidade de anuros de folhiço estimada com base na amostragem por plots foi de 4,3 ind/100m^2. *Haddadus binotatus* apresentou a maior densidade (1,1 ind/100m^2). Os anuros foram registrados predominantemente durante a noite. *Thoropa miliaris* apresentou os maiores valores de CRC (39,0 $\pm$ 10,3 mm). As menores espécies foram *Euparkerella brasiliensis* (16,7 $\pm$ 2,2 mm) e *E. cochranae* (16,0 $\pm$ 2,7mm). *Rhinella ornata* apresentou a maior massa corporal média (12,1 $\pm$ 7,5 g) e *E. cochranae* (0,4 $\pm$ 0,2 g) a menor. A massa média total foi de 938,6 g/ha. Nossos resultados corroboram com a tendência de maiores densidades de anuros de folhiço na região Neotropical quando comparado com áreas Tropicais do Velho Mundo, tendendo a serem maiores na América Central do que na América do Sul.

Palavras-chave: Anfíbios, Mata Atlântica, Brasil, parâmetros da comunidade, densidade, folhiço.

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