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A survey of the leaf-litter frog assembly from an Atlantic forest area (Reserva Ecológica de Guapiaçu) in Rio de Janeiro State, Brazil, with an estimate of frog densities

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We studied the leaf-litter frog community of the Reserva Ecológica de Guapiaçu (REGUA), in Rio de Janeiro State, southeastern Brazil, and present data on species composition and frog densities. We combined three sampling methods: large plots, transects and pit-fall traps. We recorded 12 frog species associated with forest leaf-litter: *Adenomera marmorata* Steindachmer 1867, *Leptodactylus ocellatus* (Linnaeus 1758), and *Physalaemus signifer* (Girard 1835) (Leptodactylidae); *Eleutherodactylus binotatus* (Spix 1824), *E. guentheri* (Steindachmer 1864), *E. octavioi* Bokermann 1965, and *Euparkerella cochranae* Izechsohn 1988 (Brachycephalidae); *Proceratophrys boiei* (Wied-Neuwied 1821) (Cycloramphidae); *Chaunus ornatus* Spix 1824 and *Chaunus ictericus* Spix 1824 (Bufonidae); *Chiasmocleis carvalhoi* Cruz et al. 1997 (Microhylidae); and *Scinax* aff. *x-signatus* (Spix 1824) (Hylidae). The area had a relatively high overall density (8.43 ind/100 m^2) of leaf-litter frogs compared to other Atlantic forest areas. *Eleutherodactylus* Duméril & Bibron 1841 was the most speciose genus with three species and *Eleutherodactylus guentheri* was the most abundant species (mean density of 2.71 frogs/100 m^2). Despite their relatively lower abundance in the area, *Chaunus ictericus, C. ornatus* and *Proceratophrys boiei* comprised most of the frog biomass in the leaf-litter community, due to their larger body sizes. Our data indicate that the overall leaf-litter frog density at the study site is similar to other species-rich areas, not only in South America, but also in other tropical forests in the world.

KEY WORDS: Amphibia, Atlantic Rainforest, Brazil, community parameters, density, leaf-litter.

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INTRODUCTION

The Brazilian Atlantic Rainforest concentrates one of the highest biological diversities on Earth, with approximately 7% of the world's plant and animal species (QUINTELA 1990, MYERS et al. 2000). Unfortunately, this biome has been suffering from intense habitat degradation and fragmentation, leaving its biological diversity particularly vulnerable (MYERS et al. 2000); this will likely result in a high rate of animal and plant species loss (PIMM & ASKINS 1995, WHITMORE 1997, ROCHA et al. 2003). Along the large latitudinal range (from 5º to 30ºS) of this biome, the species diversity and degree of endemism for different animal groups, such as lizards (VANZOLINI 1988), birds (SCOTT & BROOKE 1985, COLLAR et al. 1992, WEGE & LONG 1995), mammals (COSTA et al. 2000) and butterflies (BROWN & FREITAS 2000), tends to be higher in its "middle portion", comprising the states of Rio de Janeiro, Espírito Santo, eastern São Paulo and southeastern Minas Gerais.

Studies carried out in different tropical forests throughout the world provide data on richness, composition and density of frogs living on the leaf-litter (e.g. BROWN & ALCALA 1961; HEATWOLE & SEXTON 1966; LLOYD et al. 1968; SCOTT 1976, 1982; TOFT 1980a, 1980b; LIEBERMAN 1986; FAUTH et al. 1989; ALLMON 1991; GASCON 1996). For the Atlantic Rainforest, data on leaf-litter frog species composition and richness is limited to a few studies (HEYER et al. 1990; HADDAD & SAZIMA 1992; GIARETTA et al. 1997, 1999; MACHADO et al. 1999; ROCHA et al. 2000, 2001; POMBAL & GORDO 2004), most of them in southeastern Brazil. Only four of these studies present data on relative densities of frogs in the leaf-litter communities (GIARETTA et al. 1997, 1999; ROCHA et al. 2000, 2001).

The Reserva Ecológica de Guapiaçu (hereafter REGUA), in Rio de Janeiro State, is an important remnant of the continental Atlantic Rainforest area in southeastern Brazil. As in most of the forested areas of the Atlantic Rainforest biome, there is no information on the leaf-litter frog community for this area. In the present study, we studied the leaf-litter frog assembly of the REGUA, collecting data on community parameters such as species composition and densities.

MATERIALS AND METHODS

Study area

The study was carried out in the Atlantic Rainforest area of the REGUA (22º24'S, 42º44'W), in the municipality of Cachoeiras de Macacu, in Rio de Janeiro State, southeastern Brazil. This area is within one of the largest remnants of Atlantic forest in the state (over 60,000 ha). The Reserve has an area of 2558 ha and is covered by Atlantic Rainforest with different levels of conservation, with remnants of undisturbed forests occurring in the steepest and less accessible areas of the reserve. The climate is wet and warm, and annual rainfall var-

ies from 2000 to 2500 mm. Mean annual temperature is about 24 °C. The present study was conducted at elevations between 40 and 400 m above sea level.

Methodology and analyses

Surveys were carried out mostly during October 2004 (though pit-fall traps were used until November). To obtain the most comprehensive dataset of leaf-litter frogs for the study area, we used three sampling methods: large plots (see JAEGER & INGER 1994), transects, and pit-fall traps with drift fences (see CORN 1994). Although samplings with pit-fall traps were performed for a longer period than the other two methods, the samplings were all carried out within the same season, and the environmental variations within the whole period were presumably not significant enough to affect the species composition of the frog community.

For the large-plot method, we sampled only at night (18:00-23:00 hr) as it is expected that most of the activity of Atlantic forest leaf-litter frogs occurs during the nocturnal period (ROCHA et al. 2000). We established 28 quadrats of 5 × 5 m (25 m^2) on the forest floor in the course of 7 days (four quadrats per day). We marked the corners of each plot with wooden stakes and the plot was completely enclosed by a soft plastic fence about 50 cm high. The bottom of the plastic fence was buried or attached to the ground with strings and sticks, to prevent frogs from escaping from the plot. After setting the fence, each plot was carefully searched for frogs by a crew of five persons wearing head lamps. During searches, each crew member moved up the entire plot on hands and knees, side-by-side, with the aid of hand rakes. All leaves, pieces of dead wood, fallen branches and stones inside the plot were overturned and rock crevices and spaces between tree roots were also checked for frogs. Each plot was searched for about half an hour.

For transect sampling, we carried out 214 search transects of 30 min duration each, totaling approximately 107 hr of transects. The same number of transects (69, totaling approximately 35 hr) was surveyed during each period of the day (diurnal, crepuscular and nocturnal). During each transect, the observer moved at a slow walking pace along trails inside the forest, carefully searching for frogs on the leaf-litter. All frogs found were captured for future identification.

Pit-fall traps were used for 20 days. Each pit-fall trap system consisted of ten 60-liter buckets (50 cm deep) buried on the ground and set ca 5 m apart, with soft plastic drift fences about 50 cm high extended between them. Each system was composed of six aligned buckets and, at each extremity, a line of two buckets set perpendicular to the main line, in opposite directions. Three pit-fall systems totaling 30 buckets were set. Pit-fall traps were checked once per day (always in the morning) and all frogs found inside them were removed.

To determine the species composition and richness of the leaf-litter frog community in the area, we considered the frog species recorded by all three sampling methods. For estimates of leaf-litter frog density, we considered only the data obtained by the large-plot sampling. This method has been the most frequently and widely used in tropical forests (see ALLMON 1991), which allows us to make comparisons with other forested areas for which data is available. We estimated the overall density of frogs per unit of forest floor (frogs/100 m^2) by dividing the total number of frogs found by the total area sampled. Relative abundance for each leaf-litter frog species was estimated from the data obtained in the transects. We also regressed the mean body mass and the snout-vent length (SVL) of each frog species (based on the averaged values of individuals collected by all sampling methods pooled, plus individuals occasionally collected opportunistically) with the total number of collected individuals of the same species (pooled values of the three sampling methods), after log-transforming the variables.

RESULTS

From all sampling methods combined, we recorded 12 frog species associated with the forest floor leaf-litter at the REGUA: *Adenomera marmorata* Steindachner

1867, *Leptodactylus ocellatus* (Linnaeus 1758), and *Physalaemus signifer* (Girard 1853) (Leptodactylidae), *Eleutherodactylus binotatus* (Spix 1824), *E. guentheri* (Steindachner 1864), *E. octavioi* Bokermann 1965, and *Euparkerella cochranae* Izecksohn 1988 (Brachycephalidae), *Proceratophrys boiei* (Wied-Neuwied 1825) (Cycloramphidae), *Chaunus ornatus* Spix 1824 (formerly *C. crucifer* Wied-Neuwied 1821; see BALDISSERA et al. 2004) and *Chaunus ictericus* Spix 1824 (Bufonidae), *Chiasmocleis carvalhoi* Cruz et al. 1997 (Microhylidae), and *Scinax* aff. *x-signatus* (Spix 1824) (Hylidae). The leaf-litter community of REGUA was thus dominated by species in the family Brachycephalidae, with *Eleutherodactylus* being the most speciose genus in the area.

In the large-plot sampling, we recorded 59 individuals in eight frog species (Table 1). The number of frogs per plot ranged from zero (6/28 or 21.4% of all plots) to six (1/28 or 3.5%) with a mean of 2.1 $\pm$ 1.8 frogs per plot. In 25% of the plots in which frogs were found only one individual was recorded. The density of the leaf-litter frog species estimated from the large-plot sampling differed substantially among species. Those having the highest density were *Eleutherodactylus guentheri* (2.71 ind/100 m^2), which comprised 32.2% of all frogs found in plots, followed by *Physalaemus signife*r (1.86 ind/100 m^2), whereas *Scinax* aff. *x-signatus* had the lowest density in the leaf-litter (0.14 ind/100 m^2) (Table 1). The overall leaf-litter frog density estimated from large-plot sampling was 8.43 frogs/100 m^2 (Table 1). During plot sampling, four frogs (i.e. 6.8% of the total) evaded capture: two *E. binotatus*, one *E. guentheri* and one individual that could not be identified (the latter was only considered for the overall frog density estimates).

Seventy-eight frogs in nine species were found on the leaf-litter of the REGUA during transect sampling (Table 2). The most abundant species recorded during

Table 1.

Total number of individuals sampled and estimated density (frogs/100 m^2, in parentheses) of each frog species found in the leaf-litter frog community in the Atlantic Rainforest of Reserva Ecológica de Guapiaçu (REGUA), in southeastern Brazil, using a 5 × 5 plot sampling method. (*) One individual of an unidentified species evaded capture.

Frog species	No. individuals (density)
Brachycephalidae	
Eleutherodactylus binotatus	9 (1.28)
Eleutherodactylus guentheri	19 (2.71)
Euparkerella cochranae	6 (0.86)
Cyclorhamphidae	
Proceratophrys boiei	2 (0.29)
Leptodactylidae	
Adenomera marmorata	6 (0.86)
Physalaemus signifer	13 (1.86)
Hylidae	
Scinax aff. *x-signatus*	1 (0.14)
Microhylidae	
Chiasmocleis carvalhoi	2 (0.29)
Total (*)	59 (8.43)

Table 2.

Number of frogs of each species sampled by each sampling method at Reserva Ecológica de Guapiaçu (REGUA), in southeastern Brazil. Mean values (± one standard deviation) of snout-vent length (SVL, in mm) and body mass (in grams), calculated from all animals collected both inside and outside of the official sampling, are given for each species (with sample sizes in parentheses).

Frog species	Plots	Transects	Pitfall traps	Mean SVL in mm (N)	Mean body mass in g (N)
Adenomera marmorata	6	22	3	21.6 ± 1.8 (39)	0.96 ± 0.22 (37)
Chaunus ictericus			1	128.6 ± 48.0 (4)	163.47 ± 163.03 (3)
Chaunus ornatus		4	12	40.3 ± 18.5 (17)	10.16 ± 16.58 (16)
Chiasmocleis carvalhoi	2		1	12.7 ± 0.8 (3)	0.16 ± 0.05 (2)
Eleutherodactylus binotatus	9	10		34.1 ± 9.7 (20)	4.23 ± 3.9 (20)
Eleutherodactylus guentheri	19	23	2	24.9 ± 5.6 (55)	1.77 ± 1.08 (55)
Eleutherodactylus octavioi		1	3	22.6 ± 2.8 (4)	1.20 ± 0.29 (4)
Euparkerella cochranae	6	3	2	15.7 ± 3.7 (11)	0.56 ± 0.36 (11)
Leptodactylus ocellatus		1		72.2 ± 17.6 (5)	42.90 ± 42.88 (5)
Physalaemus signifer	13	8	9	24.9 ± 2.9 (31)	1.56 ± 0.54 (31)
Proceratophrys boiei	2	6	1	38.7 ± 12.2 (23)	9.53 ± 8.56 (23)
Scinax aff. *x-signatus*	1			43.5 (1)	4.67 (1)
Total	59	78	34		

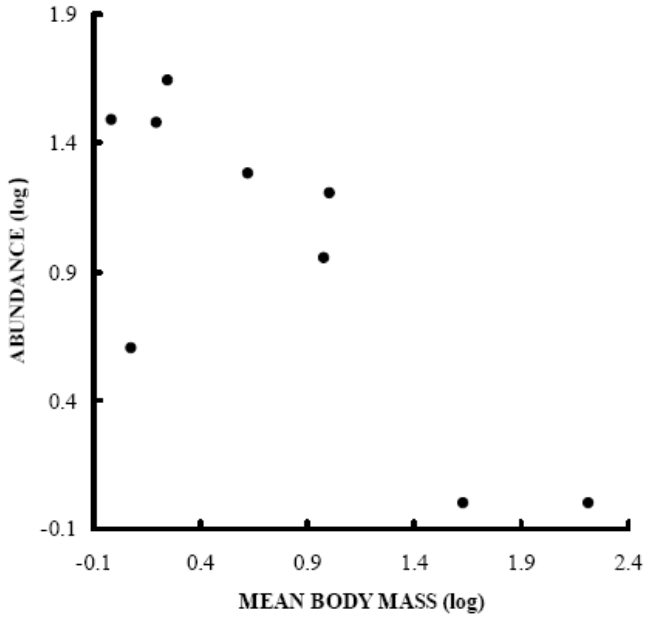

Fig. 1. — Relationship between number of individuals encountered and mean body mass of frog species (both variables log-transformed) at the Atlantic Rainforest of REGUA in Rio de Janeiro State, Brazil.

Table 3.

Number of frogs of each species sampled along transects in each period of the day (diurnal, crepuscular and nocturnal) at the Atlantic Rainforest of Reserva Ecológica de Guapiaçu (REGUA), in southeastern Brazil.

Species	Diurnal	Crepuscular	Nocturnal
Adenomera marmorata	1	9	12
Chaunus ornatus	1	2	1
Eleutherodactylus binotatus	3	5	2
Eleutherodactylus guentheri	3	15	5
Eleutherodactylus octavioi		1	
Euparkerella cochranae		1	2
Leptodactylus ocellatus			1
Physalaemus signifer	2	3	3
Proceratophrys boiei		3	3
Total	10	39	37

transect sampling were *Eleutherodactylus guentheri* (29.5% of all individuals found along the transects) and *Adenomera marmorata* (28.2%), while the least frequent were *Eleutherodactylus octavioi* and *Leptodactylus ocellatus* (1.3% each). During transect sampling, most frogs were found during crepuscular (n = 39, or 45% of individuals sampled) and nocturnal (n = 37, or 43%) periods, whereas the proportion of frogs found during the diurnal sampling (n = 10, or 12%) was comparatively low (Table 3).

Thirty-four frogs in nine species were captured in the pit-fall traps (Table 2). The most frequently captured species in the pit-fall traps were *Chaunus ornatus* (35.3% of all specimens captured) and *Physalaemus signifer* (26.5%).

The largest species of the local leaf-litter frog community was *Chaunus ictericus*, followed by *Leptodactylus ocellatus*, *Chaunus ornatus* and *Proceratophrys boiei*, whereas the smallest were *Chiasmocleis carvalhoi* and *Euparkerella cochranae* (Table 2). The overall abundance (combined methods) per frog species was not significantly related to the mean body mass (r = 0.48, $F_{1,9}$ = 2.763, P = 0.131) or the mean SVL (r = 0.53, $F_{1,9}$ = 3.459, P = 0.096) of the frog species (*Scinax* aff. *x-signatus* was not included in these analyses, as its occurrence on leaf-litter was considered casual; see Discussion). Nevertheless, there was a general tendency for abundance to decrease with body size (Fig. 1).

DISCUSSION

The results of plot sampling at the REGUA indicate a relatively high overall density (8.4 ind/100 m^2) of leaf-litter frogs compared to other Atlantic forest areas for which data are available, namely Serra do Japi (richness = 5 species; pooled density = 1.4 ind/100 m^2; Giaretta et al. 1997) and Parque Florestal do Itapetinga (richness = 16 species; pooled density = 4.6 ind/100 m^2; Giaretta et al. 1999), both

in São Paulo State, and Ilha Grande (richness = 10 species; pooled density = 5.9 ind/100 m^2; ROCHA et al. 2001), in Rio de Janeiro State. The frog density in the forest-floor leaf litter at the REGUA was similar to that of other species-rich forest areas in South America and elsewhere in the tropics (see ALLMON 1991 for compiled data from different areas). In the leaf-litter frog assembly of the REGUA, *Eleutherodactylus guentheri* was the most abundant species (mean density of 2.7 individuals/100 m^2) and *Eleutherodactylus* was the most speciose genus, with three species (though only two were recorded with plot sampling). *Eleutherodactylus* has also been found to be the most (or one of the most) speciose genera in other Neotropical leaf litter communities, not only in the Atlantic Rainforest (e.g. GIARETTA et al. 1997, 1999; ROCHA et al. 2000, 2001) but also in Amazonian (e.g. RODRIGUEZ 1992, GASCON 1996) and Central American forests (e.g. SCOTT 1976, TOFT 1981, LIEBERMANN 1986, FAUTH et al. 1989, HOFER & BERSIER 2001).

Based on the pooled data from all three methods, the three most abundant species in the local leaf-litter frog community are apparently *E. guentheri*, *A. marmorata* and *P. signifer*, at least at altitudes below 400 m. Those three species were all well represented in both transect and plot sampling, with *P. signifer* also well represented in pit-fall sampling. Pit-fall traps sampled a lower number of individuals than the other two methods, though the species richness was about the same. Curiously, pit-falls were apparently more efficient than the other methods for sampling bufonids. It is possible that bufonids move for comparatively greater distances along the forest floor than the other species in the assemblage, due to their more active habits (TOFT 1981, STRÜSSMANN et al. 1984), increasing their probability of falling into pit-fall traps. Additionally, some types of frogs (such as hylids and some *Eleutherodactylus*) may be able to climb or jump out of the buckets, which could result in those taxa being under-represented in the pit-fall sampling (N.J. SCOTT pers. comm.).

The two most abundant frog species (*Eleutherodactylus guentheri* and *Physalaemus signifer*) comprised more than 54% of the sampled litter frog fauna at the REGUA in plot sampling, which suggests that they are the dominant species in the local leaf-litter community. Conversely, the rarest species in the leaf-litter community seemed to be *E. octavioi* and *Scinax* aff. *x-signatus*. *Eleutherodactylus octavioi* was among the least frequent species in the transect sampling (1.1%) and in the pit-fall traps (5.8%), and was not recorded in the plot sampling, which reinforces the idea of its rarity in the area. The local rarity of *E. octavioi*, endemic to the Atlantic Forest biome, partly explains the current absence of data on its ecology. *Scinax* aff. *x-signatus* was represented by one individual found in the plots. Due to their arboreal habits, hylids are not usually inhabitants of the leaf-litter, although in some studies involving plot-sampling they have been included in the leaf-litter community as they were found inside plots (e.g. RODRIGUEZ 1992; GIARETTA et al. 1997, 1999). GIARETTA et al. (1999) referred to some hylids as casual species in the leaf-litter frog community, which we also consider to be the case for *Scinax* aff. *x-signatus* at the REGUA.

The data obtained from transects indicated that most frogs (and, generally, most individuals for each species) at the REGUA are found during crepuscular and nocturnal periods. ROCHA et al. (2000), studying leaf-litter frog activity in three periods (morning, afternoon and night) at another Atlantic forest area, found that 66.3% of frog activity was concentrated in the nocturnal period. Our data are consistent with the idea that most leaf-litter frog activity in the Atlantic forest is crepuscular-nocturnal.

Although not among the most abundant species in the area, *Chaunus ictericus, Chaunus ornatus* and *Proceratophrys boiei* comprised most of the frog biomass in the leaf-litter community, due to their relatively large size. The large-bodied leptodactylid *Leptodactylus ocellatus*, albeit locally common at the REGUA, is rarely found within the forest. All five specimens of *L. ocellatus* collected during the study (four of them outside of the official sampling) were found on broad trails or at the margins of rocky streams, suggesting that this species is not a regular inhabitant of the forest floor leaf-litter.

Although the relationships between frog body size and frog abundance were not significant, a general trend in these relationship could be perceived graphically. However, three of the species (*C. carvalhoi, E. cochranae* and *E. octavioi*) deviated consistently from this relationship, as they are both small and rare. Thus, it seems that large species normally occur at lower densities, although small species may not necessarily occur at high densities in leaf-litter frog communities.

Of the 12 frog species associated with the leaf litter of REGUA, all but one (*Leptodactylus ocellatus*) are endemic to the Atlantic Forest biome and two (15.4%) (*Eleuterodactylus octavioi* and *Euparkerella cochranae*) are endemic to Rio de Janeiro State (Rocha et al. 2004). Additionally, *Scinax* aff. *x-signatus* apparently represents a still undescribed species that may also be endemic to that state (M.C.S. Cardoso pers. comm.). Two other species found during transect sampling but not considered during the present study as they are not associated whit leaf-litter [*Scinax albicans* (Bokermann 1967) and *S. humilis* (B. Lutz 1954)] are also considered endemic to Rio de Janeiro State (Rocha et al. 2004). Thus, the forest of the REGUA contains a considerable proportion of the endemic frogs of the state of Rio de Janeiro. In view of the threatened status of the Atlantic Forest as a whole, and the increasing global decline of amphibians (Yong et al. 2004), this makes the REGUA an important conservation unit for the state of Rio de Janeiro.

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