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COMPOSITION AND ABUNDANCE OF ANURANS IN RIPARIAN AND NON-RIPARIAN AREAS IN A FOREST IN CENTRAL AMAZONIA, BRAZIL

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Abstract. We determined the anurofauna composition and variation in a terra-firme forest surveyed during one rainy season. The study was carried out in the Fazenda Experimental of the Universidade Federal do Amazonas, Manaus, Amazonas, Brazil. Between November 2008 and May 2009, three samples were taken at night in 41 plots distributed across a 24 km² grid. Twenty one plots were located away from water bodies (non-riparian plots) and the remaining 20 plots were located alongside the water bodies (riparian plots). Sampling was performed using standardized sampling methods: visual and auditory surveys performed simultaneously. A total of 6,677 individuals belonging to 33 species and nine families (Aromobatidae, Bufonidae, Centrolenidae, Ceratophryidae, Hylidae, Leptodactylidae, Microhylidae, Pipidae and Strabomantidae) were recorded. The number of species ranged from 23 species at the beginning of the rainy season to 26 species at the end of the season. Twenty-four species were detected in non-riparian plots, whereas 28 species were recorded in riparian plots. Fifteen species were recorded throughout the three sampling periods. The most abundant and widely distributed species in the study area were those with reproductive specializations. Differences in species richness and abundance between riparian and non-riparian plots were observed during sampling periods: in general, in the riparian plots the number of species and number of individuals were higher than those recorded in the non-riparian plots. These differences were related to the presence of species recorded exclusively in riparian plots, corresponding to species dependent on water bodies for reproduction. Differences in species composition between our study site and other nearby areas in central Amazonia may reflect local characteristics, such as variation in topography and presence of specific sites for anuran reproduction.

Keywords. Amphibia, Abundance, Amazon forest, Riparian zone, Richness.

Introduction

Knowledge about the species that occur in an area is essential for understanding the complexity of biodiversity (Halffter and Ezcurra, 1992). However, since the available data for most of the world biota has been obtained with different methods they are not comparable (Heyer *et al.,* 1994).

The Neotropical region is a sanctuary for a large diversity of frogs (Duellman, 1999), and most studies with this group in the tropics have been conducted primarily with communities within reproduction environments, such as ponds and lakes (Crump, 1974; Aichinger, 1987; Tocher *et al.,* 1997), or those associated with the leaf litter (Allmon, 1991; Moreira and Lima, 1991; Giaretta *et al.,* 1999; Rocha *et al.,* 2000, Rocha *et al.,* 2001). In some of these studies, differences among species regarding the use of space, feeding, and activity period can be observed, which can operate independently or interactively (Toft, 1985; Rincón-Franco and Castro, 1998). The use of specific microhabitats is one of the factors allowing differential use of the physical environment, making it possible to maintain high diversity with the optimal use of available resources, mitigating the degree of competition (Heyer and Berven, 1973; Rincón-Franco and Castro, 1998).

Many species of frogs are associated with aquatic environments in one or more stages of their life cycle (Duellman and Trueb, 1994). However, those species with terrestrial reproduction may exhibit a wider distribution (Menin *et al.,* 2007a) compared to the distribution of species with aquatic reproduction, which depends on the water bodies and associated riparian zones. Lower alpha diversity has been observed for different taxonomic groups in riparian areas compared to the surrounding areas, but these riparian zones contributed to regional species richness because they are home to different species (Sabo *et al.,* 2005). In contrast, high alpha diversity for herbs in riparian zones has been reported, as well as the occurrence of unique species, suggesting that the same pattern could be found for other groups (Drucker *et al.,* 2008). In central Amazonia, aquatic breeding frogs are distributed mainly near riparian areas, being rare in more distant places, indicating that these species may use the margins of water bodies as dispersal corridors (Menin, 2005).

In spatial mesoscale studies (10,000 ha) conducted in central Amazonia, variation in the occurrence

of species was observed throughout the rainy season (Menin, 2005; Menin *et al.,* 2008). However, different temporal patterns of species occurrence were already described for the Amazonian frogs. At the Adolpho Ducke Forest Reserve (RFAD), near Manaus, terrestrial breeding species and species that breed in tree microhabitats were found mainly at the beginning of the rainy season. In the southeastern Amazon forest, a significant relationship between the number of calling species and rainfall volume was observed (Bernarde, 2007). Studies conducted in French Guyana showed that calling activity was correlated with the amount of rain of the day, as well as the rainfall of the previous 24 h and 72 h preceding the sampling (Gottsberger and Gruber, 2004).

The aim of the present study was to compare the composition of anuran species inhabiting riparian and non-riparian areas in central Amazonia and to evaluate the temporal variation in abundance and occurrence of these species during a rainy season.

Materials and Methods

Study Area

This study was conducted at the Fazenda Experimental of the Universidade Federal do Amazonas (Fazenda UFAM: 02°37'17.1" and 02°39'41.4"S, 60°03'29.1" and 60°07'57.5"W), which is part of the Biodiversity Research Program (Programa de Pesquisa em Biodiversidade – PPBio: http://ppbio.inpa.gov.br). The Fazenda UFAM has recently been included in the PPBio and the anurans inhabiting this locality had not been registered until this study, which will bring new knowledge on the Brazilian Amazon biodiversity. In addition, the study area is located at the edges of the highway BR-174 and the expansion of the urban area of Manaus city. This area will probably suffer a great environmental impact with the growth of the city, so the present study will allow comparisons with future data.

The Fazenda UFAM is located at km 38 of the highway BR-174, bordered at south by lands of the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA) and at north by the Estação Experimental de Fruticultura Tropical (EEFT) and Estação Experimental de Silvicultura Tropical (EEST), both belonging to the Instituto Nacional de Pesquisas da Amazônia – INPA (Figure 1). The Fazenda UFAM has an area of 3.000 ha not yet characterized in terms of flora, topography and climate. But as it shares its borders with the reserves of IBAMA and INPA, the Fazenda UFAM's vegetation is part of a large *continuum.* The forest of the region is classified as tropical rain forest of terra-firme, with fairly dense canopy and an understory with low light, characterized by the abundance of palm trees, such as *Astrocaryum* spp. and *Attalea* spp. (Guillamet and Kahn, 1982). The average height of trees is between 35 and 40 m, with emergent trees reaching 50 m (Ribeiro *et al.,* 1999). Air temperature variation between months is very low, with average temperatures between 24.6°C and 26.9°C. Daily relative air humidity ranges from 75% during relatively dry days up to 92% in the rainy season (Araújo *et al.,* 2002), and average annual rainfall is 2,362 mm (Marques Filho *et al.,* 1981). The rainy season extends from November to May, with higher rainfalls in March, April, and May; the dry season occurs between June and October (Marques Filho *et al.,* 1981; Araújo *et al.,* 2002; Bohlman *et al.,* 2008). Preliminary topographic analysis has shown that the Fazenda UFAM is located basically on two large geomorphologic formations (E. Venticinque and L. Lança, *pers. comm.*). The area of the Fazenda UFAM also includes constructions and farming areas, a green primary forest of terra-firme featuring large streams that flood large areas, responding to the flooding of major rivers, as well as headwaters and streams of first and second order flooding small areas in response to the daily rainfall, and the relief is fairly rugged, including areas of slopes with steep inclinations.

Data Collection

Three nocturnal sampling events were carried out during the rainy season: beginning of the rainy season (November-December 2008), mid rainy season (January-February 2009), and end of the rainy season (April-May 2009). Each sampling period lasted between 19 and 21 days. Data was collected at 41 plots. Thirty one plots were evenly distributed and distant by at least 1 km from one another, and the other 10 plots were located near streams and far from uniformly distributed plots by at least 500 m. The 41 plots were distributed on a grid of 24 km² composed of four 8-km long trails in the east-west direction and nine 3-km long trails in the north-south direction (Figure 1; more information is available at http://ppbio.inpa.gov.br). Each plot covered an area of 250 × 40 m, and 31 plots were distributed systematically along the contour of the land, minimizing the

variation in altitude and soil within the plot (Magnusson *et al.,* 2005). The other 10 sites were at the margin of streams. The plots were classified as non-riparian or riparian according to the proximity to the stream (Riparian: < 100 m from the creek; Non-riparian: > 100 m from the creek).

Sampling was performed using two simultaneously standardized sampling methods: visual sampling (visual encounter surveys, with the use of headlights) and auditory survey (Crump and Scott, 1994; Zimmerman, 1994; Rödel and Ernst, 2004; Menin *et al.,* 2007a, 2008). These methods are complementary and appropriate for sampling distribution and abundance of frogs in short and long term studies (Tocher, 1998; Doan, 2003; Rödel and Ernst, 2004). Each plot was covered by two people walking side by side for about an hour. The samplings were conducted between 18:30 and 22:00 hours. After every 5 m, observers stopped and registered the number of individuals of each calling species. At the same time, they searched visually on the leaf litter and vegetation to a height of about 2 m. All frog sightings and/or all calls heard at a distance of approximately 20 m on either side of the 250 m long centerline were counted, totaling

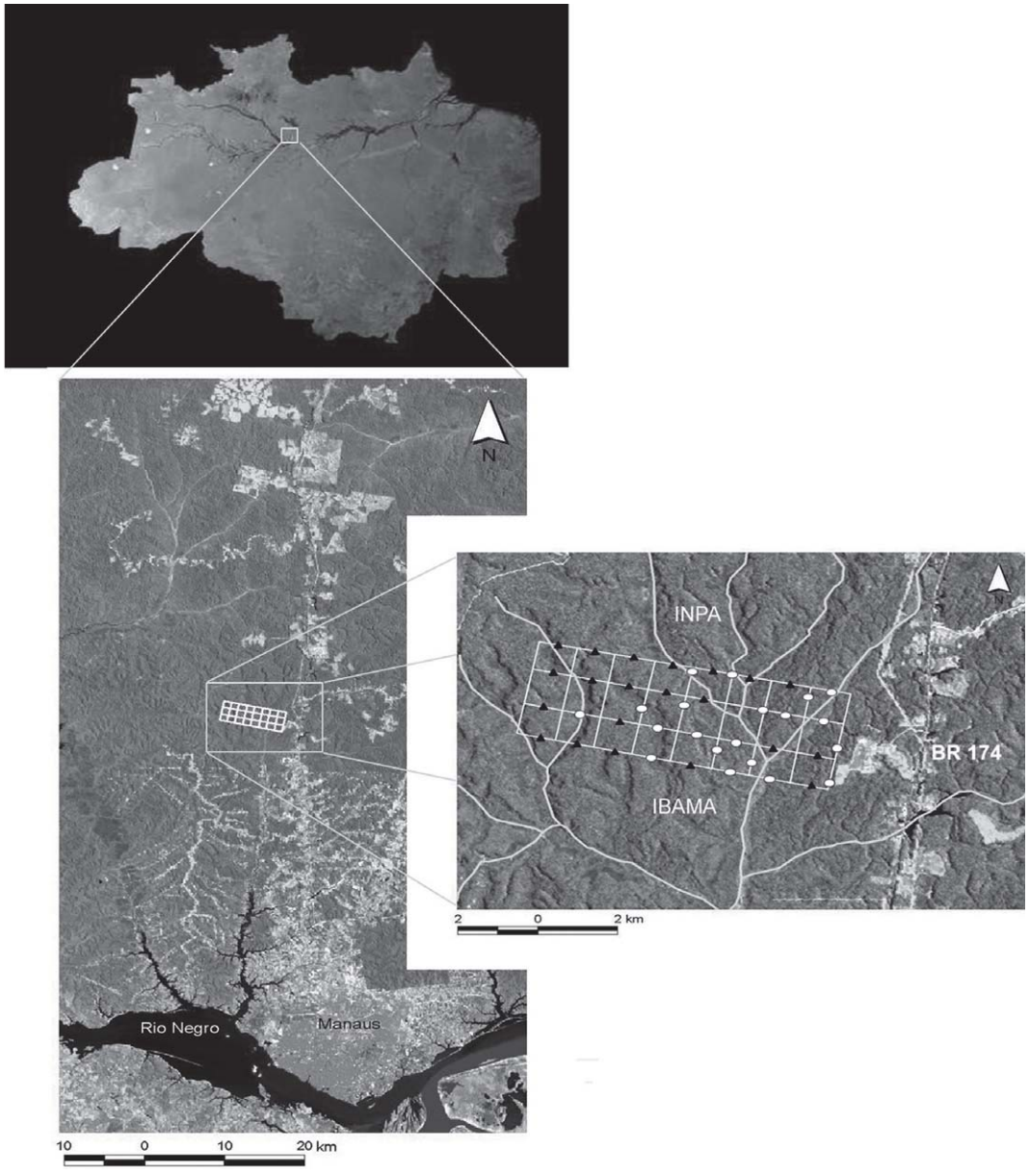

Figure 1. Geographical location of the study area, Fazenda Experimental of the Universidade Federal do Amazonas, north of Manaus city (between areas of IBAMA and INPA), Amazonas State, Brazil, and the grid system inside the study area. Circles indicate the riparian plots and triangles indicate non-riparian plots.

about 1 ha plot. The number of individual calling in groups was estimated (abundance categories: 1-5, 5-10, 10-20 or more than 20 individuals). All sampling was carried out by the same people (senior author and field assistant).

The sampling schedule was made by alternating each plot, sampling each plot for at least one period during the early evening to avoid underestimating the distribution and abundance of *Leptodactylus* aff. *andreae,* a crepuscular species (Menin *et al.,* 2008). Each individual found and captured was identified at the specific level. Some specimens collected were anesthetized, killed, and fixed with 10% formalin and later preserved in 70% alcohol. All specimens were deposited in the Collection of Amphibians and Reptiles of the Instituto Nacional de Pesquisas da Amazônia (INPA-H).

Data Analysis

Rarefaction curves of species were estimated based on the number of individuals and the number of samples (sensu Gotelli and Colwell, 2001), using the program EstimateS 7.5.1, Mao Tau Sobs index (Colwell *et al.,* 2004; Colwell, 2005). Rarefaction methods are suitable for species richness estimates and comparisons between data sets with different number of individuals (Gotelli and Colwell, 2001). These curves allowed us to evaluate the number of plots and individuals necessary to measure the greatest number of species in each sample at the study area (Menin *et al.,* 2008).

Results

Species composition

In the forty-one plots, a total of 33 species (6,677 individuals) were recorded belonging to nine families (Table 1). Thirteen species were found occasionally, of which four species showed diurnal activity (*Allobates femoralis, Atelopus spumarius, Rhinella proboscidea* and *Dendrophryniscus minutus*), being the calling activity of *A. femoralis* recorded during the initial hours of the first sampling period (between 18:30 to 19:00 h). The other three species were detected visually. Other species like *Rhinella marina, Hypsiboas lanciformis, Leptodactylus fuscus* and *L. longirostris,* are common in open areas and were eventually found later inside the forest (Menin, 2005; Lima *et al.,* 2006). These species were recorded occasionally in the plots close to the edge of the grid in the eastern portion. Other forest species and with diurnal and/or nocturnal activity were also recorded occasionally (one or two occurrences: *Ceratophrys cornuta, Phyllomedusa tarsius* and *Phyllomedusa tomopterna,* that use upland isolated temporary pools for reproduction; *Osteocephalus buckleyi,* that reproduces in water streams during the dry season; *Pipa pipa,* that occurs in pools bordering streams and depends on specific sampling methods). Except for two species, *R. proboscidea* and *D. minutus,* which were registered more than twice and in more than one period, the other 11 species found occasionally were excluded from the rarefaction analysis.

Six species accounted for 83.7% of the total of individuals recorded in the study period, being *Osteocephalus oophagus* (20.4%) the most abundant species, followed by *Pristimantis zimmermanae* (16.9%), *Synapturanus salseri* (13.8%), *Hypsiboas cinerascens* (12.4%), *Leptodactylus* aff. *andreae* (10.1%), and *Pristimantis fenestratus* (10.0%) (Table 1). *Osteocephalus oophagus* and *P. zimmermanae* were present in all 41 plots, while *P. fenestratus* and *P. ockendeni* occurred in 40 and 39 plots, respectively (Table 1).

Thirteen species (39.4%) were recorded only by auditory sampling (*A. femoralis, Vitreorana oyampiensis, Hypsiboas lanciformis, Phyllomedusa bicolor, Trachycephalus resinifictrix, L. fuscus, Leptodactylus lineatus, L. longirostris, Chiasmocleis hudsoni, Synapturanus mirandariberoi, S. salseri, P. ockendeni* and *P. zimmermanae*), while seven species (21.2%) were found only by visual sampling (*A. spumarius, D. minutus, R. marina, R. proboscidea, O. buckleyi, Phyllomedusa tarsius* and *C. cornuta*) (Table 1).

Twenty-four species (2,750 individuals), belonging to six families were recorded in the non-riparian sites (Table 2). The most abundant species were *O. oophagus* (24.7%), *P. zimmermanae* (20.2%), *S. salseri* (17.1%), *P. fenestratus* (13.0%), and *Leptodactylus* aff. *andreae* (12.5%).

In the riparian plots, 28 species (3,927 individuals) were recorded, distributed in eight families (Table 2). The most abundant species were *H. cinerascens* (21.1%), *O. oophagus* (17.6%), *P. zimmermanae* (14.5%), *S. salseri* (11.6%), *Leptodactylus* aff. *andreae* (8.5%), and *P. fenestratus* (7.9%). In addition, some species, such as *D. minutus, V. oyampiensis, H. cinereascens, Leptodactylus riveroi* and *P. pipa,* were recorded exclusively in this type of plot.

Table 1. Number of plots where each species of frog was recorded and number of individuals in each sample obtained during nocturnal samplings at Fazenda UFAM, Manaus, Amazonas, Brazil. The total number corresponds to the sum of the three samples. (V = visual sampling: A = auditory sampling).

Family/Species	Number of plots	November-December/2008		January-February/2009		April-May/2009		Total
		V	A	V	A	V	A	
Aromobatidae								
Allobates femoralis	3	0	13	0	0	0	0	13
Bufonidae								
Atelopus spumarius	1	0	0	0	0	1	0	1
Dendrophryniscus minutus	3	0	0	2	0	1	0	3
Rhinella marina	3	0	0	1	0	3	0	4
Rhinella proboscidea	7	3	0	0	0	5	0	8
Centrolenidae								
Vitreorana oyampiensis	16	0	0	0	47	0	129	176
Ceratophryidae								
Ceratophrys cornuta	1	0	0	0	0	1	0	1
Hylidae								
Hypsiboas cinerascens	18	0	131	2	432	1	261	827
Hypsiboas geographicus	7	2	0	23	1	9	0	35
Hypsiboas lanciformis	1	0	9	0	0	0	0	9
Osteocephalus buckleyi	1	1	0	0	0	0	0	1
Osteocephalus oophagus	41	39	527	44	547	27	181	1,365
Osteocephalus taurinus	19	7	0	12	3	4	4	30
Phyllomedusa bicolor	4	0	4	0	2	0	2	8
Phyllomedusa tarsius	1	0	0	0	0	1	0	1
Phyllomedusa tomopterna	1	1	0	0	0	0	0	1
Trachycephalus resinifictrix	15	0	0	0	17	0	11	28
Leptodactylidae								
Leptodactylus aff. *andreae*	33	0	130	0	456	1	89	676
Leptodactylus fuscus	1	0	6	0	0	0	0	6
Leptodactylus knudseni	6	1	0	1	2	3	2	9
Leptodactylus lineatus	18	0	3	0	4	0	23	30
Leptodactylus longirostris	3	0	0	0	0	0	4	4
Leptodactylus mystaceus	5	0	2	0	2	2	1	7
Leptodactylus pentadactylus	15	12	0	15	4	19	4	54
Leptodactylus rhodomystax	20	3	28	7	23	11	4	76
Leptodactylus riveroi	11	14	0	26	2	11	1	54
Microhylidae								
Chiasmocleis hudsoni	2	0	2	0	0	0	2	4
Synapturanus mirandaribeiroi	27	0	96	0	134	0	0	230
Synapturanus salseri	35	0	466	0	446	0	13	925
Pipidae								
Pipa pipa	1	0	0	1	0	0	0	1
Strabomantidae								
Pristimantis fenestratus	40	6	300	8	215	6	132	667
Pristimantis ockendeni	39	0	0	0	165	0	132	297
Pristimantis zimmermanae	41	0	471	0	509	0	146	1,126
Number of species		11	15	11	19	17	19	33
Total number of species		23		22		26		
Number of individuals		2,277		3,153		1,247		6,677

Table 2. Number of individuals recorded during the three sampling periods in each type of environment (riparian plots and non-riparian plots), Fazenda UFAM, Manaus, Amazonas, Brazil.

Family/Species	Riparian plots			Non-riparian plots		
	Nov-Dec 2008	Jan-Feb 2009	Apr-May 2009	Nov-Dec 2008	Jan-Feb 2009	Apr-May 2009
Aromobatidae						
Allobates femoralis	8	0	0	5	0	0
Bufonidae						
Atelopus spumarius	0	0	0	0	0	1
Dendrophyniscus minutus	0	2	1	0	0	0
Rhinella marina	0	1	3	0	0	0
Rhinella proboscidea	2	0	1	1	0	4
Centrolenidae						
Vitreorana oyampiensis	0	47	129	0	0	0
Ceratophryidae						
Ceratophrys cornuta	0	0	0	0	0	1
Hylidae						
Hypsiboas cinerascens	131	434	262	0	0	0
Hypsiboas geographicus	1	24	9	1	0	0
Hypsiboas lanciformis	0	0	0	9	0	0
Osteocephalus buckleyi	1	0	0	0	0	0
Osteocephalus oophagus	287	311	94	279	280	114
Osteocephalus taurinus	5	9	8	2	6	0
Phyllomedusa bicolor	0	2	2	4	0	0
Phyllomedusa tarsius	0	0	1	0	0	0
Phyllomedusa tomopterna	0	0	0	1	0	0
Trachycephalus resinifictrix	0	6	1	0	11	10
Leptodactylidae						
Leptodactylus aff. *andreae*	67	240	26	63	216	66
Leptodactylus fuscus	0	0	0	6	0	0
Leptodactylus knudseni	0	1	1	1	2	4
Leptodactylus lineatus	3	2	14	0	2	9
Leptodactylus longirostris	0	0	4	0	0	0
Leptodactylus mystaceus	0	2	1	2	0	2
Leptodactylus pentadactylus	12	17	20	0	2	3
Leptodactylus rhodomystax	29	22	12	2	8	3
Leptodactylus riveroi	14	28	12	0	0	0
Microhylidae						
Chiasmocleis hudsoni	0	0	2	2	0	0
Synapturanus mirandaribeiroi	19	96	0	77	38	0
Synapturanus salseri	173	271	11	293	175	2
Pipidae						
Pipa pipa	0	1	0	0	0	0
Strabomantidae						
Pristimantis fenestratus	160	94	55	146	129	83
Pristimantis ockendeni	0	119	48	0	46	84
Pristimantis zimmermanae	262	258	49	209	251	97
Number of species in each sample	16	22	23	18	12	15
Number of individuals in each sample	1,174	1,987	766	1,103	1,166	481
Number of species in each plot type		28			24	
Number of individuals in each plot type		3,927			2,750	

Temporal Variation in the Composition and Abundance of Species

Considering all 33 species, the number of species ranged from 23 at the beginning of the rainy season (November/December) to 22 in the middle of the rainy season, and 26 species at the end of the season (April/May). However, the total number of individuals varied inversely, from 2,277 at the beginning of the rainy season to 3,153 in the middle of the rainy season and 1,247 at the end of the season (Table 1).

Fifteen species were found in the three sampling periods (Table 1). The number of species in each plot ranged from two to 14 (mean = 6.22 ± 2.41, n = 123) being higher in the middle of the rainy season (14 species – January-February/2009), while the lowest number was found in the early of the rainy season (two species). There were differences in the number of plots required to achieve the same number of species throughout the rainy season. The number of plots required to achieve the minimum number of species (18 species) varied between samples. Forty-one sites were needed to reach this number at the beginning of the rainy season, approximately 16 in mid-season and 14 at the end of the rainy season (Figure 2A).

The greatest number of individuals (3,152) was recorded in the middle of the rainy season and the lowest number (1,247) was found at the end of the season (Table 1, Figure 2B). The number of individuals required to achieve the minimum number of species (18 species) was higher (approximately 2,250 individuals) at the beginning of the rainy season compared to the end of the period (approximately 430 individuals) (Figure 2B).

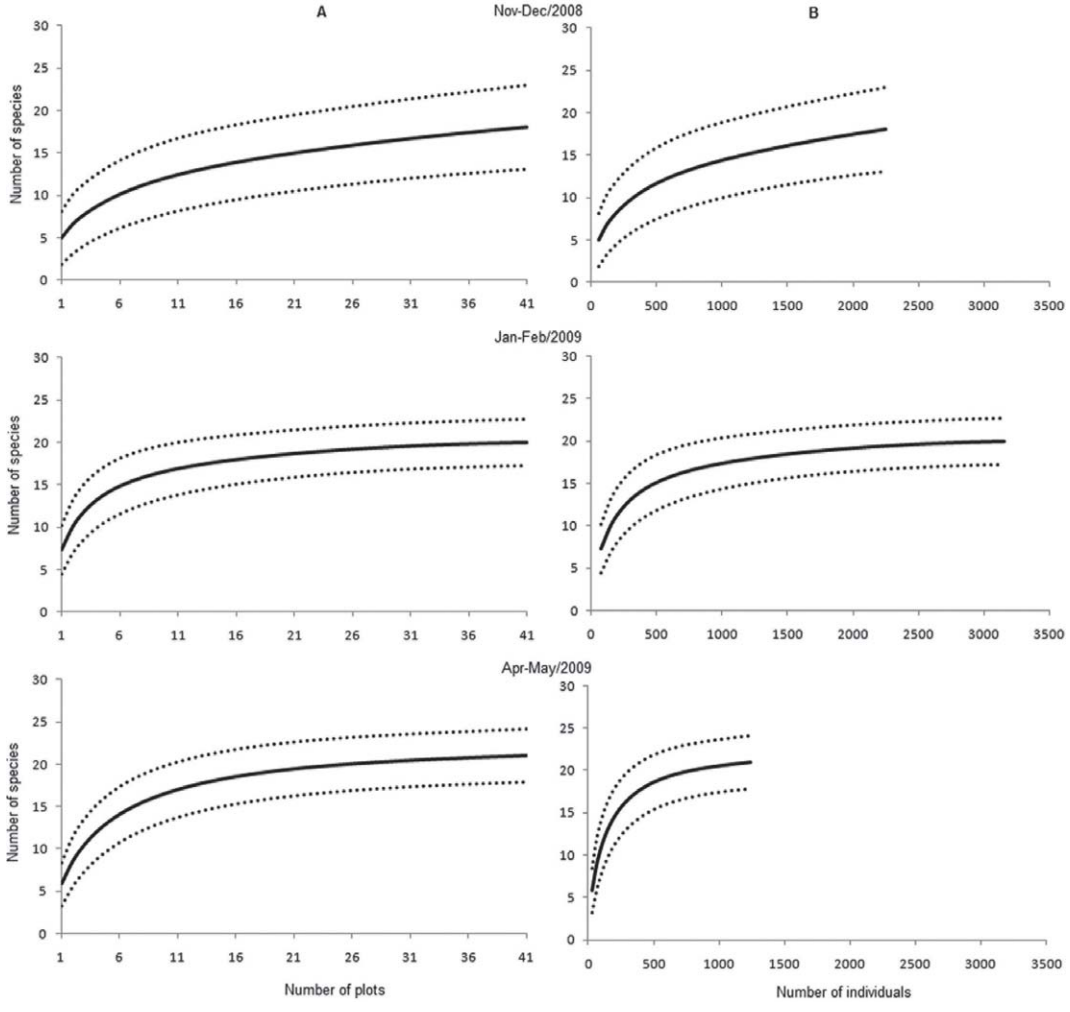

FIGURE 2. Rarefaction curves based on the number of plots (A) and number of individuals of anurans (B) for each sampling period, without considering the diurnal species and species from open areas and those occasionally recorded at Fazenda UFAM, Manaus, Amazonas, Brazil. The sampling in November-December/2008 were carried out at the beginning of the rainy season, sampling in January-February/2009 in the middle of the rainy season, and the sampling in April-May/2009 at the end of the rainy season.

In the riparian plots, the greatest number of species was recorded at the end of the rainy season (23 species) and the lowest number at the beginning of the rainy season (16 species), but the greatest number of individuals was observed in the middle of the season (1,987 individuals) and the lowest at the end of the season (766 individuals). However, in the non-riparian plots, the greatest number of species was found at the beginning of the season (18 species) and the lowest in the middle of the season (12 species); the number of individuals was higher in the middle of the rainy season (1,166 individuals) and lower at the end (481 individuals). In general, throughout the entire study period both the number of species and the number of individuals were greater in the riparian plots (Table 2).

Discussion

The species recorded at the study area have already been recorded in other areas in central Amazonia, such as the Adolpho Ducke Forest Reserve – RFAD (Lima *et al.,* 2006; Menin *et al.,* 2008) and areas of the Biological Dynamic of Forest Fragments Project – BDFFP (Zimmerman and Bierregaard, 1986; Allmon 1991). But unlike those areas, the total number of species recorded in this study is lower, probably due to lower sampling time (anurans have been studied in BDFFP and RFAD during the last 25 years; Zimmerman and Bogart, 1984; Zimmerman and Bierregaard, 1986; Allmon, 1991; Zimmerman and Simberloff, 1996; Tocher *et al.,* 1997; Lima *et al.,* 2006; Menin *et al.,* 2008). However, when compared with the study of Menin *et al.* (2008) in RFAD, carried out in 72 plots during two rainy seasons, the number of species reported by the authors in the nocturnal samples (25 species) was lower than that found in the present study (33 species). This difference may be related to the lower number of riparian plots sampled by these authors (18 plots instead of 20 in the present study). Furthermore, such difference may result from the fact that we recorded some diurnal species (*A. femoralis* and *D. minutus*), open area species occasionally found within the forest (*L. fuscus* and *L. longirostris*), and other low abundant species (*O. buckleyi, C. cornuta* and *C. hudsoni*), which has not been recorded in previous studies (Menin *et al.,* 2005, 2008). However, these species are present in RFAD and occur in specific habitats and/or low abundance in that reserve (Lima *et al.,* 2006).

Zimmerman and Bierregaard (1986) found 39 species in primary forest in the area of BDFFP; 29 of these species were found in the Fazenda UFAM in the present study. Some of these species, such as *D. minutus, V. oyampiensis, H. geographicus, H. cinerascens,* and *L. riveroi,* were recorded in both studies with distribution restricted to the vicinity of water bodies. Other species, such as *Leptodactylus* aff. *andreae, Pristimantis* spp. and *Synapturanus* spp., were recorded as species with terrestrial reproduction and apparently widely distributed in the BDFFP area (Zimmerman and Bierregaard, 1986). The latter species was also widely distributed and abundant in our study, agreeing with results obtained by Menin *et al.* (2007a, 2008) for RFAD.

Allmon (1991), in the same area of BDFFP and using 498 litter square plots sampled during the day and over a year, found 14 species, including *R. marina* and *D. minutus.* Similar to the study of Allmon (1991), these species were also low abundant at the Fazenda UFAM. Menin *et al.* (2008) reported a greater number of individuals of these species in RFAD, but the number of plots was higher (72 plots) with individuals of *D. minutus* recorded during daytime samples.

Differences in the number of species between periods may have been caused by the presence/absence of rare species in each sample, as observed in the study of Allmon (1991), where the richness and diversity rather than abundance fluctuated with the occurrence of relatively rare species. However, the present study differs from that of Menin *et al.* (2008), where the number of species was lower in the second sampling period (half of the rainy season). This may result from differences in environmental conditions during the sampling periods of each study, as the volume and intensity of rain per day or for several days preceding the sampling and the availability of breeding sites directly influence the activity of anurans (Allmon, 1991; Duellman, 1995; Gottsberger and Gruber, 2004).

Differences in species richness and abundance between riparian plots and non-riparian plots were observed during sampling periods in the present study. In general, in the riparian plots the number of species and number of individuals were higher than those recorded for non-riparian plots (except at the beginning of the rainy season where the number of species was higher in non-riparian plots) (Table 2). This difference is related to the presence of species recorded exclusively in riparian plots (*D. minutus, V. oyampiensis, H. cinerascens, H. geographicus, O. buckleyi,*

P. tarsius and *L. riveroi*), corresponding to species dependent on bodies of water for reproduction, representing 15.6% of the number of species recorded for the study area. This is similar to previous studies conducted in nearby areas, where these species were reported next to bodies of water (Zimmerman and Bierregaard, 1986). Furthermore, these results are contrary to the study of Sabo *et al.* (2005), who found that riparian areas have low alpha diversity in relation to the surrounding areas. On the other hand, our results support the work of Drucker *et al.* (2008), who found a high alpha diversity and the presence of unique species of herbs in riparian areas, suggesting that the distribution of other taxonomic groups may show higher diversity in riparian areas.

Rare species found during the sampling period may have habitat requirements related to their reproductive behavior, such as *P. bicolor, C. cornuta* and *L. lineatus.* For species of the genus *Phyllomedusa,* the reproduction occurs mainly in isolated temporary pools formed by streams and rain water in muddy areas (Lima *et al.,* 2006; Rodrigues *et al.,* 2010). The same was observed for *C. cornuta* (Zimmerman and Simberloff, 1996; Rodrigues *et al.,* 2010). For *Leptodactylus lineatus,* which is a species frequently found in association with colonies of leaf-cutting ants, the males call from underground tunnels inside the ant's nests (Lima *et al.,* 2006). Therefore, species like these may be really abundant in the study area and may have been underestimated because of our sampling method, which may have failed detecting them. Moreover, their specific breeding habitats or microhabitats may also limit the distribution of several or most forest frogs (Zimmerman and Bierregard, 1986; Rodrigues *et al.,* 2010). However, rare and/or absent species in this study (e.g., *Phyllomedusa bicolor, P. tarsius, P. tomopterna, P. vaillanti, C. cornuta, P. pipa, P. arrabali, Chiasmocleis shudikarensis, Ctenophryne geayi*) were present in other nearby areas (RFAD and BDFFP) (Zimmerman and Bierregard, 1986; Allmon, 1991; Zimmerman and Simberloff, 1996; Lima *et al.,* 2006; Menin *et al.,* 2008; Rodrigues *et al.,* 2010), where the sampling rate and/or study period differed from the ones employed at the Fazenda UFAM. Other species found in low abundance, such as *Rhinella marina,* reported in this study, is a species occasionally found in primary forests, as its reproduction occurs in water bodies of open areas (Menin *et al.,* 2008). Individuals of *R. proboscidea* and the individual of *A. spumarius* recorded in this study were found resting on leaves of small herbaceous plants or branches of shrubs, as observed by Zimmerman and Bogart (1984) and Menin *et al.* (2008). However, both species were recorded in greater abundance in RFAD, using the same sampling methods during the night (Menin *et al.,* 2008).

The most abundant species recorded in this study were those with reproductive specializations, such as reproduction in leaf axils of bromeliads and tree hollows (*O. oophagus*) (Hödl, 1990; Jungfer and Schiesari, 1995), direct development (*Pristimantis* spp.), or development of tadpoles in terrestrial nests (*Leptodactylus* aff. *andreae, Synapturanus* spp.) (Hödl, 1990; Menin *et al.,* 2007a, b), agreeing with other studies in different areas of central Amazonia (Allmon, 1991; Menin, 2005; Menin *et al.,* 2007a, 2008) and other forests in South America (Giaretta *et al.,* 1999; Rocha *et al.,* 2001; Doan and Arriaga, 2002). *Leptodactylus* aff. *andreae,* a leaf-litter and crepuscular species, was recorded in 33 (80.5%) plots. In these plots, it was possible to observe a reduction in the activity of vocalization after 19:00 h, which was also noticed by Menin *et al.* (2008), who found the species active from the beginning of the evening until early at night. However, at the end of the season, the species showed a large decrease in the abundance of calling males and an increase in juvenile number (Menin *et al.,* 2008), which may be related to the end of the breeding season of the species.

In summary, this study, conducted in a 24 km^2 area of terra firme forest at central Amazonia, showed variation in species composition between riparian and non-riparian plots and along a rainy season. Also, we detected differences in the composition of anuran assemblages between our study site and neighboring areas in central Amazonia, such as RFAD and BDFFP. The most abundant species were the same in these areas. However, the occurrence of rare species determined the high beta diversity. The differences found in species composition between neighboring areas in central Amazonia may reflect local characteristics of each area, such as variation in topography and the presence of specific sites for anuran reproduction.

Resumo

No presente estudo foi determinada a composição e a variação na abundância da anurofauna de uma floresta de terra-firme de 3000 ha, amostrada durante uma estação chuvosa. O estudo foi realizado na Fazenda Experimental da Universidade Federal do Amazonas, Manaus, Amazonas, Brasil. Foram realizadas três amostragens noturnas entre

novembro/2008 e maio/2009 em 41 parcelas distribuídas sobre uma grade de 24 km², sendo 21 parcelas localizadas distantes de igarapés (parcelas não-ripárias) e 20 parcelas localizadas nas margens dos igarapés (parcelas ripárias). As amostragens foram realizadas empregando métodos de amostragem visual e auditiva, simultaneamente, e com esforço padronizado. Foram registrados 6.677 indivíduos pertencentes a 33 espécies e nove famílias (Aromobatidae, Bufonidae, Centrolenidae, Ceratophryidae, Hylidae, Leptodactylidae, Microhylidae, Pipidae e Strabomantidae). O número de espécies variou de 23 espécies no início da estação chuvosa até 26 espécies no final da estação. Vinte e quatro espécies foram detectadas nas parcelas não-ripárias, enquanto nas parcelas ripárias foram registradas 28 espécies. Quinze espécies foram registradas nos três períodos de amostragem. As espécies mais abundantes e amplamente distribuídas na área de estudo foram aquelas com especializações reprodutivas. Diferenças na riqueza e abundância de espécies entre as parcelas ripárias e não-ripárias foram observadas durante os períodos de amostragem: de maneira geral, nas parcelas ripárias o número de espécies e o número de indíviduos foram maiores que os registrados para as parcelas não-ripárias. Essas diferenças foram relacionadas com a presença de espécies registradas exclusivamente nas parcelas ripárias, correspondendo a espécies com reprodução dependente de corpos d'água. As diferenças em composição de espécies observadas entre a Fazenda UFAM e outras áreas próximas na Amazônia Central podem ter sido determinadas pelas características locais de cada área, como variação na topografia e presença de locais específicos para reprodução de algumas espécies.

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