



Species diversity and seasonal variation in the composition of a bat community in the semi-arid brazilian caatinga

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ABSTRACT. The caatinga scrublands are relatively poorly-studied, and few data are available on the biome's chiropteran fauna. The present study focuses on the bat community of the arboreal caatinga of Serra da Guia. Bats were trapped in mist-nets on three new moon nights per month between October, 2008, and September, 2009. A total of 157 individuals were captured, representing 12 species. Species richness estimated by Jackknife1 was 14.8. *Glossophaga soricina* and *Carollia perspicillata* were by far the most common species, accounting for 56.7% of the specimens captured. Species diversity was 1.80, while equitability was 0.72. There was no significant seasonal difference in species diversity or evenness. However, the present study recorded a clear seasonal shift in community structure. The principal difference in species composition was related to the temporal distribution of the rarest forms – all of the seven rarest species were recorded exclusively in only one season (dry or wet). The nectarivorous bats predominated numerically both in the dry season as in rainy, while frugivores became prominent, in terms of both the number of species and individuals, during the wet season. The predominance of stenodermatine bats during the wet season almost certainly reflects the increased availability of resources for this group during this part of the year.

Keywords: brazilian northeast, Chiroptera, dry forest, biodiversity, Sergipe.

Diversidade de espécies e variação sazonal na composição da comunidade de morcegos na caatinga brasileira

RESUMO. A caatinga é relativamente pobre em estudos e apresenta poucos dados sobre a quiropterofauna. O presente estudo foi focado na comunidade de morcegos numa caatinga arbórea na Serra da Guia. Os morcegos foram capturados em redes de neblina durante três noites de lua nova por mês entre outubro, 2008 e setembro 2009. Um total de 157 indivíduos foram capturados, representando 12 espécies. A riqueza de espécies estimada por Jackknife 1 foi 14,8. *Glossophaga soricina* e *Carollia perspicillata* foram as espécies mais comuns, representando 56,7% dos indivíduos capturados. A diversidade das espécies (H') foi 1,80, enquanto a equitabilidade foi 0,72. Não houve diferença sazonal significativa na diversidade e equitabilidade de espécies. No entanto, o presente estudo registrou uma clara mudança sazonal na estrutura da comunidade. A principal diferença na composição de espécies foi relacionada com a distribuição temporal das formas mais raras – todas as sete espécies mais raras foram registradas exclusivamente em apenas uma das duas estações (seca ou chuvosa). Os nectarívoros predominaram numericamente tanto na estação seca quanto na chuvosa, enquanto frugívoros tornaram-se proeminentes, tanto em termos de número de espécies e indivíduos, durante a estação chuvosa. A predominância de stenodermatíneos durante a estação chuvosa provavelmente reflete o aumento da disponibilidade de recursos para esse grupo durante esta parte do ano.

Palavras-chave: nordeste de Brasil, Chiroptera, floresta seca, biodiversidade, Sergipe.

Introduction

The semi-arid caatinga scrublands of the brazilian northeast cover an area of almost one million square kilometers, but while this biome has suffered intense anthropogenic impacts over the past few centuries, its fauna and flora are still relatively poorly-known (SÁ et al., 2004). Paglia et al. (2012) recorded 77 bat species for this biome, as compared with 101 species for the

neighboring cerrado savanna, and 113 for the brazilian atlantic forest. In addition to the scarcity of studies of the local chiropteran fauna, most surveys have been conducted near the region's principal urban centers (LEAL et al., 2005).

The caatinga is characterized by an unpredictable and low precipitation regime, with annual rainfall of 400-800 mm, generally concentrated into a short,

irregular wet season. This marked seasonality, together with the intense solar radiation and highly permeable soils typical of the region, tends to impose strict limitations on the characteristics of its fauna and flora (TABARELLI; SILVA, 2003). These characteristics originally led many authors to consider the caatinga to be a region of relatively reduced faunal diversity and low rates of endemism (MARES et al., 1981; WILLIG; MARES, 1989). In one of the earliest studies of the chiropteran fauna of the caatinga, in the Brazilian State of Pernambuco, Willig (1983) recorded 33 species in distinct types of habitat over a three-year period. Over the subsequent three decades, taxonomic revisions, the identification of new species, and inventories more than doubled this total (WILLIAMS et al., 1995; MARINHO-FILHO; SAZIMA, 1998; OLIVEIRA et al., 2003; SOUZA et al., 2004; GREGORIN; DITCHFIELD, 2005; SÁ-NETO; MARINHO-FILHO, 2012), although up until now, only a few sites have been surveyed systematically, and there are few data from the southern half of the biome, south of the São Francisco River, which includes the Brazilian State of Sergipe. The present study focuses on the chiropteran community of a representative area of caatinga scrub in western Sergipe, assessing species diversity and seasonal variation in the composition of the assemblage.

Material and methods

Study area

The study area is located in the Serra da Guia (9°58'S, 37°52'W), a small mountain range located within the caatinga, in the northern extreme of the Brazilian State of Sergipe. The elevation of the study area is between 300 and 750 m above sea level. The lower elevations, up to 650 m a.s.l., are dominated by typical arboreal caatinga habitat, i.e. 'caatinga alta' according to Mares et al. (1981), in which the Cactaceae, Bromeliaceae, Leguminosae, Arecaceae and Euphorbiaceae are the most common plant families, and trees of the species *Caesalpinia pyramidalis* and *Amburana cearensis*, and *Syagrus coronata* palms dominate the landscape. Mean annual precipitation in the study area is approximately 500 mm, with a wet season between April and August, and a dry season during the rest of the year, from September to March (Figure 2).

Data collection

Bats were sampled in the arboreal caatinga at Serra da Guia between October 2008, and September 2009, following a standard monthly schedule in which 10 mist-nets (2.5 m high and 10 m long) were set along a

trail system within an area of typical habitat between 18:00 h and 05:00 h on three consecutive nights during the new moon period. During the first six hours of each session, the nets were visited every 20 minutes for the removal of captured bats, but after midnight, the nests were only checked every 90 minutes, given that the capture rate declined considerably during this part of the night. All captured specimens were placed in cotton bags until the following morning for processing.

Each specimen was examined and identified to species level, and its sex, age, reproductive condition, weight, and forearm length were recorded. The specimens were then marked with numbered plastic rings, which were attached to the distal portion of the forearm and then released. Voucher specimens (no more than four individuals per species) were collected for taxonomic verification. Identification was based on the keys of Vizotto and Taddei (1973), Anderson (1997), Simmons and Voss (1998), Lim and Engstrom (2001), and Gardner (2007).

Data analysis

Sampling effort was calculated by multiplying the total area of the mist-nets by the number of hours they were set (STRAUBE; BIANCONI, 2002). Species were considered dominant if their relative abundance was higher than $1 S^{-1}$, where S = species richness (URAMOTO et al., 2005).

The Shannon-Wiener diversity index, Jackknife1 species richness estimator and species accumulation curves (observed and estimated) based on 1000 replications (COLWELL; CODDINGTON, 1994) were run in the EstimateS 8.0 program (COLWELL, 2005). Shannon-Wiener's equitability (E) was obtained using the equation $E = H' \ln S^{-1}$, where H' = Shannon-Wiener diversity index and $\ln S$ = natural logarithm of species richness.

The species recorded were classified according to their feeding niche, based on Nowak (1994), as insectivore, frugivore, nectarivore or hematophagous. Between-season differences in species diversity (H') were evaluated using a modified t test (ZAR, 1999). Seasonal differences in abundance were tested using Chi-square, Mann-Whitney's U , and the G test. All tests were run in BioStat 5.0 (AYRES et al., 2007), considering $\alpha < 0.05$ (ZAR, 1999).

Results

Species diversity

The total sampling effort of 90,310 h m² resulted in the capture of 157 bats belonging to three families, 11 genera, and 12 species (Table 1). Almost all the specimens captured were phyllostomids, with the Emballonuridae and Vespertilionidae each being

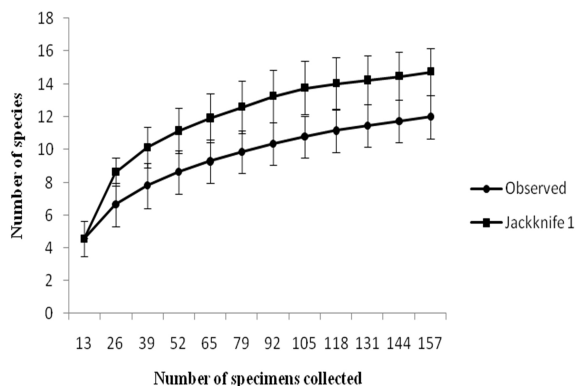
Table 1. Chiropteran species captured in the Brazilian caatinga at Serra da Guia, Sergipe, between October 2009, and September 2010.

Taxon	Specimens captured (% of the total sample)	Average weight (g)	Dietary niche
Emballonuridae			
<i>Pteropteryx macrotis</i> (Wagner, 1843)	1 (0.6)	4.0	insectivorous
Phyllostomidae			
Desmodontinae			
<i>Desmodus rotundus</i> (Geoffroy, 1810)	25 (15.9)	34.4	hematophagous
Micronycterinae			
<i>Micronycteris</i> aff. <i>sanborni</i> (Simmons, 1996)	8 (5.1)	6.2	insectivorous
Glossophaginae			
<i>Anoura geoffroyi</i> (Gray, 1838)	1 (0.6)	12.0	nectarivorous
<i>Glossophaga soricina</i> (Pallas, 1766)	54 (34.4)	9.6	nectarivorous
Lonchophyllinae			
<i>Lonchophylla mordax</i> (Thomas, 1903)	19 (12.1)	10.0	nectarivorous
Carollinae			
<i>Carollia perspicillata</i> (Linnaeus, 1758)	35 (22.3)	16.4	frugivorous
Stenodermatinae			
<i>Dermanura cinerea</i> (Gervais, 1856)	2 (1.3)	12.0	frugivorous
<i>Artibeus lituratus</i> (Olfers, 1818)	2 (1.3)	71.0	frugivorous
<i>Platyrrhinus lineatus</i> (Geoffroy, 1810)	6 (3.8)	23.8	frugivorous
<i>Uroderma magnirostrum</i> (Davis, 1968)	3 (1.9)	14.7	frugivorous
Vespertilionidae			
<i>Myotis nigricans</i> (Schinz, 1821)	1 (0.6)	5.0	insectivorous
Total	157		

represented by only a single specimen. Overall species diversity was $H' = 1.81$, and equitability $E = 0.72$.

The last of the 12 species recorded at the site was collected in June, the ninth month of the study period. Estimated total species richness according to Jackknife 1 was $S = 14.8$ species (Figure 1), which indicates that the results of the study were relatively satisfactory, given that 81.1% of this total was recorded. This is supported by the fact that the standard deviations of the two curves overlapped at many points.

Together, the four most common species (*Glossophaga soricina*, *Carollia perspicillata*, *Desmodus rotundus*, and *Lonchophylla mordax*) accounted for more than 80% of total abundance. Each of these four species was considered to be dominant, according to the criterion of Uramoto et al. (2005).

**Figure 1.** Observed and estimated (Jackknife 1) cumulative species curves (vertical lines = standard deviation) for the chiropteran community in the Brazilian caatinga at Serra da Guia, Sergipe.

Seasonal variation

The number of both specimens captured and species recorded varied considerably among months (Table 2), peaking in the wet season month of July.

Table 2. Monthly captures of bats at Serra da Guia, Sergipe, between October 2009, and September 2010.

Species	Number of specimens captured in:												Study period
	O	N	D	J	F	M	A	M	J	J	A	S	
<i>Glossophaga soricina</i>	12	2	1	2	4	-	4	-	3	10	13	3	54
<i>Carollia perspicillata</i>	1	-	-	2	1	-	1	1	8	16	1	4	35
<i>Desmodus rotundus</i>	1	6	9	3	-	1	-	1	-	3	-	1	25
<i>Lonchophylla mordax</i>	2	3	-	1	1	-	1	-	1	9	-	1	19
<i>Micronycteris</i> aff. <i>sanborni</i>	-	-	1	1	-	1	1	-	1	2	1	-	8
<i>Platyrrhinus lineatus</i>	-	-	-	-	-	-	-	2	1	3	-	-	6
<i>Uroderma magnirostrum</i>	-	-	-	-	-	-	-	1	1	1	-	-	3
<i>Dermanura cinerea</i>	-	1	-	-	-	1	-	-	-	-	-	-	2
<i>Artibeus lituratus</i>	-	-	-	-	-	-	-	-	1	1	-	-	2
<i>Anoura geoffroyi</i>	1	-	-	-	-	-	-	-	-	-	-	-	1
<i>Myotis nigricans</i>	-	1	-	-	-	-	-	-	-	-	-	-	1
<i>Pteropteryx macrotis</i>	-	-	-	-	1	-	-	-	-	-	-	-	1
Total	17	13	11	9	7	3	7	5	16	45	15	9	157
Total species	5	5	3	5	4	3	4	4	4	7	8	3	12

While there was a tendency for greater abundance and species richness during the wet season (Figure 2), there was no clear overall pattern, and July was distinctly exceptional in both respects, although June was similar in terms of species richness. As expected according to their overall abundance, *G. soricina* and *C. perspicillata* were also the most frequently recorded species over the course of the study period, being captured in ten and nine of the 12 months, respectively (Table 2), with *D. rotundus* and *L. mordax* appearing in eight months each.

Differences in capture rates between seasons were influenced primarily by the exceptional values from July.

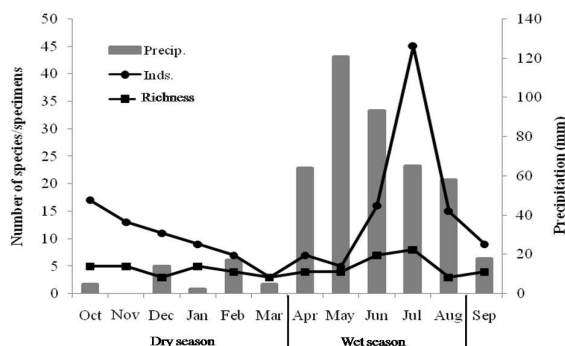


Figure 2. Number of individuals and bat species captured per month at Serra da Guia, Sergipe, and monthly precipitation rates during the study period, between October 2009, and September 2010.

Thus, while the mean number of specimens collected per month in the wet season was almost twice that for the dry season, the difference between seasons was not significant when monthly records are compared (Mann-Whitney's $U = 13.5$, $p = 0.516$). Similarly, while the number of species recorded per month was higher, on average, during the wet season, there was no significant difference across months ($U = 14.0$, $Z = 0.568$, $p = 0.570$).

There is a similar lack of seasonal difference in species diversity, with $H' = 1.68$ in the wet season ($E = 0.80$) and $H' = 1.65$ in the dry season ($E = 0.75$). The difference between diversity indices was not significant ($t = -0.30$, $p = 0.81$, $df = 2$). The principal seasonal difference in species composition was related to the temporal distribution of the rarest forms – all of the seven rarest species were recorded exclusively in only one of the two seasons (Figure 3). Of the more abundant species, only two – *C. perspicillata* and *D. rotundus* – were collected in significantly larger numbers in one season, following

distinct patterns. Whereas the number of *C. perspicillata* collected during the wet season was significantly higher than that recorded during the dry season (χ^2 with Yates' correction = 16.641, d.f. = 1, $p < 0.0001$), *D. rotundus* was significantly more common during the dry season (corrected $\chi^2 = 5.731$, d.f. = 1, $p < 0.017$).

Although the variation in the individual species was unclear, the nectarivorous guild (*A. geoffroyi*, *G. soricina*, and *L. mordax*), which predominated numerically in both seasons, was significantly more abundant during the wet season (corrected $\chi^2 = 5.644$, d.f. = 1, $p < 0.018$). In addition, while the hematophagous *D. rotundus* was the second most common species in the dry season, it was only the fifth most abundant in the rainy season, when the frugivores became prominent in terms of both the number of species and individuals (Figure 3). Overall, the guild structure of the community shifted significantly between seasons ($G = 25.938$, d.f. = 3, $p < 0.0001$).

Discussion

The chiropteran fauna of the semi-arid caatinga is relatively poorly-known in comparison with other Brazilian biomes, but the scenario increasingly evident from recent surveys, including the present study, is one of relatively reduced abundance and species diversity.

However, while the species richness estimators indicated that most of the local species were recorded during the present study, the relatively low number may have also been related to a variety of sampling effects, not least the relatively small number of specimens captured.

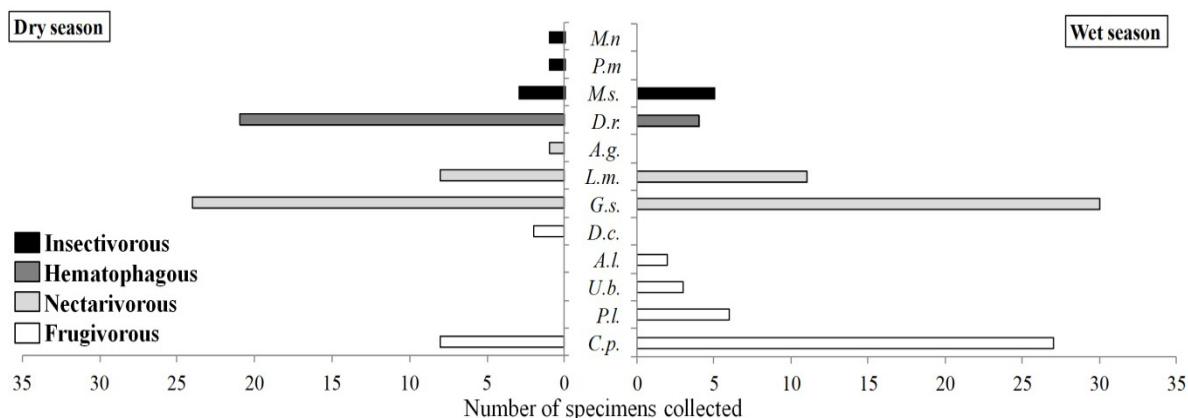


Figure 3. Seasonal variation in the feeding guild structure of the chiropteran community at Serra da Guia, Sergipe. Dry season = October-December, 2009, and January-March and September, 2010; Wet season = April-August, 2010. C.p. = *Carollia perspicillata*; P.l. = *Platyrrhinus lineatus*; U.b. = *Uroderma bilobatum*; A.l. = *Artibeus lituratus*; D.c. = *Dermanura cinerea*; G.s. = *Glossophaga soricina*; L.m. = *Lonchophylla mordax*; A.g. = *Anoura geoffroyi*; D.r. = *Desmodus rotundus*; M.s. = *Micronycteris aff. sanborni*; P.m. = *Peronycteris macrotis*; M.n. = *Myotis nigricans*.

In the Atlantic Forest of southeastern Brazil, for example, Bergallo et al. (2003) estimated that a sample of at least 1000 specimens would be necessary for the cumulative species curve to reach its asymptote, although it is unclear whether this value is equally valid for the caatinga. Additional factors include the probable under-sampling of insectivorous species and the surveying of only one type of habitat (WILLIG, 1983). Some active searches for daytime roosts were conducted during the present study, but were unsuccessful. Given the low capture rates, however, procedures of this type may be essential for the reliable sample of chiropteran communities in the caatinga. In addition, the use of ultrasound detectors, while still incipient in Brazil, has been proven to be an effective complementary method, principally for the inventory of insectivores (MURRAY et al., 1999). Even so, this acoustic approach is ineffective for the majority of phyllostomid bats or other cryptic species with similar acoustic characteristics (OBRIST et al., 2004).

Despite these apparent methodological limitations, the results of the study are broadly consistent with the structure of most other Neotropical chiropteran communities. The predominance of a few abundant species combined with a large number of rare species is a common pattern (McGILL et al., 2007), as is the predominance of the Phyllostomidae, in terms of both abundance and the number of species. This is typical of most Neotropical biomes (SIMMONS; VOSS, 1998; BERNARD, 2001; LIM; ENGSTROM, 2001; BIANCONI et al., 2004; ZORTÉA; ALHO, 2008), including the Brazilian caatinga (WILLIG, 1983; SILVA et al., 2001; ; GREGORIN et al., 2008). This not only reflects the relative diversity of this family (GARDNER, 2007), but also the comparative effectiveness of mist-netting for the capture of phyllostomids (FENTON et al., 1992; SIMMONS; VOSS, 1998). Overall species diversity ($H' = 1.81$) was also broadly similar to that recorded in other studies in Brazil (PEDRO; TADDEI, 1997; ROCHA et al. 2010), including the caatinga (BELTRÃO et al. 2014).

The present study recorded a clear seasonal shift in community structure, with more than half the species being recorded in only one season. While this is probably at least partly a result of the sampling effects discussed above, the shift towards a greater predominance of stenodermatine bats during the wet season almost certainly reflects the increased availability of resources for this group during this part of the year (BARBOSA et al., 1989, 2003; MACHADO et al., 1997). As the loss of foliage is a characteristic of the caatinga during the dry season,

an additional factor reducing the diversity of the Stenodermatinae during this period may have been the loss of cover for daytime roosting.

While represented by relatively few species, the nectarivores were the predominant group throughout the study period, in terms of abundance. This may be related to a number of factors, including the local abundance of *Encholirium spectabile*, a bromeliad classified as chiropterophilic by Sazima et al. (1989). The relative abundance of nectarivores in comparison with frugivores may also reflect the reduced availability of edible fruit in the caatinga. Vicente et al. (2003) found that only around a fifth of this biome's plant species were zoochoric. The production of edible fruit is also highly concentrated in the relatively short and unpredictable wet season (GRIZ; MACHADO, 2001). In addition, the relatively small size of the nectarivorous species may be advantageous in environments with reduced resource availability, like the caatinga (HELVENSEN; WINTER, 2003). Overall, then, the numerical predominance of nectarivorous bats may be a characteristic of communities of bats of this caatinga phytophysiognomy.

Conclusion

The present study recorded a clear seasonal shift in community structure. The principal seasonal difference in species composition was related to the temporal distribution of the rarest forms – all of the seven rarest species were recorded exclusively in only one of the two seasons. Overall, the guild structure of the community shifted significantly between seasons. The nectarivorous guild predominated numerically in both seasons, while frugivores became prominent, in terms of both the number of species and individuals, during the wet season. The predominance of stenodermatine bats during the wet season almost certainly reflects the increased availability of resources for this group during this part of the year.

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