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The anuran fauna of a semi-arid Caatinga area in northeastern Brazil

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Anuran amphibians are a diverse group of vertebrates with approximately 990 species and 19 families known to occur in Brazil (Segalla et al. 2014). Despite increased efforts towards improving our understanding of their biology, remarkable knowledge gaps remain (Rodrigues 2003). Given this, new inventories, especially of under-sampled regions, are essential to understanding this prominent vertebrate group.

The Caatinga morphoclimatic domain is confined to Brazil and has recently been considered a centre of endemism for many taxa including anurans (Caldas et al. 2010, Napoli et al. 2011a, Cavalcanti et al. 2014). This region is characterized by dry climate, high temperatures, and low humidity, with vegetation that supports a number of different microhabitats exploited by anurans (Vieira et al. 2007, Lyra-Neves & Telino-Júnior 2010).

In the past, the anuran fauna of the Caatinga received little attention, but recent efforts have considerably expanded the available information (Caldas et al. 2010, Napoli et al. 2011b, c, Cavalcanti et al. 2014, Magalhães et al. 2014). As a result, Rodrigues (2003) confirmed the occurrence of 49 anuran species in the Caatinga domain. Additional species have since been described (Magalhães et al. 2014) and new records of established taxa published (Napoli et al. 2011b, c, Ribeiro et al. 2012, Garda et al. 2013).

Despite the variety of available methods, anuran sampling often involves opportunistic searching for individuals at dusk and night when anurans are most active (Arzabe 1999). In an attempt to assess the efficiency of the sampling procedures used in the present study and permit comparisons between different periods and areas, we compiled MacKinnon lists based on the direct observation of anurans and records of their vocalizations (Herzog et al. 2002). This method is commonly applied to estimate bird species richness through the compilation of lists of a predefined number of species, which are used to calculate cumulative species curves (MacKinnon & Phillips 1993, Herzog et al. 2002). While this method has been acknowledged as most effective in ornithological studies (O'Dea et al. 2004), it has also been successfully used for anuran inventorying (Muir & Muir 2011).

The goal of this study was to record the diversity of anurans based on MacKinnon lists in an area of the Caatinga morphoclimatic domain.

The study area is located on the Fazenda Tamanduá (7°01'31.23" S, 37°23'31.04" W), a farm in the municipality of Santa Teresinha in Paraíba, Brazil. This site is located in the Caatinga morphoclimatic domain and has a typical tropical semi-arid climate, with a mean annual rainfall of ca 800 mm and arboreal-shrubby vegetation of xerophilous and deciduous woody species. The study site is a 350 ha private natural heritage reserve, which is used for the sustainable production of organic raw materials (Lyra-Neves & Telino-Júnior 2010).

Data were recorded during the rainy season in May of 2011 at three sites during a total of 60 man-hours of sampling effort involving five collectors. All sampling was conducted at night. A total of 25 lists of four anuran species were compiled, based on direct observations or records of vocalizations (cf. Muir & Muir 2011). In this approach, species lists for each site were compiled without repeating a given species in the same list. The decision to limit the lists to four taxa was made in order to decrease repetitions of the same species and increase the number of lists, as was proposed by Herzog et al. (2002).

Table 1. Anuran species recorded in May of 2011 in our study area in the municipality of SantaTeresinha, Paraíba, Brazil, their IUCN Red List status (www.redlist.org) and information if endemic to the Caatinga. IFL – index of species frequency in the lists.

Family	Species	IUCN Red List status	Caatinga-endemic species	IFL
Bufonidae	*Rhinella jimi* (Stevaux, 2002)	Least Concern	yes	0.52
	Rhinella granulosa (Spix, 1824)	Least Concern	–	0.08
Odontophrynidae	*Proceratophrys cristiceps* (Müller, 1884 "1883")	Least Concern	yes	0.04
Hylidae	*Dendropsophus branneri* (Cochran, 1948)	Least Concern	no	0.08
	Dendropsophus soaresi (Caramaschi & Jim, 1983)	Least Concern	no	0.04
	Dendropsophus minutus (Peters, 1872)	Least Concern	no	0.04
	Hypsiboas raniceps Cope, 1862	Least Concern	no	0.72
	Phyllomedusa nordestina Caramaschi, 2006	Data Deficient	yes	0.12
	Scinax x-signatus (Spix, 1824)	Least Concern	no	0.24
Leptodactylidae	*Leptodactylus macrosternum* Miranda-Ribeiro, 1926	Least Concern	no	0.68
	Leptodactylus vastus Lutz, 1930	Least Concern	yes	0.08
	Leptodactylus fuscus (Schneider, 1799)	Least Concern	no	0.12
	Pseudopaludicola falcipes (Hensel, 1867)	Least Concern	no	0.84
	Pleurodema diplolister (Peters, 1870)	Least Concern	yes	0.04
	Physalaemus centralis Bokermann, 1962	Least Concern	no	0.04
	Physalaemus cuvieri Fitzinger, 1826	Least Concern	no	0.04

The lists were compiled along three transects, each covering approximately 1,000 m² (200 m in length by 5 m in width). Pairs of transects were separated by a distance of at least 500 m. Transect 1 – adjacent to a small reservoir; the flanking aquatic vegetation and presence of herbaceous plants provide substrates for anurans at different stages of development; some rocky outcrops and bromeliads. Transect 2 – characterized by herbaceous vegetation, primarily grasses, seasonal marshy patches, and patches of damp soil maintained by the increased precipitation typically occurring during the rainy season; the habitat in this area is open and anthropogenic, with few shrubs adjacent to the road. Transect 3 – located next to the second reservoir, this area is characterized by the transition from lentic to lotic conditions; this site lies also near a large rocky outcrop; margins of this reservoir are dominated by grasses and herbaceous vegetation as well as aquatic angiosperms.

Data obtained were analysed using Primer 6.0. Shannon's diversity index (H') and Pielou's equitability (J') for each transect (Weaver & Shannon 1949) were calculated. Species accumulation curves were plotted using the MacKinnon lists for the study area as a whole in order to evaluate the effectiveness of this approach for sampling anurans. The relative abundance of the different species in the whole study area was also calculated, as was the index of frequency of each anuran species in the lists (IFL). The IFL was obtained by dividing the number of lists in which the species was recorded by the total number of lists (MacKinnon 1991). The species were classified as 'very frequent' (> 50%), 'frequent' (50–25%) and 'rare' (< 25%), based on Almeida et al. (1999).

A total of 16 anuran species was recorded, representing ten genera in five families (Table 1). Representatives of all anuran families have been recorded at other Caatinga sites before (Arzabe 1999, Ribeiro et al. 2012). Viera et al. (2007) reported a similar predominance of hylid species at other sites in the state of Paraíba as we do here. All the species recorded in the present study have 'generalist' habits and have been recorded in open habitats in both Caatinga and Cerrado savannas of central Brazil (e.g., Santana et al. 2008).

The most frequent species recorded in the MacKinnon lists were *Pseudopaludicola falcipes*, *Hypsiboas raniceps*, and *Leptodactylus macrosternum* (Table 1). *Pseudopaludicola falcipes* typically forms congregations of individuals at breeding sites (Lisboa et al. 2013), with a highly clustered distribution pattern, as it did in our study area. *Hypsiboas raniceps,* in our study, occurred mainly in association with vegetation in the border areas of the reservoir. *Leptodactylus macrosternum* was mostly found in 'open' areas, such as herbaceous vegetation and sites adjacent to lentic bodies of water, where they engaged in reproductive activity. The least frequent species were *Proceratophrys cristiceps*, *Dendropsophus soaresi, Dendropsophus minutus, Pleurodema diplolister, Physalaemus centralis* and *P. cuvieri* (Table 1). Four species – *P. falcipes*, *H. raniceps*, *L. macrosternum* and *Rhinella jimi*– were classified as very frequent (> 50%), while all other species were assigned to the 'frequent' category 25–50%.

The cumulative species curve based on MacKinnon lists reached the asymptote (Fig. 1), indicating that the method employed was effective for sampling anuran species based on records of sightings and vocalizations. Cavalcanti et al. (2014) recorded eight anuran taxa in a 30-day study in the Caatinga, whereas Loebmann & Haddad (2010) registered 37 species over a 24-month period. In the present study, the Mackinnon method proved highly efficient for the comparison of species richness among sites, periods

Table 2. Total and relative abundance of the anuran species recorded at the three study sites.

Species	Relative abundance [%]	Number of specimens recorded at:		
		Study site 1	Study site 2	Study site 3
Dendropsophus branneri	2.15	1	–	1
Dendropsophus soaresi	1.07	1	–	–
Dendropsophus minutus	1.07	1	–	–
Hypsiboas raniceps	19.35	8	5	5
Leptodactylus macrosternum	18.27	7	6	4
Leptodactylus vastus	2.15	2	–	–
Leptodactylus fuscus	3.22	1	1	1
Phyllomedusa nordestina	3.22	1	2	–
Pseudopaludicola falcipes	22.58	11	5	5
Pleurodema diplolister	1.07	1	–	–
Physalaemus centralis	1.07	1	–	–
Physalaemus cuvieri	1.07	–	–	1
Proceratophrys cristiceps	1.07	1	–	–
Rhinella jimi	13.97	7	4	2
Rhinella granulosa	2.15	2	–	–
Scinax x-signatus	6.45	4	1	1

and observers, given the standardization of the analysis as suggested by Muir & Muir (2011). The lists can also be used to evaluate the efficiency of the sampling effort from the analysis of the cumulative species curve.

Pseudopaludicola falcipes was the most abundant species overall, accounting for approximately 23% of the records, followed by *H. raniceps* (19%), *L. macrosternum* (18%), and *R. jimi* (14%). The least abundant species were *D. soaresi*, *D. minutus*, *P. diplolister*, *P. centralis*, *P. cuvieri,* and *P. cristiceps*, for each of which only a single individual was recorded during our study (Table 2).

Anuran species diversity at Fazenda Tamanduá was H' = 2.178, while equitability was J' = 0.786. Transect 1 (Table 3) had the highest species richness (15 species), greatest abundance, highest diversity (H' = 2.594) and was also characterized by the greatest diversity of microhabitats, such as rocky outcrops and bromeliads, which presumably contributed to the greater anuran species richness

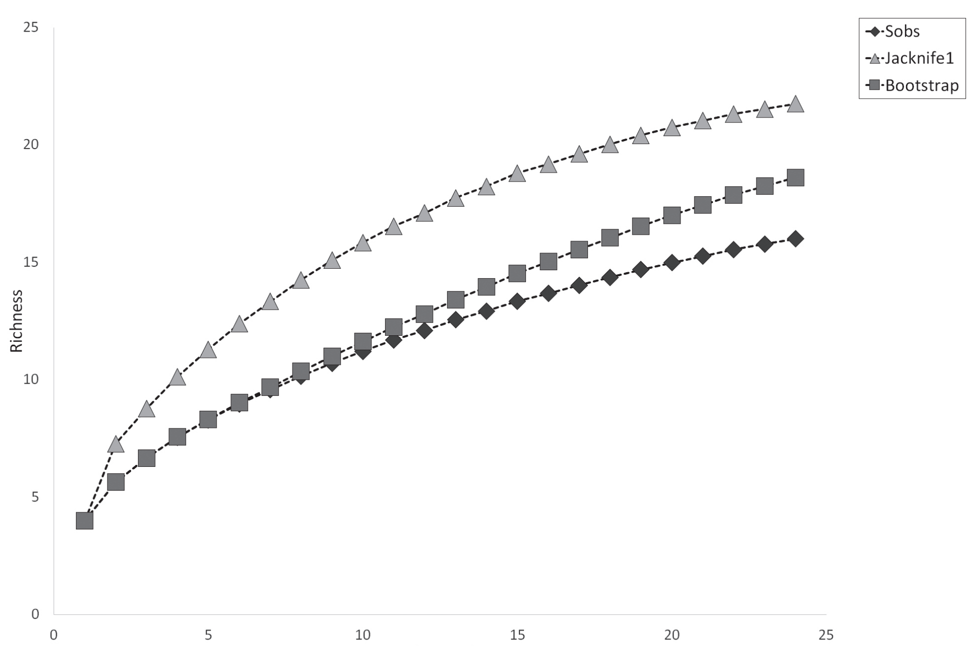

Figure 1. Cumulative species curve of the anurans recorded using the MacKinnon list method.

Table 3. Shannon's index of diversity (H'), Pielou's equitability (J'), species richness, and the number of specimens recorded (N) at the three study sites.

	H'	J'	Richness	N
Study site 1	2.594	0.958	15	49
Study site 2	1.891	0.9717	6	24
Study site 3	2.015	0.9689	8	20

recorded at this locality (Table 2). Transect 2, which had the lowest species richness, was considered to be the most impacted, given its proximity to the road. The lotic conditions found along Transect 3 are favourable to only some anuran species. Temporary or permanent pools are favourable environments for anurans during their breeding season, providing the wet conditions necessary for hatching, maintenance of tadpoles, and feeding resources, insects in particular (Santos et al. 2004). The anuran breeding season in the Caatinga is intimately related to abiotic factors, such as low temperatures, rainfall and high humidity, and the availability of temporary bodies of water (Duellman & Trueb 1986). Rocky outcrops in which water may accumulate and plants such as phytotelmic bromeliads provide important microhabitats in which many anurans roost and breed (Vieira et al. 2007) and may also provide calling perches. Some *Scinax* species are commonly found in bromeliads (Pederassi et al. 2012) and are well adapted to arid areas (Arzabe 1999).

Duellman (1985) considers anurans to be a useful indicator of environmental quality, given their sensitivity to habitat modifications and anthropogenic pressures. Maintenance of microhabitats, preservation of the anuran diversity and other components of the local fauna and flora found in the study area appear to reflect the sustainable exploitation of the local natural resources. The area is used for organic farming and ranching techniques that do without the application of toxic chemicals.

The Caatinga is one of the most threatened Brazilian morphoclimatic domains. It is also the least well protected, despite the fact that it is suffering from rapid and unsustainable anthropogenic modifications (Leal 2003, Rodrigues 2003). Priority areas for the conservation of this domain have been suggested by Rodrigues (2003) and Camardelli & Napoli (2012). While the conservation status of the species recorded in the present study is of little immediate concern, five of them are endemic to the Brazilian northeast and may thus require special attention.

This is the first inventory of anurans in a Caatinga region that is used for sustainable farming and is part of a region whose frog diversity is little known. The data reported here may support future studies on distribution patterns (spatial and temporal) of the region's anurans and provide a basis for the development of conservation strategies to protect the fauna and flora of the Caatinga domain.

The diversity of anurans recorded in the present study was consistent with the findings of previous studies in the Caatinga morphoclimatic domain. The MacKinnon method proved appropriate for inventorying anuran communities. Inventories of the local fauna are a first step towards the identification of priority areas for conservation and the identification of areas of species' occurrence, in some cases, the known distribution of the species may be extended. The results of the present study also reinforce the ecological importance of the Caatinga, a region severely threatened by ongoing anthropogenic impact.

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