Introduction

The Caatinga, along with the Cerrado and Chaco, is classified as a Seasonally Dry Tropical Forest and is considered the only biome located entirely within the Brazilian territory (Oliveira and Diniz-Filho, 2010). This biome is subject to a climatic regime of intense and irregular rainfall distributed between three to six months of the year, presents shallow soils with a savannah vegetation, including xerophytic, shrubby, and thorny deciduous physiognomies (Oliveira and Diniz-Filho, 2010). In recent decades, natural areas of Caatinga have been under intense degradation, and approximately 62% of zones susceptible to desertification in Brazil (Borges-Nojosa et al., 2010).

Amphibians comprise one of the groups with greatest morphological and physiological variation among vertebrates (Duellman and Trueb, 1994), covering approximately 7643 species, distributed mainly in the tropics (Frost, 2017). Among the amphibians, the order Anura is the most abundant (Vieira et al., 2007), and the families Hylidae and Leptodactylidae are the most representative in the Neotropics (Bertoluci et al., 2007). Hylids predominate in forested environments and leptodactylids concentrate mainly in open areas (Arzabe, 1999).

Heyer (1988) identified the Caatinga as one of the least known biomes of South America, with extensive areas lacking information on composition, natural history, and ecology of amphibians. Although the number of studies is still much lower when compared with Brazilian forested areas (Loebmann and Haddad, 2010), there has been an increase in the number of studies conducted in areas of Caatinga (e.g., Arzabe., 1999; Borges-Nojosa and Cascon., 2005; Garda et al., 2013; Santana et al., 2015).

In this paper, we present new information on the composition and diversity of an anuran assemblage from rock outcrops in the Caatinga.

Materials and Methods

**Study area.**—This study was conducted at the **Sitio**
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Paleontológico Lajinhas (SPL; Lajinhas Paleontological site), in the municipality of Itapipoca, Ceará, northeastern Brazil (3.41770833S/39.69210278W). Caatinga vegetation is predominant in the area, with forest and shrub species of the Cactaceae, Fabaceae and Euphorbiaceae families (Ximenes, 2008). The homogeneity of the landscape is often interrupted by granite rock outcrops, very common in certain areas of Caatinga and locally called *lajeiros* (Ximenes, 2008). The study area has a hot semiarid climate with high temperatures and low annual rainfall (from 600 to 800 mm), which is concentrated from January to June, with the remaining months of the year being very dry (Funceme, 2011) (Fig 1).

**Data collection.**—Fieldwork was conducted monthly from July 2010 to July 2011, consisting of three days per month. We conducted active and acoustic surveys with three observers at each study site that were sampled during the daytime (8:00 to 12:00 am each day) and at night (18:00 pm to 1:00 am each day, or while vocalizing animals were heard), with a total effort of 429 hrs/person.

This study was conducted at three *lajeiros* (LC, LA and LJ, see detailed description below). The distances between these areas are: LC/ LA= 700 m; LC/LJ = 800 m; LA/LJ= 200 m (Fig 2):

- **“Lajeiro do Criminoso”** (LC) (3.42183333S/39.69422222W) (Fig 2A): The largest rocky outcrop in the study area, up to 10 m high. It has about 40 temporary pools of different sizes, and two ponds with accumulated sediment, with vast vegetation encrusted in sediment and rock crevices.

- **“Lagoa da Aposta”** (LA) (3.41616667S/39.69219444W) (Fig 2B): Area of low topography, with a maximum height of 1.5 m. It has five lentic and temporary ponds up to five square meters and small puddles on the rock surface. The vegetation presents few Cactaceae and Bromeliaceae species, and scrub vegetation, but also a massive presence of macrophytes inside the ponds, completely covering the surface of two of them.

- **“Lajeiro da Jia”** (LJ) (3.41594444S/39.69083333W) (Fig 2C): It has five temporary pools with a maximum depth of 8 m, approximately. There is no scrub vegetation on the *lajeiro*, but it accumulates large amount of aquatic weeds during the rainy season.

In order to improve the sampling, animals found between the *lajeiros* were also recorded (Fig 2D).

The abundance of each species was estimated using an active search method at the reproductive sites (Scott and Woodward, 1994). All individuals on the perimeter of the water bodies were recorded, including non-active ones. We used toe clipping (Ferner, 2007) to mark all individuals. The monthly occurrence of the species was assessed using the method of Silveira-Neto et al. (1976), which classifies the species as: constant, when they are present in more than 50% of samples; accessory, those present between 25% to 50% of samples; and occasional, when found in less than 25% of the samples. Specimens were deposited in the Coleção de Herpetologia da Universidade Federal do Ceará (CHUFC; Herpetological Collection of the Federal University of Ceará) and the species nomenclature follows Duellman et al. (2016) and Frost (2017).

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**Figure 1.** Climatic diagram Walter and Lieth (temperature and rainfall x months), during the study period (2010-2011) for Sítio Paleontológico Lajinhas, Itapipoca, Ceará, Brazil. R environment, package climatol (R Development Core Team, 2013).
Statistical analyzes.—To determine sampling efficiency, we constructed species richness curves (Krebs, 1999). Species richness of the sampled area was estimated by extrapolation of a species accumulation curve using Jackknife 1 and Chao 1 estimators, with 500 randomizations in the software Estimates, version 7.5 (Colwell, 2005). To analyse the relative abundance of anurans, we built a Whittaker plot and the species abundance distribution was fitted to four models of abundance (Broken stick, log normal, logarithmic and geometric series) (Magurran, 2011), which were tested using a chi-square test in the program PAST (Hammer et al., 2001).

Results

We found 19 species distributed in 13 genera and five families: Bufonidae (2), Odontophrynidae (1), Hylidae (6), Leptodactylidae (9) and Microhylidae (1). The Lajeiro do Criminoso (LC) site had the highest richness (15 species). The Lagoa da Aposta (LA), Lajeiro da Jia (LJ) and the areas between lajeiros showed an equal number of species (11) (Table 2). The accumulation curve suggested that more species may be found at these sites, and Chao 1 and Jackknife 1 estimated the richness of the area to be between 20 - 23 species (Fig 3).

The species with the highest abundances were, in decreasing order: Pseudopaludicola mystacalis (Cope, 1887) (n = 603); Pleurodema diplolister (Peters, 1870) (n = 293); Physalaemus albifrons (Spix, 1824) (n = 135); and Scinax x-signatus (Spix, 1824) (n = 131). With regard to the species abundance distribution, the assemblage fit best to the log-normal model (Chi-square = 2.73; p = 0.43) (Fig 4). Pseudopaludicola mystacalis was the most frequent species, followed by Leptodactylus vastus A. Lutz, 1930, and they occurred in all sampling months and at all sampling points (P = 100%). Considering rate of occurrence, 47% of species were occasional, 21% were regarded as accessory and 32% had a constant occurrence (Table 1).

Figure 2. Sampled Lajeiros in Sítio Paleontológico Lajinhas, Itapipoca, Ceará, northeastern Brazil. A: Lajeiro do Criminoso (rainy season); B- Lagoa da Aposta (rainy season); C- Lajeiro da Jia (dry season); D- Area between lajeiros (rainy season).
We found that the assemblage of frog species in the "Sítio Paleontológico Lajinhas" follows the pattern repeated in different regions of the Caatinga, with species of wide distribution and few endemic species of the biome (Cascon, 1987; Arzabe, 1999). This distribution pattern is also found in other semi-arid environments in the world, probably because the species of wide distribution are less susceptible to climatic instability of the semi-arid region (Chesson et al., 2004; Oliveira and Diniz-Filho, 2010). Hylidae and Leptodactylidae had similar proportions of species richness in the present study. Caatinga areas commonly have a great number of species of the Leptodactylidae family, due to their adaptations to climate unpredictability (Cascon and Langguth, 2016). Our findings are similar to those found in other studies conducted in the Caatinga (Arzabe, 1999; Vieira et al., 2007) and are probably associated with the environmental dynamics of the Caatinga. Species inhabiting large geographic areas can tolerate a wider range of environmental conditions and exhibit high reproductive rates in environments with marked instability (Oliveira and Diniz-Filho, 2010).

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All species recorded in this study are cited in the IUCN Red List and Brazilian List of Threatened Species as Least Concern (LC). The number of anuran species found in our study represents 34.5% of the 55 anurans registered by Roberto and Loebmann (2016) for the state of Ceará. The species richness found here is similar to that recorded for other areas of Caatinga stricto sensu in the state of Ceará: Serra das Almas (22 species, Borges-Nojosa and Cascon, 2005), Vale do Jaguaribe (19 species, Santana et al., 2015), and slightly lower than that found for mountain and coastal regions in the state (Borges-Nojosa, 2007, Borges-Nojosa et al., 2010, Loebmann and Haddad, 2010, Ribeiro, et al., 2012, Borges-Leite et al., 2014, Cascon et al., 2014). Roberto and Loebmann (2016) recorded only two species of anurans for the municipality of Itapipoca (L. macrosternum and P. mystacalis). Thus, our paper presents the first complete list of anurans for this municipality.
The accumulation curve did not reach an asymptote, indicating that the richness of the surveyed area may be greater than that found in this study. Considering abundance, four of the 19 species represented 76.69% of all individuals collected, while the other 15 recorded species comprised only 23.30% of the total. The dominance of a few species over the others shows an inverted “J” distribution in the Whittaker’s distribution curve of abundances (log-normal pattern). According to Magurran (2011), most biological assemblages follow this pattern, which can be explained by the central limit theory, which states that if a large number of independent factors, such as climate, acts on a certain variable (e.g. abundance), it tends to acquire a normal distribution. The log-normal model found here is identified as the one in which most species have intermediate abundance and few have small or large abundance (Magurran, 2011).

Descriptive studies are very important for the characterization of the diversity of anurans in Ceará state, especially in lowland Caatinga sites outside protected areas. Our paper contributes to increase the knowledge of the diversity of these areas. New studies are required to improve the characterization of the biodiversity of the region and for the conservation of the Caatinga biome.

Acknowledgments: The authors are grateful to Tiago A. Sousa, Wadson A. M. Frota, Rafaela Santos and Wallony Brito for help during the fieldwork; Carla Rezende for initial critiques of the manuscript and three anonymous reviewers for their important and expressive suggestions. We also would like to acknowledge the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) for the collecting license (Number 25458-2) and the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for the master scholarship conceded to Déborah Praciano de Castro.

References


Appendix 1. Voucher list.

The reference specimens can be found at CHUF under numbers *Dendropsophus rubin-cundulus*: (CHUFCA5831), *Leptodactylus fuscus*: (CHUFCA5820; CHUFCA5821), *L. macrosternum*: (CHUFCA6170; CHUFCA6171), *L. vastus*: (CHUFCA6172; CHUFCA6173), *Pithecopus nordestinus*: (CHUFCA6175), *Physalaemus albifrons*: (CHUFCA6181; CHUFCA6182), *Pleurodema diplolister*: (CHUFCA6176; CHUFCA6177), *Proceratophrys cristiceps*: (CHUFCA6179; CHUFCA6180), *Pseudopaludicola mystacalis*: (CHUFCA5837; CHUFCA5838), *Rhinella granulosa*: (CHUFCA6168; CHUFCA6169), *Scinax x-signatus*: (CHUFCA6165; CHUFCA6166).