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Natural history of an anuran community in a coastal zone of north-eastern Brazil

IGOR JOVENTINO ROBERTO[1*] & PAULO CASCON[2]

[1]Universidade Federal do Cariri, Instituto de Formação de Educadores, Laboratório de Biologia e Ecologia de Animais Silvestres, 63.260-000, Brejo Santo, CE, Brazil
[2]Universidade Federal do Ceará, Departamento de Biologia, Campus do Pici, 60440-900, Fortaleza, CE, Brazil

[*]Corresponding author e-mail: igorjoventino@yahoo.com.br

ABSTRACT – We investigated the species composition and reproduction of an anuran community in a Restinga habitat in Ceará State of north-eastern Brazil. Twenty species of four families were observed and most of these reproduced in temporary ponds, whereas *Boana raniceps* and *Scinax x-signatus* were observed in a larger number of reproductive sites and micro-habitats. Vocalisation was seasonal, with the majority of the species showing reproductive activity only during the rainy season. Only three species also vocalised during the dry season. Increases in the number of vocalising species were associated with increases in rainfall and humidity but appeared to fall with rising temperatures. For most species, there was spatial overlap of vocalisation sites and strong temporal overlapping. The anuran community in the area was composed of a mix of species that can also be found in the Caatinga and Cerrado domains but not those of the Atlantic Forest.

INTRODUCTION

There have been several previous studies of amphibian communities in Restingas (coastal, moist broadleaf forest habitats) of eastern Brazil (Xavier et al., 2015) but most of those have focused on anuran composition on the south-east coast, mainly associated with Atlantic Forest (e.g. Rocha et al., 2008; Oliveira & Rocha, 2014; Xavier et al., 2015; Oliveira et al., 2020). There have been fewer studies on the northern coast, in the states of Ceará, Piauí and Maranhão, mostly in the Delta do Parnaíba (Loebmann & Mai, 2008; Loebmann et al., 2010; Andrade et al., 2014; 2016; Araújo et al., 2018; 2020) and only one on the coast of Ceará (Borges-Leite et al., 2014).

The Restinga habitats in Brazil, especially in the north-east region, suffer from a high degree of degradation, due to hotels and beach houses built for tourism, which has led to deforestation, sand dune degradation and pollution of water bodies (Lima et al., 2000, Silva et al., 2011; Gondim-Silva et al., 2016). These impacts may lead to the disappearance or even extirpation of amphibian species. Our research has focused on anuran species composition, habitat use and calling activity in a Restinga habitat in Ceará state, north-eastern Brazil to better understand the natural history of the anurans in this region.

MATERIALS & METHODS

Study area

The study area was located in the Ecological Station of Pecém (3° 35´33" S, 38° 47´24" W, 18 m a.s.l.), a state Conservation Unit in the Municipality of Caucaia, Ceará state, 1.5 km from the Atlantic Ocean and 40 km from Fortaleza, the state capital. The area is located on Cenozoic sedimentary deposits of the Barreiras Formation (Souza, 1988), having Quartzarenic Neosol (Embrapa, 1999) as the predominant soil type. The climate is Hot Tropical semi-arid, with a pre-rainy season from November to January and a rainy season from February to May, with the highest rainfall in February to April (Funceme, 2006). The vegetation of the area is composed of coastal forest on sandy soil, with a predominance of herbaceous and shrub vegetation, which are associated with sand dune forests (Figueiredo, 1997; Castro et al., 2012).

Study sites

Observations on anuran vocalisation were made at the following sites:

Site I: A permanent pond (accumulating water the entire year), dimensions 1,195 m x 200 m, to a depth of 2.5 m with a sandy bottom and muddy areas. The vegetation included an abundance of cyperaceous *Kyllinga* sp and *Eleocharis interstincta* at the margins and the pond was set within an arbustive-arboreal vegetation with a predominance of Anacardiaceae and Malpighiaceae. This was the only water body with fish - *Cichla ocellaris* and *Hoplias malabaricus*.

Site II: An ephemeral pond (accumulating water for a maximum of three months yearly), dimensions 10 m x 6 m to a depth of 0.5 m. It had muddy and sandy portions at the margins, was 100 m from site I and was surrounded with the same vegetation as site I.

Site III: A semi-permanent pond (accumulating water for more than three months but less than a year), dimensions 500 m x 20 m to a depth of 1.5 m. It was located between sand dunes in the forest interior, 20 m from site I. There was a predominance of *Eleocharis interstincta* both within the pond and on its margins.

Site IV: A shaded forested area, without water accumulation, with sandy soil and accumulated leaf litter. The vegetation was dominated by *Anacardium occidentale*, *Byrsonima crassifolia*, *Chrysobalanus icaco*, and *Ipomoea asarifolia*.

Methodology

Data were collected monthly from April 2005 to May 2006 using a complete species inventory methodology (sensu Rocha et al., 2004). Observations were made between 17:00 h and 23:00 h for four days/month in the wet season and one day/month in the dry season, giving a total of 26 days of observation and 156 man-hours of effort.

Each site was monitored every hour from 17:00 h and 23:00 h, and for each species observed, we recorded the microhabitat used, calling site, and the vocalisation period. Specimens of the plants associated with the anuran calling sites were collected and deposited in the Herbário Prisco Bezerra at the Federal University of Ceará, Brazil.

Voucher specimens of the anurans were collected, euthanised with Tiopental anaesthetic, fixed with 10 % formalin and preserved in 70 % alcohol. The specimens were deposited in three Brazilian collections (for details see Appendix 1 in the Supplementary Material). For the species taxonomy we followed Frost (2023).

Mean monthly data on temperature, humidity and rainfall were obtained from the Fundação Cearense de Meteorologia (FUNCEME) station located in the municipality of São Gonçalo do Amarante, about 30 km from the study area.

RESULTS

Composition and calling site

We recorded a total of 20 anuran species, distributed in four families: Leptodactylidae (10 spp), Hylidae (7 spp), Bufonidae (2 sp) and Microhylidae (1 sp) (Table 1).

The ephemeral and semi-permanent ponds had higher and similar diversity of calling species than the permanent pond and the forested area (Table 2). Some species had characteristic calling sites. For example, *Leptodactylus pustulatus* was only found vocalising from within the water bodies where it was well camouflaged among the debris and dead vegetation of *Eleocharis* sp. *Scinax fuscomarginatus* was found calling at 40–60 cm above the water's surface and *Dendropsophus minusculus* at 10–30 cm above the water's surface.

Leptodactylus troglodytes and *L. mystaceus* were occasionally observed calling from the swampy water body margins but most of the time they were calling in the leaf litter of the forest, in site IV, usually hidden under roots, dead trunks or in small holes. *Boana raniceps* and *Scinax x-signatus* called while partially submerged in the water within the ponds as well as from arbustive-arboreal vegetation away from the water. *Physalaemus albifrons*, *P. cuvieri*, *Leptodactylus macrosternum* and *Pleurodema diplolister* vocalised only from the water's surface, usually hidden among the aquatic vegetation. *Elachistocleis* cf. *piauiensis* was found calling in a vertical position leaning against the aquatic vegetation, partially submersed in the water. *Rhinella granulosa* was only found foraging in the site IV, we did not record calling and/or reproductive activity for the species in the area.

Table 1. Anurans species recorded at different sites at ESEC Pecém, Ceará, Brazil and those vocalising at the various study sites, from April 2005 to May of 2006. All species have been classified as of Least Concern (IUCN, 2022).

Family	Species	Site I	Site II	Site III	Site IV
Bufonidae	*Rhinella granulosa* (Spix, 1824)				X
	Rhinella diptycha (Cope, 1862)	X	X		
Hylidae	*Dendropsophus minusculus* (Rivero, 1971)	X	X	X	
	Dendropsophus soaresi (Caramaschi & Jim, 1983)		X	X	
	Boana raniceps (Cope, 1862)	X	X	X	
	Scinax fuscomarginatus (Lutz, 1925)	X	X	X	
	Scinax nebulosus (Spix, 1824)		X		
	Scinax x-signatus (Spix, 1824)	X	X	X	
	Pithecopus gonzagai Andrade, Haga, Ferreira, Recco-Pimentel, Toledo & Bruschi, 2020			X	X
Leptodactylidae	*Leptodactylus fuscus* (Schneider, 1799)		X		
	Leptodactylus vastus A. Lutz, 1930		X	X	
	Leptodactylus mystaceus (Spix, 1824)				X
	Leptodactylus macrosternum Miranda-Ribeiro, 1926				X
	Leptodactylus pustulatus (Peters, 1870)		X	X	X
	Leptodactylus troglodytes Lutz, 1926	X			X
	Physalaemus albifrons (Spix, 1824)		X	X	X
	Physalaemus cuvieri Fitzinger, 1826		X	X	
	Pseudopaludicola mystacalis (Cope, 1887)	X	X	X	X
	Pleurodema diplolister (Peters, 1870)		X	X	
Microhylidae	*Elachistocleis* cf. *piauiensis* Caramaschi & Jim, 1983	X	X	X	X
	Total number of species vocalising	**8**	**15**	**13**	**9**

Calling season

At the beginning of the rainy season, January and February, the first species to start calling were *Rhinella diptycha*, *Leptodactylus fuscus*, *L. troglodytes*, *Dendropsophus minusculus* and *Pseudopaludicola mystacalis*. Two months

Table 2. Reproductive seasonality based on male anuran vocalisation at ESEC Pecém, Ceará, Brazil, from April 2005 to May 2006

SPECIES	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Rhinella diptycha										■	■			
Dendropsophus minusculus	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Dendropsophus soaresi		■											■	
Boana raniceps	■	■	■	■									■	■
Scinax fuscomarginatus	■	■	■										■	■
Scinax nebulosus		■	■											
Scinax x-signatus		■	■									■	■	■
Pithecopus gonzagai	■	■												■
Leptodactylus fuscus	■									■	■	■	■	
Leptodactylus vastus												■	■	
Leptodactylus mystaceus	■	■										■	■	
Leptodactylus macrosternum													■	
Leptodactylus pustulatus		■	■	■	■	■	■						■	■
Leptodactylus troglodytes	■	■								■	■	■	■	■
Physalaemus albifrons		■	■									■	■	
Physalaemus cuvieri	■	■	■									■	■	■
Pseudopaludicola mystacalis	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Pleurodema diplolister		■										■	■	■
Elachistocleis cf. *piauiensis*		■	■									■	■	■
TOTAL	9	14	10	4	3	3	3	2	2	5	5	11	16	11

later, after the intensity of rainfall had increased, we observed a greater number of calling species in the area with the arrival of the *Physalaemus* spp and most of the hylids (Table 2).

Most of the species began to call at dusk, around 17:30 h, with increasing calling activity at the beginning of the night, most intensively from 19:00 to 21:00 h. The only species observed calling during the day time was *Pseudopaludicola mystacalis*, which continued calling into the night.

Most of the species showed an explosive or intermediate breeding behaviour, concentrated over a few weeks or months only during the rainy season (Table 2). Only *D. minusculus*, *P. mystacalis* and *L. pustulatus* were observed calling in the dry season. *Dendropsophus minusculus* and *P. mystacalis* called all year long while *L. pustulatus* vocalised for six continuous months from May to October (Table 2).

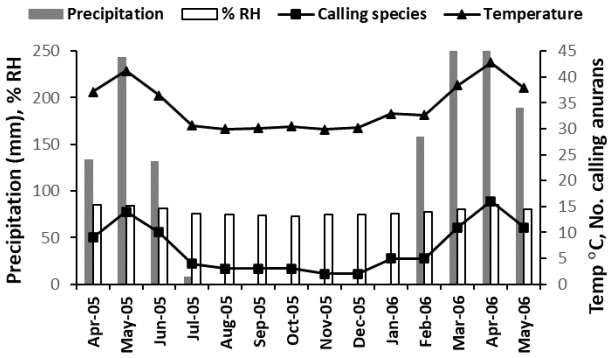

Figure 1. Number of anuran species calling plotted against the prevailing climatic conditions - total monthly rainfall (mm), % relative humidity and mean monthly temperature at ESEC Pecém, Ceará, Brazil, from April 2005 to May 2006. Environmental data from FUNCEME (2006)

DISCUSSION

The anuran community we have described comprised 20 species that are typical of the open environments of the Caatinga and Cerrado domains (Valdujo et al., 2012) and could also have included a further three species *Proceratophrys cristiceps*, *Adenomera hylaedactyla* and *Dermatonotus muelleri* that are known to occur at the Ecological Station of Pecém. The community is similar to that of São Gonçalo do Amarante, another coastal area in Ceará State closely located to our study area, where 23 species were recorded (Borges-Leite et al., 2014). The more southerly coastal areas include species associated with Atlantic forest, which as a result have greater anuran diversity (Araújo et al., 2020; Oliveira et al., 2020). Most of the species observed in the Ecological Station of Pecém anuran community use temporary ponds for reproduction and these species are explosive breeders (sensu Wells, 1977). To exploit temporary ponds they are rapid colonisers and have fast growth rates (Wilbur & Collins, 1973; Wilbur, 1997). In temporary ponds the availability of suspended nutrients for tadpoles, such as phytoplankton, is greater than in older or permanent ponds, which can influence the suitability of ponds for reproduction (Wilbur, 1995). Furthermore, the presence of carnivorous fish in the permanent pond may be a deterrent (Heyer et al., 1975; Azevedo-Ramos & Magnusson, 1999).

A high overlap in the spatial distribution of calling sites was verified for most of the species, including congeners such as *Physalaemus albifrons* with *P. cuvieri*, and *Leptodactylus mystaceus* with *L. troglodytes*. This has been reported previously for other leptodactylid species (e.g. Pombal Jr, 1997; Rossa-Feres & Jim, 2001), mostly because of the exclusive use of the horizontal substrates of soil or water, instead of vertical substrates as used by the hylids (e.g. Cardoso et al., 1989; Bertoluci & Rodrigues, 2002; Protázio et al., 2015).

Most species showed either explosive or intermediate reproductive patterns, vocalising only during the humid and rainy period of the year, typical of the seasonal tropics (Duellman & Trueb, 1986). Only three species

vocalised during both the hotter and drier period of the year; these species show prolonged or continuous patterns of reproduction: *Dendropsophus minusculus* and *Pseudopaludicola mystacalis* vocalised throughout the year, while *Leptodactylus pustulatus* vocalised for six consecutive months in 2005, three of them during the dry season. Haddad & Cardoso (1987) found continuous reproduction through the year for *Pseudopaludicola mystacalis*. However, it should be noted that vocalisation can also play different social roles, not related to reproduction (Toledo et al., 2015).

At the beginning of the rainy season there is an increase in the rate of precipitation which is associated with decreasing air temperature and increasing relative humidity (Fig. 1). In anuran communities with greater seasonal climatic changes, as in the Caatinga, Chaco and Cerrado habitats, weather is strongly correlated with the calling activity and breeding period (Prado & Pombal Jr, 2005; Kopp & Eterovick, 2006).

A strong temporal overlap was observed in the reproductive period among the species, which suggests that reproduction at different times of the year may not represent an important mechanism of reproductive isolation or habitat partitioning between species of this community. The same pattern was also observed for other anuran communities in open area domains, such as Cerrado and Caatinga (e.g. Arzabe, 1999; Toledo et al., 2003; Prado & Pombal Jr, 2005; Cascon & Langguth, 2016).

Our study contributes to the understanding of the diversity and natural history of anurans on the coast of Ceará state. Even though all of the amphibian species recorded at this site are classified as of least concern (IUCN, 2022), the negative impacts of deforestation, forest fires and discarded waste inside this conservation unit present a significant conservation threat.

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