Papéis Avulsos de Zoologia

Museu de Zoologia da Universidade de São Paulo

Volume 57(34):445-449, 2017 **www.mz.usp.br/publicacoes** **ISSN impresso: 0031-1049**
www.revistas.usp.br/paz **ISSN *on-line:* 1807-0205**

Frog assemblage associated with bromeliads in a sandy coastal plain in the state of Espírito Santo, southeastern Brazil

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ABSTRACT

*Amphibians may use bromeliads for reproduction (*i.e., *bromeligenous species) or only for refuge and foraging (*i.e., *bromelicolous species). The partition of bromeliad resources is essential to maintain the coexistence of the associated assemblages. We sampled 913 bromeliads in a sandy coastal plain (*i.e., *restinga habitat) in southeastern Brazil and found 234 frogs belonging to seven species. One of the frog species was bromeligenous and the other six were facultative bromelicolous. The bromeliads of the genus* Aechmea *were the most frequently used by frogs. The low degree of frog occupancy of bromeliads (26%) suggests habitat segregation. Our study highlights the importance of maintenance of bromeliad species for conservation of the associated frog assemblages.*

Key-Words: Anura; Atlantic forest; Bromelicolous; Bromeligenous; Restinga.

INTRODUCTION

Anurans occupy many types of habitats generally related to their reproductive mode (Haddad *et al.,* 2013). Some frog species occupy bromeliads due to these plants' capacity to accumulate rainwater between their leaves, becoming an important microhabitat for shelter, foraging and reproduction (Peixoto, 1995).

The Brazilian Atlantic Forest harbors more than 100 frog species that use bromeliads, which represents about 18% of the regional frog richness (Haddad *et al.,* 2013). The degree of association between frogs and bromeliads range from obligate users (*i.e.,* bromeligenous), which depend on these plants for breeding purposes, to facultative users (*i.e.,* bromelicolous) that use bromeliads only as refuges and for foraging

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http://dx.doi.org/10.11606/0031-1049.2017.57.34

purposes (Peixoto, 1995; Haddad *et al.,* 2013; Pertel *et al.,* 2010). Because bromelicolous species breed at ponds and rivers and use bromeliads as secondary microhabitat, they may use more species of bromeliads.

Many frog species in sandy coastal plains (*i.e.,* restinga habitat) use bromeliads (Rocha *et al.,* 2008; Schineider & Teixeira, 2001; Ferreira *et al.,* 2012; Mageski *et al.,* 2016). This association is important because of the harsh environmental conditions in restingas, such as low free water availability (because sandy soils increase water percolation), high temperature, high solar exposition and salinity (da-Silva, 1998; Scarano *et al.,* 2001; Pereira *et al.,* 2004). Sandy coastal plains are under severe anthropic threats such as pollution, sand extraction, increase of tourism and bromeliad collection (Brown & McLachlan, 2002; Mageski *et al.,* 2016). Thus, understanding the bromeliad frog assemblages and the associated bromeliads is a key priority for the maintenance of the species and their ecological function in sandy coastal plains.

In this work, we aimed to assess the composition and diversity of a frog assemblage that uses bromeliads in a sandy coastal plain in state of Espírito Santo, southeastern Brazil. We also present data about bromeliad species that each frog used and discuss conservation implications for the sandy coastal plains. Although our study was conducted in a sandy coastal plain, the results may have implications for other restingas in the Atlantic Forest domain.

MATERIAL AND METHODS

The fieldwork was carried out during five days per month from January to April 2013 in the sandy coastal plain (hereafter restinga) of Parque Estadual

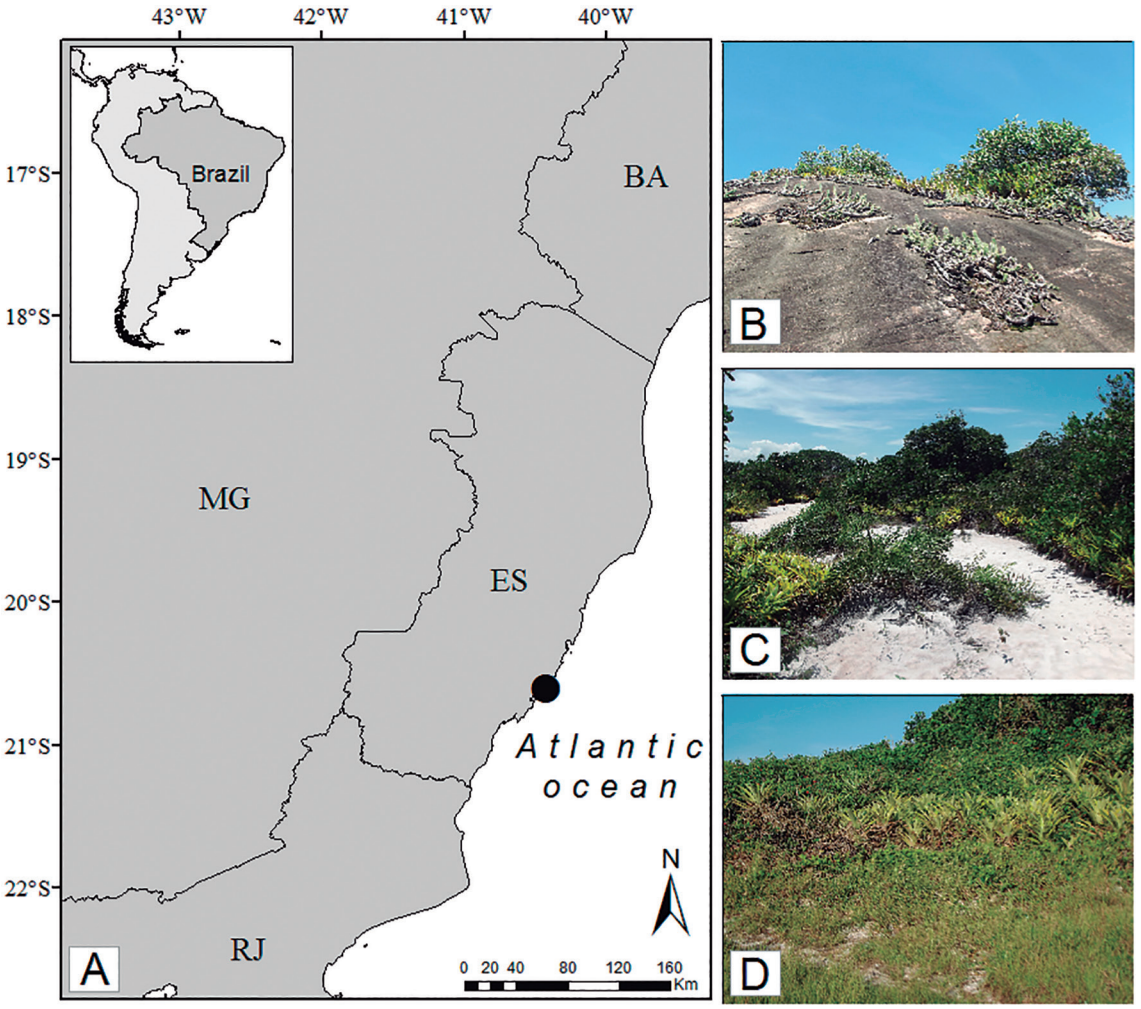

FIGURE 1: Location of Parque Estadual Paulo César Vinha (black dot) in the state of Espírito Santo, southeastern Brazil **(A)** and sampled sites: rocky outcrop **(B)**, open shrub vegetation **(C)**, both in the mainland, and open herbaceous vegetation in coastal island **(D)**. States are Bahia (BA), Espírito Santo (ES), Minas Gerais (MG) and Rio de Janeiro (RJ).

TABLE 1: Abundance of bromeliad frogs in restinga habitat of Parque Estadual Paulo César Vinha, southeastern Brazil. Information about size (snout vent length, cm) of the frogs were based on Haddad *et al.* (2013). Bromeliad use classification: F = facultative (Bromelicolous) and O = obligate (Bromeligenous). Bromeliad species, Ab = *Aechmea blanchetiana,* An = *Aechmea nudicaulis,* Qq = *Quesnelia quesneliana,* and Vn = *Vriesea neoglutinosa.* Population trend according to IUCN (2016): D = decreasing and S = Stable. * recorded by other studies.

Species	Size	Use	Ab	An	Qq	Vn	Pop
Bufonidae							
Rhinella crucifer (Wied-Neuwied, 1821)	8.2-10.1	F	—	1	—	—	D
Hylidae							
Aparasphenodon brunoi (Miranda-Ribeiro, 1920)	7.5-8	F	5	9	—	—	D
Boana semilineata (Spix, 1824)	5-5.6	F	—	1	—	—	S
Dendropsophus decipiens (Lutz, 1925)	1.4-1.9	F	2	4	—	—	S
Ololygon argyreornata (Miranda-Ribeiro, 1926)	1.9-2.1	F	3	—	—	—	S
Phyllodytes luteolus (Wied-Neuwied, 1824)	2.4-2.5	O	101	25	2	50	D
Scinax alter (Lutz, 1973)	2.7-2.8	F	10	7	1	13	S
Total of frogs per bromeliad (H')			121 (0.63)	47 (0.64)	3 (0)	63 (0)	

Paulo César Vinha (hereafter PEPCV, 20°36'16.391"S and 40°25'32.934"W, Fig. 1A) in Guarapari municipality, state of Espírito Santo, southeastern Brazil. The study site comprises about 1,500 ha of native restinga with rocky outcrop (Fig. 1B) and open shrub vegetation (Fig. 1C) on the mainland and open herbaceous vegetation in coastal islands (Fig. 1D). There are abundant ground bromeliads and temporary and permanent ponds. We sampled in all three vegetation types (Fig. 1B, 1C and 1D) for frogs during four hours at night (18-22 h) with a sampling method in which four researchers walked in a straight line parallel to each other searching bromeliads randomly along the trail. We identified all frog species in the field and followed Haddad *et al.* (2013) for classification into either bromeligenous or bromelicolous guilds (Table 1). We compared the proportions of occupied and unoccupied bromeliads to test if each bromeliad species are occupied in proportion to their local abundance, using chi-square exact test (χ^2) in software R 3.3.0 (R Development Core Team, 2016). We calculated diversity of frogs based on richness and abundance in the study area and in each bromeliad species by Shannon-Wiener index (H') in software Past 2.17 (Hammer *et al.,* 2001). All frogs were released in the bromeliads where they were found after collection of data.

RESULTS

We sampled 913 bromeliads of four species and found 234 frogs of seven species (Table 1), most of which were members of the family Hylidae. Only one frog species (*Phyllodytes luteolus*) was bromeligenous and the other six were bromelicolous (Haddad *et al.,* 2013). Three frog species have decreasing population trends according to IUCN (2016). The diversity of bromeliad frogs of the entire study area was H' = 0.84. Of the 913 sampled bromeliads (354 *A. blanchetiana,* 489 *A. nudicaulis,* 5 *Q. quesneliana,* and 65 *V. neoglutinosa*), 234 (26%) were occupied by frogs (121 *A. blanchetiana,* 47 *A. nudicaulis,* 3 *Q. quesneliana,* and 63 *V. neoglutinosa*). *Aechmea blanchetiana* was the most frequently occupied bromeliad, followed by *Vriesea neoglutinosa* (Table 1). However, *A. nudicaulis* harbored the highest diversity of frog species (H' = 0.64). The proportion of occupied and unoccupied bromeliads species were different ($\chi^2 = 255.83$, $p < 0.01$).

DISCUSSION

Our results highlight the importance of the PEPCV for conservation of bromeliad frogs. The frog richness that we found (seven) was higher than those recorded in other sandy coastal plains of Espírito Santo state. For example, six species were found by Schineider & Teixeira (2001) and six species were found by Ferreira & Mendes (2010). In addition, we recorded more species than other similar environments in the state of Espírito Santo. For example, Pertel *et al.* (2010) recorded three species, Mageski *et al.* (2014) and Pertel *et al.* (2006) five species, and Pertel *et al.* (2007) and Teixeira & Rödder (2007) six species.

Apparently, the degree of bromeliad occupancy was low in our study site. Furthermore, occupancy was not proportional to the abundance of each bromeliad species. This result may be a consequence of bromeliad selection by the frogs. In the same study site, *Phyllodytes luteolus* selected small plants with more leaves (Mageski *et al.,* 2016). In addition, another study have showed that the structure of the plants

influences bromeliad selection by *Ololygon argyreornata* (Pederassi *et al.,* 2012). The structure of bromeliads are related to the capability to accumulate rainwater (Pontes *et al.,* 2013). In this way, the bromeliads of the genus *Aechmea* seem to be the most important plants for the local frog assemblage. *Aechmea blanchetiana* has more leaves and harbored a higher abundance of frogs whereas *Aechmea nudicaulis* has a deep and wide central tank and harbored a higher diversity of bromeliad frogs (Cogliatti-Carvalho *et al.,* 2010).

This study shows the conservation importance of bromeliads for the maintenance of frog assemblages in sandy coastal plains. These frogs are greatly affected by the dramatic reduction of the sandy coastal plain habitats that can result in the destruction of the bromeliads and in the consequent local extinction of many associated species. In addition, bromeliad collecting may transport frogs to other environments in which they can become invasive species (Salles & Silva-Soares, 2010). We recommend further studies to address information about population viability over time that improves our knowledge on the ecology of these bromeliad-associated frogs and their conservation in sandy coastal plains.

RESUMO

*Os anfíbios podem utilizar as bromélias para reprodução (*i.e., *espécies bromelígenas) ou apenas para refúgio e forrageamento (*i.e., *espécies bromelícolas). A partição dos recursos de bromélias é essencial para manter a coexistência da assembleia associada. Amostramos 913 bromélias em uma planície costeira arenosa (*i.e., *restinga) no sudeste do Brasil e encontramos 234 anfíbios pertencentes a sete espécies. Uma espécie de anfíbio é bromelígena e as outras seis espécies são bromelícolas. As bromélias do gênero* Aechmea *foram as mais frequentemente utilizadas pelos anfíbios. A baixa taxa de ocupação de bromélias (26%) sugere segregação de habitats. Nosso estudo destaca a importância da manutenção de espécies de bromélias para a conservação das assembleias de anfíbios associadas.*

Palavras-Chave: Anura; floresta Atlântica; Bromelícolas; Bromelígenas; Restinga.

ACKNOWLEDGMENTS

This work is part of the Bromeligenous Project. We thank A. Silva, W. Krohling and two anonymous reviewers for their comments on previous versions of the manuscript, and Cinthia Casotti and Namany Lourpen for fieldwork assistance. We also thank the Instituto Estadual de Meio Ambiente e Recursos Hídricos (IEMA) and the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio,SISBIO) for providing sampling permits (Proc. No. 59666501/2013 and No. 37762-2/2013, respectively). MMM received scholarships from Fundação de Amparo à Pesquisa e Inovação do Espírito Santo (FAPES) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES). RBF received scholarships from the Ecology Center at Utah State University and CAPES.

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Aceito em: 14/09/2017
Publicado em: 20/12/2017
Editor Responsável: Marcelo Duarte