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POTENTIAL SPOTS OF OCCURRENCE OF MICROENDEMIC AMPHIBIAN SPECIES FROM ATLANTIC FOREST: THE CASE OF THE GENUS *EUPARKERELLA* GRIFFITHS, 1959

Andressa M. Bezerra[1*]; Mariana de-Carvalho[2]; Nathalie Q. K. Citeli[3]; Sergio P. Carvalho-e-Silva[1]; Fábio Hepp[1]

ABSTRACT – Forecasts indicate an increase in the number of endangered species and a high risk of extinction for the near future, mainly for endemic species on impacted regions, as the amphibians of the genus *Euparkerella*. Recently, populations of *Euparkerella* found in poorly sampled forest fragments have been presenting evidence that they might represent new species. In this scenario, the goal of this study was to identify forest remnants climatically appropriate to the occurrence of the group through models of potential distribution, pointing out unexplored regions to search for populations that might represent unknown species. The models were generated with the Maxent algorithm, and pointed out the south, center and north region of Rio de Janeiro state, and center and south of Espírito Santo state, regions that are affected by anthropogenic actions. The results indicate that the genus *Euparkerella* has its real distribution underestimated, and undescribed species might be already under threat.

Keywords: Anura, Endemic Amphibians, Potential Distribution Model, Rain Forest.

RESUMO (Localidades de ocorrência potencial de espécies de anfíbios microendêmicos da Mata Atlântica: o caso do gênero *Euparkerella* Griffiths, 1959) – Previsões para um futuro próximo indicam aumento no número de espécies ameaçadas e alto risco de extinção, principalmente para espécies endêmicas de regiões impactadas, como os anfíbios do gênero *Euparkerella*. Recentemente, populações de *Euparkerella* encontradas em fragmentos florestais pouco amostrados têm apresentado evidências de que podem representar novas espécies. Nesse cenário, o objetivo desse estudo foi identificar remanescentes florestais climaticamente apropriados para a ocorrência do grupo através de modelos de distribuição potencial, apontando regiões não exploradas visando localizar populações que podem representar espécies desconhecidas. Os modelos foram gerados com o algoritmo Maxent e apontaram adequabilidade para a região sul, centro e norte do estado Rio de Janeiro, e centro e sul do estado do Espírito Santo, regiões amplamente atingidas por ações antrópicas. Os resultados indicam que o gênero *Euparkerella* tem sua distribuição real subestimada, e que espécies ainda não descritas podem já estar sob ameaça.

Palavras-chave: Anfíbios endêmicos, Anura, Floresta ombrófila, Modelo de distribuição potencial.

[1] Laboratório de Anfíbios e Répteis, Departamento de Zoologia, Universidade Federal do Rio de Janeiro, RJ 21944-902, Brazil.

[2] Laboratório de Comportamento Animal, Departamento de Zoologia, Universidade de Brasília, DF 70910900, Brazil.

[3] Laboratório de Fauna e Unidades de Conservação, Departamento de Engenharia Florestal, Universidade de Brasília, DF 70910900, Brazil.

[*] Corresponding author: andressademellobezerra@gmail.com

INTRODUCTION

The Brazilian Atlantic Forest is considered one of the 34 biodiversity hotspots in the world (Mittermeier *et al.*, 2011), harboring about 430 anuran species, which 80% are endemic to that biome (Cruz & Feio, 2007; Frost, 2019). Despite its great biodiversity, the vegetation of the Atlantic Forest is currently composed of only 12% of its original area (Ribeiro *et al.*, 2009; SOS Mata Atlântica, 2016).

The numbers of threatened species and the severity of extinction risk will increase in a near future (Collins & Storfer, 2003; Tilman *et al.*, 2017). Species with the distribution restricted to highly impacted regions are even more susceptible (*e.g.*, Rocha *et al.*, 2005), such as the small amphibians of the genus *Euparkerella* Griffiths, 1959 (Fusinatto *et al.*, 2013; Hepp *et al.*, 2015; Figure 1), which measure approximately 15 mm, and inhabit the humid layer of leaf litter in the ground of forests along the Atlantic Forest in states of Rio de Janeiro and Espírito Santo (Frost, 2019; Izecksohn, 1988).

Figure 1. Individual of *Euparkerella brasiliensis* (Parker, 1926) from Cachoeira de Macacu (*ca.* 15 mm), Rio de Janeiro. Photo: Bezerra, A.M.

Currently, *Euparkerella* Griffiths, 1959 has five recognized species (Frost, 2019), one considered Least Concern with decreasing population [*E. brasiliensis* (Parker, 1926)]; two considered Vulnerable (*E. tridactyla* Izecksohn, 1988 - stable population; *E. robusta* Izecksohn, 1988 - decreasing population); and two with unknown status according to the International Union for Conservation of Nature (*E. cochranae* Izecksohn, 1988 and *E. cryptica* Hepp, Carvalho-e-Silva, Carvalho-e-Silva, and Folly, 2015; IUCN, 2018).

Populations of the genus have been found in poorly sampled forest fragments (*e.g.*, Hepp *et al.*, 2015). Some of these populations have been recognized as belonging to new species based on integrative studies that included morphological, molecular, and acoustic evidences (*e.g.*, Hepp *et al.*, 2015). These recent discoveries suggest that other unknown populations might also belong to undescribed species (Fusinatto *et al.*, 2013).

Considering the deforestation rates in the Atlantic Forest in the last decades, many fragments might be completely vanished before their fauna being surveyed and studied (Carnaval *et al.*, 2009; Rocha *et al.*, 2007). Tools that identify which of the remaining areas are climatic adequate to the occurrence of taxa, are essential to conservation plans (Marco Júnior & Siqueira, 2009). In this scenario, geographic distribution models have been used to predict potential distribution of poorly studied taxa, guide field researches, and consequently find new populations, accelerating the discovery of unknown species (*e.g.*, Bourg *et al.*, 2005; Guisan *et al.*, 2006; Raxworthy *et al.*, 2003).

The main goal of the present study was to identify forest remnants climatically appropriate to the occurrence of the group through the modeling of *Euparkerella* potential distribution, pointing out unexplored regions suitable for species occurrence aiming to find new populations that can represent unknown species, some of which might be already facing the risk of extinction.

MATERIAL AND METHODS

The cohesion of the genus, the resemblance of ecological habits of all *Euparkerella* species, their conservative morphology, and the few known locations of occurrence of the species (Fusinatto *et al*., 2013; Hepp *et al*., 2015; Izecksohn, 1988) lead us to choose modeling for the entire genus rather than for each species. The inventory of the geographic locations was done through the access of the Amphibian Collection of the Instituto de Biologia, Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, Brazil (ZUFRJ); the Eugenio Izecksohn Collection at the Universidade Federal Rural do Rio de Janeiro, Seropédica, RJ, Brazil (EI); the Amphibian Collection of the Museu Nacional, Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, Brazil (MNRJ); and the Amphibian Collection of the Museu de Biologia Professor Mello Leitão, Instituto Nacional da Mata Atlântica, Santa Teresa, ES, Brazil (MBML). The climate variables were extracted from the platform WordClim v. 2.0, restricted to the period from 1970 to 2000 (Fick & Hijimans, 2017), with the resolution of 30 *arc sec* (*ca*. 1 km^2). We considered the biological requirements of the genus (following the climates features related to periods with higher numbers of collected specimens and also the knowledge of specialists on the genus), and then selected the variables less correlated ($R< 0.7$) through a Principal Component Analysis (PCA). This analysis was performed in R environment using the package *Vegan* (Oksanen *et al*., 2018), *Dismo* (Hijmans *et al*., 2017) and *Rgdal* (Bivand *et al*., 2018). Four variables were selected based on these criteria: (1) maximum temperature of the month; (2) annual temperature variation; (3) precipitation seasonality; (4) precipitation of the warmer quarter. The models were generated using the Maxent algorithm (Phillips *et al*., 2006) and the final maps were made with the software QGIS 2.18.4 (QGIS Development Team, 2016), using the less conservative cut limit. We chose a less conservative threshold to identify more areas of potential occurrence of *Euparkerella* species, and consequently increase the number of remnants to search for those species as suggested by Giannini *et al*. (2012). In order to identify the priority remnants to search, we overlay the last forest cover map available (SOS Mata Atlântica, 2016). We considered only the remnants above 40 ha, which is the size of the smallest remnant with known occurrence of the genus.

RESULTS

We found 31 localities of occurrence for the genus (Table 1).

Table 1. Localities of occurrence of *Euparkerella* spp. populations. ES= Espírito Santo; RJ=Rio de Janeiro. *Asterisks indicate protected areas. Number of specimens examined is in parenthesis in the column “Source”. EI, MBML, MNRJ, and ZUFRJ correspond to the acronyms of the collections in which examined specimens are deposited (see text). The collection number for each specimen can be accessed in Hepp *et al*. (2015).

Source	Locality	Municipality	State
MNRJ (3)	Serra das Torres*	Atílio Vivácqua	ES
MBML (1)	RPPN Oiutrem*	Alfredo Chaves	ES
MBML (3)	Reserva Biológica de Duas Bocas*	Cariacica	ES
MBML (1)	Parque Municipal Goiapaba-Açu*	Fundão	ES
EI (1)	Fazenda Joaquim	Mimoso do Sul	ES
ZUFRJ (6) MNRJ (17)	Margem do Itabapoana	Mimoso do Sul	ES
ZUFRJ (1) MBML (1)	Fazenda Projeto Muriqui	Santa Maria de Jetibá	ES
ZUFRJ (4) EI (6) MBML (1)	Fazenda dos Bozza	Santa Teresa	ES
MNRJ (1)	Boca do Mato	Cachoeira de Macacu	RJ
MNRJ (4)	Fazenda Santa Bárbara*	Cachoeira de Macacu	RJ
MNRJ (4)	Guapiaçu	Cachoeira de Macacu	RJ
ZUFRJ (3) MNRJ (19)	Reserva Ecológica de Guapiaçu*	Cachoeira de Macacu	RJ
MNRJ (1)	Morro de São João*	Casimiro de Abreu	RJ
MNRJ (10)	Reserva Biológica União*	Casimiro de Abreu	RJ
MNRJ (1)	Cachoeira das Dores	Duque de Caxias	RJ
MNRJ (1)	Parque Nacional Municipal da Taquara*	Duque de Caxias	RJ
MNRJ (2)	Barreiras*	Guapimirim	RJ
MNRJ (7)	Centro de Primatologia*	Guapimirim	RJ
MNRJ (1)	Estação Ecológica Estadual Paraíso*	Guapimirim	RJ
MNRJ (3)	Reserva Biológica União*	Macaé	RJ
ZUFRJ (31) MNRJ (1)	Campo de Escoteiro Geraldo Hugo Nunes	Magé	RJ
MNRJ (7)	Reserva Biológica União*	Rio das Ostras	RJ
MNRJ (3)	Grumari*	Rio de Janeiro	RJ
ZUFRJ (10)	Pedra Bonita, São Conrado*	Rio de Janeiro	RJ
ZUFRJ (18)	Parque Nacional da Tijuca*	Rio de Janeiro	RJ
MNRJ (1)	Pedra da Gávea*	Rio de Janeiro	RJ
MNRJ (21)	Serra do Mendanha*	Rio de Janeiro	RJ
EI (3)	Vargem Grande	Rio de Janeiro	RJ
ZUFRJ (1)	Reserva Biológica Poço das Antas*	Silva Jardim	RJ
ZUFRJ (27)	Sítio Igarapê*	Silva Jardim	RJ
MNRJ (11)	Serra dos Gaviões*	Silva Jardim	RJ

We observed that the current known distribution of the genus presents a large gap between the states of Rio de Janeiro and Espírito Santo (Figure 2). In the generated model, we found 2.907 potential remnants distributed in forest fragments of Rio de Janeiro and Espírito Santo states, including in the gap region. Only 22 of these found remnants have record of individuals of the genus. The main regions with adequate climate that presented larger fragments were the south (*e.g.*, municipalities of Angra dos Reis and Paraty), central (*e.g.*, municipalities of Petrópolis and Teresópolis), and north of the state of Rio de Janeiro (*e.g.*, municipality of Santa Maria Madalena); and central and south of state of Espírito Santo (*e.g.*, municipalities of Matilde, Mimoso do Sul, Rio Fundo, São José das Torres, and Vargem Alta; Figure 2). These areas represent potential areas (*i.e.*, they match the climate and ecological requirements, *e.g.*, rain seasonality and maximum temperature of the month) for the occurrence of populations of *Euparkerella*. Most of them are located in regions that are targets of the real estate speculation and agriculture advance (Güneralp & Seto, 2013; Laurance *et al.*, 2014), activities that might be a threat to this unknown populations. In the Espírito Santo state, none of the previous registers of the genus were within Conversation Units (Table 1). Considering it, it is important to highlight the 21 Federal Conservation Units that presented suitability for *Euparkerella* occurrence, seven in Espírito Santo state, and 14 in Rio de Janeiro state (Table 2).

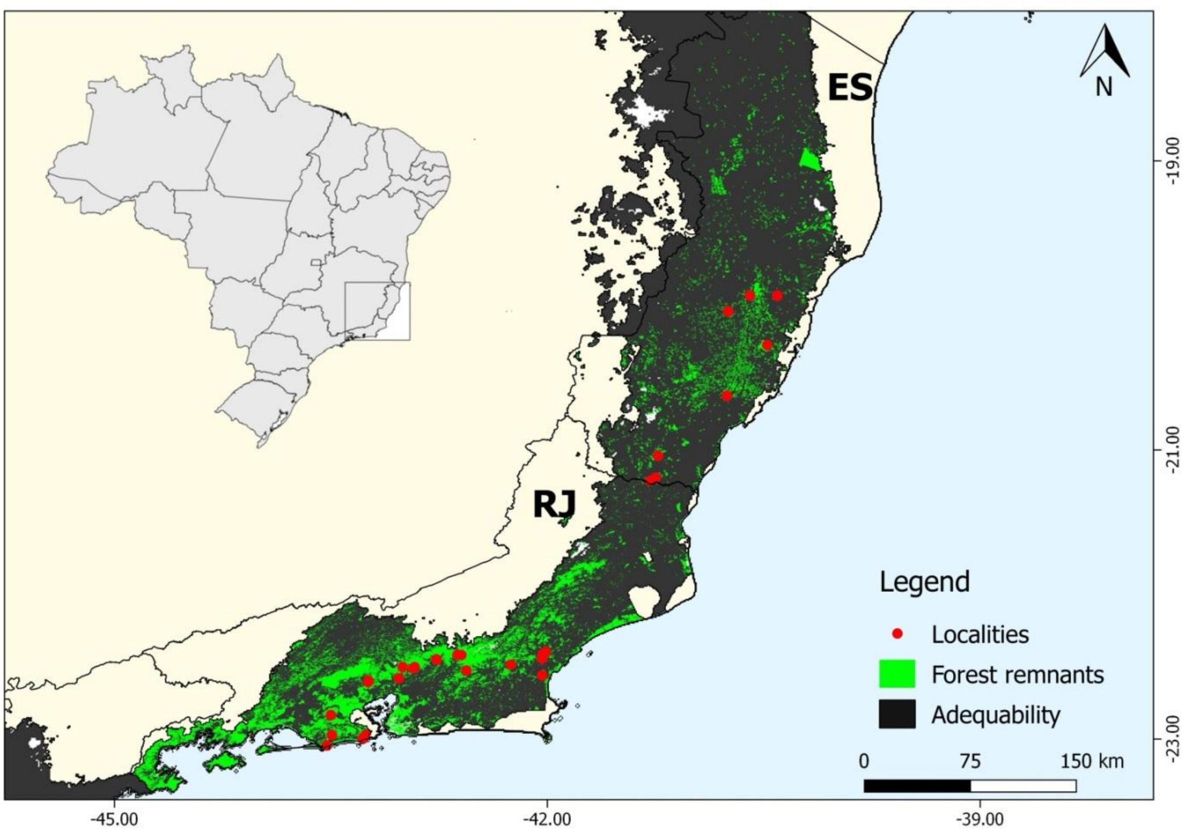

Figure 2. Potential distribution (gray) with the known records of specimens of the genus *Euparkerella* (red spots) and forest remnants (green) in the states of Rio de Janeiro (RJ) and Espírito Santo (ES), southeastern Brazil.

Table 2. Federal Conservation Units that show suitability for *Euparkerella* spp. populations in the states of Espírito Santo and Rio de Janeiro, Brazil. * Single asterisks indicate the units where specimens have already been recorded (see Table 1). ** Specimens have been collected in the sub-sede of Parque Nacional da Serra dos Órgãos, Guapimirim, only.

Federal Conservation Units	State
Floresta Nacional de Goytacazes	ES
Floresta Nacional de Pacotuba	
Monumento Natural dos Pontões Capixabas	
Reserva Biológica Augusto Ruschi	
Reserva Biológica de Sooretama	
Reserva Biológica do Córrego do Veado	
Reserva Biológica Santa Lúcia	
Área de Proteção Ambiental da Bacia do Rio São João/Mico-Leão-Dourado*	RJ
Área de Proteção Ambiental de Cairuçu	
Área de Proteção Ambiental de Guapimirim	
Área de Proteção Ambiental da Região Serrana de Petrópolis*	
Estação Ecológica da Guanabara	
Estação Ecológica de Tamoios	
Parque Nacional da Restinga de Jurubatiba	
Parque Nacional da Serra da Bocaina	
Parque Nacional da Serra dos Órgãos**	
Parque Nacional da Tijuca*	
Reserva Biológica de Poço das Antas*	
Reserva Biológica do Tinguá	
Reserva Biológica União*	

DISCUSSION

Our results may contribute to the discovery of these populations by identifying and pointing out the remaining forest areas with potential occurrence for the genus (*e.g.*, Bourg *et al.*, 2005; de Siqueira *et al.*, 2009; Guisan *et al.*, 2006; Raxworthy *et al.*, 2003). It is necessary to concentrate efforts on those areas through surveys, taxonomic studies, and proposing conservative measures.

Most of the remaining fragments of the Atlantic Forest are small and isolated, surrounded by pasture or plantation matrix (Ribeiro *et al.*, 2009). Potential *Euparkerella* populations might be already under threat due to the low mobility of the individuals and the dependency of forest fragments (see Fusinatto *et al.*, 2013; Hepp *et al.*, 2015; Izecksohn, 1988).

The results found in the present study indicate that the genus *Euparkerella* possibly has its real distribution underestimated, which increases the need of focusing on conservation of microendemic fauna, by primarily preserving forest fragments of the Atlantic Forest of southeastern Brazil, and studying the local fauna before it is gone.

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