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# Distribution pattern of anurans from three mountain complexes in southeastern Brazil and their conservation implications

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**ABSTRACT**

Biogeographic tools support spatial distribution pattern hypotheses and help to determine priority areas for conservation. Our aim was to verify biogeographic patterns for anurans in three mountain complexes in southeastern Brazil, as well as to discuss the status of species conservation recorded and the biogeographical units evaluated. We selected 16 areas distributed in the Serra da Mantiqueira complex, south of Serra do Espinhaço and Serra da Canastra. We used the occurrence (geographic coordinates) of each species in the localities to determine areas of endemism applying the Endemicity Analysis method. We also tested whether similarity between areas was explained by geographic distance (Multiple Regression on distance Matrices-MRM). The Serra do Itatiaia, Serra da Canastra, Plateau of Poços de Caldas and Serra do Cipó were the areas that presented the highest number of species restricted to them. Through the Endemicity Analysis, we identified four areas of endemism with higher scores. The MRM revealed that the geographic distance explained 41% of species dissimilarity between areas. Most of the endemic species from these areas have inaccurate conservation statuses (data deficient or unevaluated). These results highlight the need for greater research efforts towards understanding species restricted by distribution, as well as the priority in conserving these endemic areas.

**Key words:** endangered species, endemism, highlands, Mantiqueira Complex, Serra da Canastra, Serra do Espinhaço.

## INTRODUCTION

Processes that maintain and produce biological diversity are complex and difficult to measure (Cassemiro and Padial 2008). Currently, the uplift of the Andean mountain chain in the middle Miocene, has been considered the main geologic event structuring the biota in South America (Chaves et al. 2015). Glaciation events and marine transgressions occurred in the upper and middle Miocene, they are also responsible for the exchange of South American fauna (Zanella 2011),

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contributing to the high biological diversity of the continent. This high biodiversity has generated hypothesis about their patterns of establishment, supported by the Pleistocene forest refugia theory (Haffer 1969) and the seasonally dry tropical forest (Prado 2000).

Linking distributional data of species and studying areas of endemism is essential for a better view on the biogeography of a given area (Brown et al. 1996, Goldani and Carvalho 2003, Carstensen et al. 2013). Also, it is possible to see the pattern of similarity of species between biogeographic areas considering different variables, such as, vegetation cover of the region, geographic barriers, and distance between evaluated areas (Serafim et al. 2008, Santos et al. 2009). The use of biogeographic tools also helps with mapping priority areas for conservation (e.g., Goldani and Carvalho 2003). Some informations of the group studied are fundamental as premise for biogeographic studies, such as knowledge about phylogeny and levels of species endemism. As well as previous information of their spatial distributions, and capacity and limits of their dispersion (Goldani and Carvalho 2003).

Although amphibians inhabit several types of environments and are adapted to adverse situations, such as extreme cold or desert climates (Duellman and Trueb 1986), amphibians are vulnerable animals, highlighted as the group that are most affected by climate change and human disturbance (Verdade et al. 2010). Consequently, the group is generally used as an indicator of environmental disturbances (Verdade et al. 2010).

In Southeastern Brazil, the three mountain complexes, the Serra da Mantiqueira, south of Serra do Espinhaço, and Serra da Canastra, present high amphibian diversity (Cruz and Feio 2007, Leite et al. 2008, Barros 2011). Several studies conducted in these regions (e.g., Cruz and Feio 2009, Moura et al. 2012, Pirani et al. 2012, Pimenta et al. 2014a, b, Neves et al. 2017a, b) allowed us to develop database for the present study. These informations also make possible evaluate the historical biogeography of the region and delimit endemism areas in order to implement conservation areas for environmental preservation (Domínguez et al. 2006, Chaves et al. 2015). Through this historical evaluation it is possible to determine patterns of species distribution occurring in these high altitude areas (surrounded by Atlantic Forest and Cerrado, hotspots of biodiversity). In this study, we have three main goals: (1) we aim identify areas of endemism in these three mountainous regions, (2) as well as to test whether anuran species composition is more similar in more proximal areas, and (3) also we sought to provide conservation aspects and distribution patterns of anurans of these three montain complexes.

## METHODS

### STUDY AREA

The region studied is located in the southeast of Brazil, between two global hotspot of biodiversity, the Cerrado and Atlantic Forest (Mittermeier et al. 2004). We analyze studies developed in three complex mountains: Serra da Mantiqueira, Serra do Espinhaço, and Serra da Canastra (Figure 1).

The Serra da Mantiqueira complex extends over the borders between the Brazilian States of Minas Gerais with São Paulo, Rio de Janeiro, and Espírito Santo in Atlantic Forest biome, for the most part. This mountain complex is inaccurately delimited, varying between authors. For this study, we divided the extension into two distinct regions, North Mantiqueira (MN) and South Mantiqueira (MS) (Cruz and Feio 2007) (Figure 1). These regions are divided by a lowland, with some tributaries of the Paraíba do Sul river, such as the Pomba River, Muriaé River, Carangola River and Itabopoana River. The highest altitude areas are located in the Serra do Caparaó (MN) and in the Serra do Itatiaia (MS). The Serra do Espinhaço extends approximately 1000 km along the States

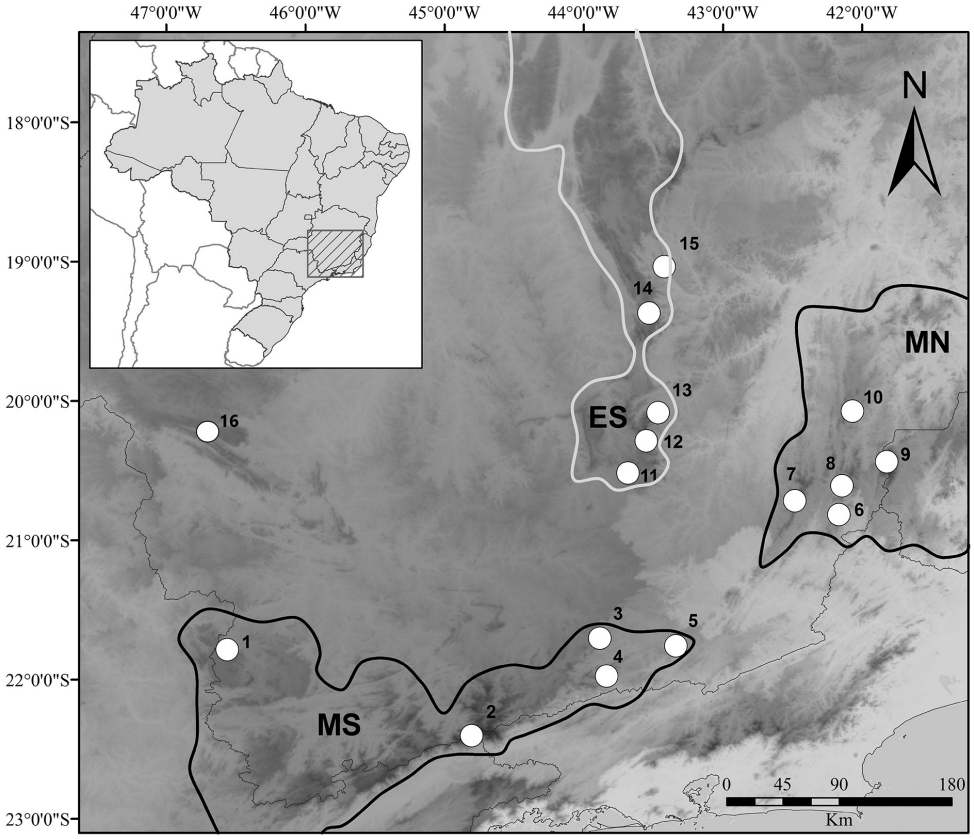


**Figure 1 -** Demarcation adopted for the Serra da Mantiqueira complex and Serra do Espinhaço and the localities used in this study: (**1**) Plateau of Poços de Caldas, (**2**) Serra do Itatiaia, (**3**) PE do Ibitipoca, (**4**) Serra Negra, (**5**) Municipality of Juiz de Fora, (**6**) Pedra Dourada, (**7**) Serra do Brigadeiro, (**8**) Municipality of Divino, (**9**) Serra do Caparaó, (**10**) Municipality of Simonésia, (**11**) Municipality of Ouro Branco, (**12**) Floresta Estadual do Uaimií, Municipality of Ouro Preto, (**13**) Serra do Caraça, (**14**) Serra do Cipó, (**15**) Microregion of Conceição do Mato Dentro and (**16**) Serra da Canastra. MS: South of Serra da Mantiqueira; MN: North of Serra da Mantiqueira; ES: South of Serra do Espinhaço.

of Minas Gerais and Bahia. It is situated between two ecological hotspots, the Cerrado and Atlantic forest, as well as the Caatinga in its northern portion (Leite 2012). Altitudes of this mountain range vary between 800 and 1900 meters, and is characterized by rupestrian fields with predominantly sandstone and quartzite soils (Giulietti and Pirani 1988, Silva et al. 2005). In our analysis, we used information from the South of Espinhaço (ES). The Serra da Canastra is located predominantly in a crystalline plateau isolated from other mountains complexes studied and presents altitudes ranging from 800 to 1496 m (Romero and Martins 2002).

We selected 16 areas of high altitude from this region (Table I). To run the analysis the selected regions had to have a minimum altitude of 650 meters but greater than 1000 meters. We selected 10 localities in the Serra da Mantiqueira complex (MS: Serra Negra, Parque Estadual do Ibitipoca, Municipality of Juiz de Fora, Serra do Itatiaia, and Plateau of Poços de Caldas; and MN: Pedra Dourada, Serra do Brigadeiro, Municipality of Divino, Serra do Caparaó, and Municipality of Simonésia), five localities in the ES (Floresta Estadual do Uaimií, Municipality of Ouro Branco, Serra do Caraça, Serra do Cipó and Microregion

**TABLE I**
**Areas used in the analysis with varying altitudes, Number of species recorded, Corrected number of species used, and their references.**

| Locality | Altitude | Nº species | Nº revised | References |
|---|---|---|---|---|
| Serra Negra | 846 - 1698 m | 48 | 43 | Pinheiro et al. 2016, Neves et al. 2017a |
| Parque Estadual do Ibitipoca | 1050 - 1784 m | 41 | 36 | Cruz et al. 2009 |
| Municipality of Juiz de Fora | 650 - 1000 m | 47 | 40 | Neves et al. 2017b |
| Serra do Itatiaia | 2791 m | 68 | 61 | Werner 1903, Lutz 1926, Cochran 1938, 1948, Lutz and Carvalho 1958, Lutz 1968a, IBDF 1982, Heyer 1983, Izecksohn and Gouvêa 1987, Peixoto 1989, Peixoto and Cruz 1992, Haddad and Pombal Jr 1995, Caramaschi and Cruz 2004, Targino et al. 2009, Pimenta et al. 2014b |
| Pedra Dourada | 1300 m | 39 | 36 | Neves 2014 |
| Serra do Brigadeiro | 1600 m | 59 | 50 | Moura et al. 2012, Guimarães et al. 2017 |
| Municipality of Divino | 700 - 1500 m | 40 | 37 | Hote 2016 |
| Serra do Caparaó | 2892 m | 41 | 32 | IBDF 1981, Heyer 1982 |
| Municipality of Simonésia | 1180 - 1626 | 30 | 23 | Santos 2015 |
| Floresta Estadual do Uaimií | 900 - 1400 m | 37 | 35 | Pirani et al. 2012 |
| Municipality of Ouro Branco | 900 - 1600 m | 47 | 47 | São-Pedro and Feio 2011 |
| Serra da Caraça | 900 - 2000 m | 45 | 40 | Afonso and Eterovick 2007, Canelas and Bertoluci 2007, Baêta and Silva 2009 |
| Serra do Cipó | 1200 m | 43 | 37 | Eterovick and Sazima 2004 |
| Microregian of Conceição do Mato Dentro | 1600 m | 58 | 51 | Pimenta et al. 2014a |
| Plateau of Poços de Caldas | 1500 m | 33 | 32 | Lutz 1966, 1968b, Andrade and Cardoso 1987, Giaretta and Sazima 1993, Caramaschi and Cruz 2004, Monteiro-Leonel 2004, Vasconcelos and Giaretta 2005 |
| Serra da Canastra | 800 - 1496 m | 39 | 35 | Barros 2011, Caramaschi and Napoli 2012, Lourenço et al. 2013, Pimenta et al. 2015 |

of Conceição do Mato Dentro), and the Serra da Canastra (Figure 1).

SPECIES COMPOSITION

We inventoried the anuran community from high altitude areas of the Serra da Mantiqueira Complex, the South of Serra do Espinhaço, and Serra da Canastra using the database of anuran surveys from these regions (Table I). We updated these databases with information from studies about species descriptions, species revisions, and geographic distribution records. Using information from recent articles we corrected or removed questionable species (classified as nomenclature aff., sp., and cf.), except *Proceratophrys* sp. which is in the process of being describe (PS Hote personal communication). We verified conservation status of endemic species from the Serra da Mantiqueira complex, Serra da Canastra and south of Serra do Espinhaço according to the Red list of Internacional Union for Conservation of Natures (IUCN 2016), the list of Brazilian endangered animals of the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio 2014), and the lists from the States of Minas Gerais (Drummond et al. 2008), Rio de Janeiro (Bergallo et al. 2000), São Paulo (Bressan et al. 2009), and Espírito Santo (Passamani and Mendes 2007).

### BIOGEOGRAPHIC ANALYSES

To show biogeographic patterns and areas of endemism of the regions, we first used traditional methods which involve the mapping and superposition of species distributions. We considered an area of endemism when there were at least two species that had restricted distribution, or did not occur in any other area.

To complement the traditional methods we also used the occurrence (geographic coordinates) of each species in this localities to determine areas of endemism applying the Endemicity Analysis method (Szumik et al. 2002, Szumik and Goloboff 2004). This analysis maps the spatial occurrence of each species, calculates an index of endemicity (IE) for each one and selects areas through the overlap of their geographic distribution. The endemicity value of each area selected (score) represents the sum of the IE of all species present. In order to keep only one locality in each area unit (pixel), since they represent mountain peaks isolated by altitudinal differences, we used pixel size of 0.3 X 0.3 degrees. We saved localities sets with more than two endemic species and score (endemicity value) higher than two. We used the NDM/VNDM software version 3.1 for the area selection (Goloboff 2004). We present the endemicity areas selected in maps made with Quantum GIS software version 2.18.4 (Quantum GIS Development Team 2017).

We calculated geographic distance between areas (available coordinates from other studies) using Euclidian distance and species similarity using the Jaccard Index. Afterwards we used a Multiple Regression on Distance Matrices (MRM), proposed by Lichstein (2007), to evaluate how geographic distance explains similarity of species. For data analysis we used R v 3.3.0 (R Core Team 2016) software, with the packages vegan (Oksanen et al. 2016) and ecodist (Goslee and Urban 2007).

## RESULTS

### SPECIES COMPOSITION

We analyzed a total of 635 individuals, a total of 182 anurans species distributed in 14 families: Brachycephalidae (14), Bufonidae (7), Centrolenidae (3), Ceratophrynidae (1), Craugastoridae (3), Cycloramphidae (8), Dendrobatidae (1), Eleutherodactylidae (1), Hemiphractidae (1), Hylidae (81), Hylodidae (17), Leptodactylidae (32), Microhylidae (4), and Odontophrynidae (9). The Serra do Itatiaia was the richest area (61 species), followed by the micro-region of Conceição do Mato Dentro (51 species) and Serra do Brigadeiro (50 species). Sixty-four of the 182 species were restricted to either the Serra da Canastra, the South of Serra do Espinhaço and/or to the Serra da Mantiqueira complex.

The species conservation status, according to the International Union for Nature Conservation (IUCN 2016), had 1.79% presenting some degree of endangerment (i.e., Critically Endangered – CR, Endangered – EM and Vulnerable – VU), 29.31% were data deficient (DD) and 12.57% were not evaluated. When we considered just endemic species of the region (n=64) these values increased to 3.2% for some degree of threat, 51.56% for data deficient and 28.2% were not evaluated (Figure 2).

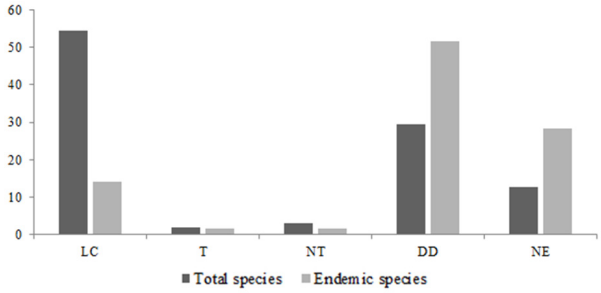


**Figure 2 -** Percentage of species in each conservation status according to the IUCN Red list (2016). Dark gray bars indicate the total species recorded (n=182); Light gray bars indicate endemic species to the Serra da Canastra, South of Espinhaço and the Mantiqueira complex (n=64). LC = Least concern; T = under some degree of threat (Critically Endangered, Endangered, Vulnerable); NT = Near Threatened; DD = Data deficient; and NE = not evaluated.

BIOGEOGRAPHY OF THE REGION

The distribution pattern of amphibians in the Serra da Mantiqueira complex presents species that occur just over their extension (34 endemic species), as well as species that occur only in MS (22 spp.) and MN (seven spp.) portions. On the other hand, the ES presents 23 endemic species. The other species present peculiar distribution patterns, including dispersal between two of the study mountains: the distribution of *Ischnocnema izecksohni* ranges from both portions of the Serra da Mantiqueira complex and the South of Serra do Espinhaço; *Bokermannohyla nanuzae* occurs in the South of Espinhaço and South of Serra da Mantiqueira complex; *I. surda*, *Hylodes babax,* and *Physalaemus maximus* occur in the South of Espinhaço and in the North of the Serra Mantiqueira complex.

Many species registered in this study present large distributions in the study area and most of them (64.8%, n=118) exceed the borders of the study area. Among the species recorded in this study, 11.1% occurred in more than 10 localities, 42.9% were recorded between two to nine localities, and 45% was restricted to one locality.

Among species evaluated with the traditional method, 29 presented distributions restricted to a single mountain unit. Areas with the highest endemism were in the Serra do Itatiaia with nine endemic species (*Ischnocnema concolor*, *I. melanopygia*, *Holoaden bradei*, *Bokermannohyla gouveai*, *Boana latistriata*, *Hylodes glaber*, *H. regius*, *Megaelosia lutzae,* and *Paratelmatobius lutzae*), followed by the Serra da Canastra with five species (*Vitreorana franciscana*, *Bokermannohyla ibitiguara*, *Scinax pombali*, *Crossodactylus franciscanus* and *Odontophrynus monachus*). We also highlighted four species recorded in the Plateau of Poços de Caldas (*Bokermannohyla vulcaniae*, *Scinax caldarum*, *Scinax ranki,* and *Proceratophrys palustris*), three species of the Serra do Cipó (*Scinax pinima*, *Physalaemus deimaticus,* and *Pseudopaludicola mineira*), while two species were recorded for the Serra do Caparaó (*Cycloramphus bandeirensis* and *Hylodes vanzolinii*) and Serra Negra (*Hylodes perere* and *Boana cambui*). Though presenting a single species in each area, the Serra do Brigadeiro (*Brachycephalus darkside*) and, the Municipality of Juiz de Fora (*Adelophryne meridionalis*) harbor

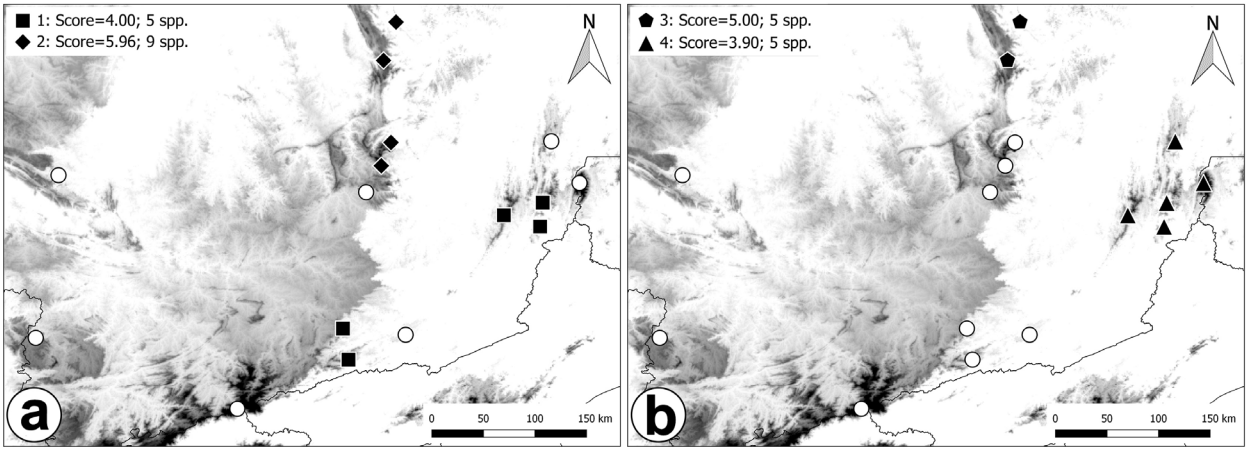


**Figure 3 -** The four areas of endemism generated by EA with their scores and number of species, separated in two maps: (**a**) Area of endemism one with PE do Ibitipoca, Serra Negra, Pedra Dourada, Serra do Brigadeiro and Municipality of Divino, and area of endemism two with Floresta Estadual do Uaimií, Serra do Caraça, Serra do Cipó and Microregion of Conceição do Mato Dentro. (**b**) Area of endemismo three with Serra do Cipó and Microregion of Conceição do Mato Dentro, and area of endemismo four with Pedra Dourada, Serra do Brigadeiro, Municipality of Divino, Serra do Caparaó and Municipality of Simonésia.

species that, until now, were only recorded in these areas (Table SI – Supplementary Material).

Using the Endemicity Analysis we were able to identify four areas of endemism with higher scores (Figure 3): the first area comprises three localities from northern and two from southern Serra da Mantiqueira (Figure 3a); the second comprises most of the points (four of five) located at southern Serra do Espinhaço (Figure 3a); the third comprises two localities from southern Serra do Espinhaço (Figure 3b); the fourth comprises all the points located at northern Serra da Mantiqueira (Figure 3b). The area two has the higher score (5.96), followed by area three (5.00), area one (4.00) and area four (3.90), respectively. Higher number of species contributing to the area's endemicity value was also found at area two (nine species), followed by the other three areas (five species).

The MRM test showed that geographic distance explained 41% of species dissimilarity between evaluated areas ($R^2$=41, p=0.001).

## DISCUSSION

### BIOGEOGRAPHY OF THE REGION

Regions of altitude are areas with high degrees of endemism due to the genetic isolation of the population in different areas, as occurs in every extension of the Serra da Mantiqueira complex (Cruz and Feio 2007) and the Serra do Espinhaço (Leite et al. 2008). In the mountain areas of the southeast of Brazil, the vicariant processes that occurred in the region until the quaternary (Gatto et al. 1983) have nowadays revealed a great number of endemic species in the region, as confirmed for amphibians, and other groups such as birds (Chaves et al. 2015) and plants (Rapini et al. 2008). However, it is expected that this panorama will increase as taxonomic revisions are provided for complexes of cryptic species (e.g., *Rhinella* gr. *crucifer* by Thomé et al. 2010, *Ischnocnema guentheri* by Gehara et al. 2013, *Proceratophrys melanopogon* by Mângia et al. 2014).

The area of endemism two generated by EA comprise the southern Serra do Espinhaço Complex (excepted Ouro Branco) with high score (Score=5.96). For Cerrado anurans and squamates, the region of southern Serra do Espinhaço had also been recovered as an endemism area (Azevedo et al. 2016). When evaluating the pattern of endemicity in bird distribution in the southeast mountains of Brazil, Chaves et al. (2015) revealed geographic barriers to the gene flow, reinforcing the separation of the endemism areas showed by the pattern of amphibian distribution. In the southern Serra do Espinhaço, geographic barriers separate the area three generated by EA (Serra do Cipó and Conceição do Mato Dentro) to the others localities (Chaves et al. 2015). They also found a genetic barrier between the Southern Regions of the Serra da Mantiqueira complex and the region of Poços de Caldas (Chaves et al. 2015).

The Plateau of Poços de Caldas, considered by some authors as part of the Serra da Mantiqueira complex (Valverde 1958, Cruz and Feio 2007), proved to be a unique and separated area of endemism that unites the other locations of the complex of Serra da Mantiqueira. The phytophisionomy factors may explain part of this similarity due to the strong influence of the Cerrado in this location, which is emphasized by species like *Rhinella rubescens*, *Phyllomedusa ayeaye,* and *Odontophrynus cultripes* (Valdujo et al. 2012). Furthermore, the volcanic formation that characterizes the highlands of Poços de Caldas (Schorscher and Shea 1992) also shows a differentiated geology in this region when compared to the rest of the Serra da Mantiqueira complex, making these highlands a unique and representative area of endemism for the anurans of the region.

There are common species found in both Serra do Espinhaço and Serra da Mantiqueira mountain complexes that confirm the relation of proximity

between these two locations. Species that are phylogenetically close with similar habitats in different geographic units suggest biogeographical homologies (Morrone 2001). *Physalaemus deimaticus*, *P. erythrus* and *P. rupestris* are species phylogenetically related (Lourenço et al. 2016), and occur in three different mountains (Baêta and Silva 2009). Due to their habitat and restrict distribution, the mountain complexes where they occur were suggested to have an ancient connection (Cruz and Feio 2007) confirming such biogeographical homologies in the studied area. Besides that, some historical events validate this relationship due to the fact that the Serra do Espinhaço use to be covered by Rainforest until the middle of the Oligocene (Maxson and Heyer 1982), presenting relict species in this domain. Another important factor to be considered is the continuous altimetry of 800 meters that extends from the Serra do Ibitipoca region to the Quadrilátero Ferrífero, connecting the southern portion of the Serra do Espinhaço to the Serra da Mantiqueira complex (Cruz and Feio 2007).

The geographic distance between the sampled areas explained 41% of the dissimilarity; this result indicated by the MRM is expected (Hubbel 2001). This inverse proportion between the geographic distance and the similarity between areas was registered in other works with anurans (Bertoluci et al. 2007, Santos et al. 2009), also associated with mountainous complexes of the Serra do Mar (Giasson 2008) and some other locations in the southern part of the Serra da Mantiqueira complex (Juarez 2011). The geographic distance is just one more variable that influences the pattern of anuran species distribution, which may also be controlled by the vegetation, hydro period, and topography of the analyzed region (Serafim et al. 2008, Santos et al. 2009).

## CONSERVATION OF SPECIES AND ENDEMISM AREAS

The connection of endemism areas is fundamental for those who search for the conservation of biodiversity (Brown et al. 1996, Goldani and Carvalho 2003), because these locations are key for investments in protection and environmental studies. Although slow in comparison to the declining amphibian populations (Verdade et al. 2010), studies have been done in the Serra da Mantiqueira complex and South of Serra do Espinhaço. Cruz and Feio (2007) indicated a total of 63 endemic species in the Serra da Mantiqueira complex, with 36 restricted to only one biogeographic unit. However, due to the taxonomic dynamic, the magnification of species distribution areas, and the description of new species, this number is already outdated. Furthermore, reports of the decrease in local populations were already recorded for *Cycloramphus granulosus* and *Hylodes glaber* in the Serra do Itatiaia (Heyer et al. 1988), mainly due to anthropic actions, such as pollution, introduction of exotic species, deforestation, and consequently habitat fragmentation (Pimenta et al. 2014a).

Species with restricted distribution are of greatest concern and need to be studied, because most have conservation statuses classified as data deficient or unevaluated (Figure 2). These type of studies are necessary to allocate species to their actual conservation categories (Bland et al. 2012). In the last years, few studies have been developed about endangered species or data deficient species, with only 16% of the studies published between 2000 and 2010 targeting these animals (Campos et al. 2014). This lack of information is due to the difficulty to access areas where these species are distributed, as well as to the habits of these species, mostly being nocturnal and/or cryptozoic (Morais et al. 2013).

The Serra do Itatiaia was the area with the highest richness and endemic species, which is

protected to Parque Nacional do Itatiaia (IBDF 1982). Among the species present there, occurs the critically endangered *Holoaden bradei* (IUCN 2016). Besides, most areas of endemism found by the EA are protected, such as the Parque Nacional da Serra da Canastra, Parque Nacional da Serra do Cipó, and Parque Nacional do Caparaó. However, the Plateau of Poços de Caldas has just a small area protected by the Jardim Botânico de Poços de Caldas, which configure this region as an important area that presents critically endangered species, such as *Bokermannohyla vulcaniae* and *Proceratophrys palustris* (ICMBio 2014). However, it is unclear how far the boundaries of these protected areas contain these endemic species and how they are conserved.

Although more surveys efforts are necessary in some areas, such as the area one generated by EA, composed by Serra Negra, Divino and Pedra Dourada, which is not protected, the other areas are protected by the Parque Estadual do Ibitipoca and Parque Estadual da Serra do Brigadeiro, and together configure an area of endemism. The same occurs with areas of endemism four protected by the Parque Nacional do Caparaó and Parque Estadual da Serra do Brigadeiro. Nevertheless, these isolated highland areas have a necessity for conservation actions due to their unique biota.

The largest part of the Serra da Mantiqueira complex is located in Minas Gerais State, where approximately 20% of its vegetal cover remains due to the destruction of large natural areas (Valor Natural 2005). The Ecological Corridor of Mantiqueira, which includes some areas of endemism present in the Southern portion of Serra da Mantiqueira complex (except Plateau of Poços de Caldas and the Municipality of Juiz de Fora), is ideal for connecting fragmented areas, as well as encouraging scientific research and environmental education for the local populations of the municipalites involved (Valor Natural 2005).

Though there are efforts in the conservation of endemic and endangered species of these mountains areas with great biodiversity, it is still not sufficient due the rapid anthropization and consequent loss of habitat. Increasing studies like the present work, with punctual focus on the conservation areas and endangered species, need to be clarified for this knowledge to generate concrete results about the conservation of mountain areas in southeastern Brazil.

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## SUPPLEMENTARY MATERIAL

**TABLE SI -** Endemic species of Serra da Mantiqueira complex and South of Serra do Espinhaço and the status of conservation according to the International Union for Nature Conservation (IUCN 2016), the list of Brazilian endangered animals from the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio 2014), and the lists from Minas Gerais State (Drummond et al. 2008), Rio de Janeiro State (Bergallo et al. 2000), São Paulo State (Bressan et al. 2009), and Espírito Santo State (Passamani and Mendes 2007).