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ANURANS OF JUIZ DE FORA MUNICIPALITY, ZONA DA MATA OF MINAS GERAIS STATE, BRAZIL

Matheus de Oliveira Neves[1], Vanessa Gonçalves Ferreira[2], Emanuel Masiero da Fonseca[3], Karoline Ceron[1], Celso Henrique Varela-Rios[4] & Rose Marie Hoffmann de Carvalho[4]*

[1]*Universidade Federal de Mato Grosso do Sul (UFMS), Instituto de Biociências, Programa de Pós Graduação em Ecologia e Conservação. Cidade Universitária, Campo Grande, MS, Brasil. CEP: 79070-900*
[2]*Universidade Federal de Mato Grosso do Sul (UFMS), Instituto de Biociências, Programa de Pós Graduação em Biologia Animal. Cidade Universitária, Campo Grande, MS, Brasil. CEP: 79070-900*
[3]*Universidade Federal do Rio Grande do Norte (UFRN), Departamento de Ecologia, Programa de Pós Graduação em Ecologia. Lagoa Nova, Natal, RN, Brasil. CEP: 59072-970*
[4]*Universidade Federal de Juiz de Fora (UFJF), Instituto de Ciências Biológicas, Laboratório de Herpetologia/Anfíbios, Departamento de Zoologia, Campus Universitário, São Pedro, Juiz de Fora, MG, Brasil. CEP: 36036-900*
E-mails: nevesmo@yahoo.com.br, vanessagf.09@gmail.com, emanuelmfonseca@gmail.com, adenomera@gmail.com, celsohvrios@gmail.com, rosemarie.hoffmann@ufjf.edu.br

ABSTRACT
The Atlantic Forest is considered a biodiversity hotspot due to a large concentration of endemic species and an associated high vulnerability to human disturbance. The Serra da Mantiqueira in southeastern Brazil stands out as an important region to anurofauna composition, presenting endemic and threatened species. Conversely, the species composition of the amphibian communities of several areas in the Serra da Mantiqueira is still unknown. Filling these knowledge gaps is a fundamental task to protect these areas and the associated biota. Herein, we provide a list of anurans for the Juiz de Fora municipality, Minas Gerais state, in southeastern Brazil. The species list is based on museum records of specimens deposited in the Coleção de Anfíbios da Universidade Federal de Juiz de Fora (CAUFJF). In addition, other records were derived from fieldwork on five urban fragments. We recorded 46 species belonging to 11 families and 22 genera. Of that total, thirty-eight species (83%) can be found in urban fragments. No species are on lists of endangered species, although *Chiasmocleis mantiqueira, Ischnocnema verrucosa, Myersiella microps, Phasmahyla cochranae*, and *Zachaenus carvalhoi* are considered data deficient. *Adelophryne meridionalis* is so far considered endemic to the Parque Municipal Lajinha, in Juiz de Fora. The municipality also showed high species richness when compared with other regions in the Serra da Mantiqueira. The present study demonstrates that even small and disturbed areas harbor important, endemic species and may help to fill the knowledge gaps about diversity in the state of Minas Gerais.
Keywords: amphibians; Atlantic Forest; Serra da Mantiqueira; species inventory; species richness.

INTRODUCTION

The Brazilian Atlantic Forest (AF) originally covered about 1,500,000 km^2 of the eastern coast of South America, extending from northeastern to southern Brazil (Ribeiro *et al.* 2009). Historically, the AF domain has been deeply impacted by agriculture, cattle ranching, timber extraction, and urban expansion (Morellato & Haddad 2000), with only about 11.4%-16% of its original extension remaining (SOSMA 2017). The remarkable high levels of species richness and endemism have often been used to describe AF biodiversity (Myers *et al.* 2000, Silva *et al.* 2004, Haddad *et al.* 2013). The AF regions occupy the large proportion of the Brazilian coastal region. The AF highlands are considered biodiversity hotspots, with a large concentration of endemic species and an associated high vulnerability to human disturbance (Myers *et al.* 2000).

Amphibians are a prominent group of vertebrates, with more than 7,690 described species (Frost 2017) and higher species richness found in the tropics (Pyron & Wiens 2013). Currently, 1,080 species are registered in Brazil (Segalla *et al.* 2016) and approximately 50% of them occur in the AF (Haddad *et al.* 2013). Most of this high diversity occurs in areas of medium elevation (about 600 m a.s.l.) in the AF (Siqueira & Rocha 2013), although some studies suggest that high elevation areas (about 1000 m a.s.l.) in mountainous regions of southeastern Brazil reach higher levels of endemism (*e.g.*, Serra do Mar and

Serra da Mantiqueira) (Cruz & Feio 2007). These highlands promote genetic isolation between populations, favoring allopatric speciation (Firkowski *et al*. 2016). The Mantiqueira highland complex (Serra da Mantiqueira here on) stands out as an important region to anurofauna composition, presenting endemic and threatened species (Moura *et al.* 2012, Vasconcelos *et al.* 2014, Barata *et al.* 2016). Large areas in the Serra da Mantiqueira still need inventories of amphibians and many localities have been subsampled (Silvano & Segalla 2005). Further studies are necessary to show patterns of diversity and endemism of these animals (Moura *et al.* 2012).

Despite that, knowledge about the composition of amphibian communities in the Serra da Mantiqueira has increased in the last decade, which is a consequence of valuable studies in this region (*e.g*., Cruz *et al.* 2009, Almeida *et al*. 2011, Gomides & Sousa 2012, Moura *et al.* 2012). This knowledge is still incipient and fragmented, because most studies have focused on high elevation regions (>1,000m a.s.l.) (Nascimento *et al.* 2009). In addition, extensive areas remain subsampled, and the information generated about species distribution in these areas is fundamental for the management and conservation planning in the AF (Silveira *et al.* 2010, Verdade *et al.* 2012). Moreover, other areas such as biogeography, ecology, and evolution will benefit from this information (*e.g*., Costa *et al.* 2007, Rosauer *et al.* 2009, Vasconcelos *et al*. 2014, Barata *et al*. 2016).

Herein, we provide the first list of anurans for the Juiz de Fora municipality, Minas Gerais state, in southeastern Brazil. The aim of this study is to contribute to the gap in knowledge about amphibian diversity of the Serra da Mantiqueira.

MATERIAL AND METHODS

Study site

Juiz de Fora (21°45'44.73"S, 43°20'36.24"W, *Datum* WGS84; Figure 1) is one of the most populous municipalities in the state of Minas Gerais, southeastern Brazil. Juiz de Fora is located at the Serra da Mantiqueira, extending over 1,424 km². It is drained by the middle Paraibuna River, and the elevation ranges from 467 to 1,104 m a.s.l. (Pifano *et al.* 2007). Although originally covered by the AF vegetation, most of the landscape is now used for agriculture. According to the Köppen's classification, the climate is Cwa type (Alvares *et al*. 2013) with hot summers and an annual average temperature around 22.5ºC and an average annual rainfall of 1,470 mm (Borges 2006).

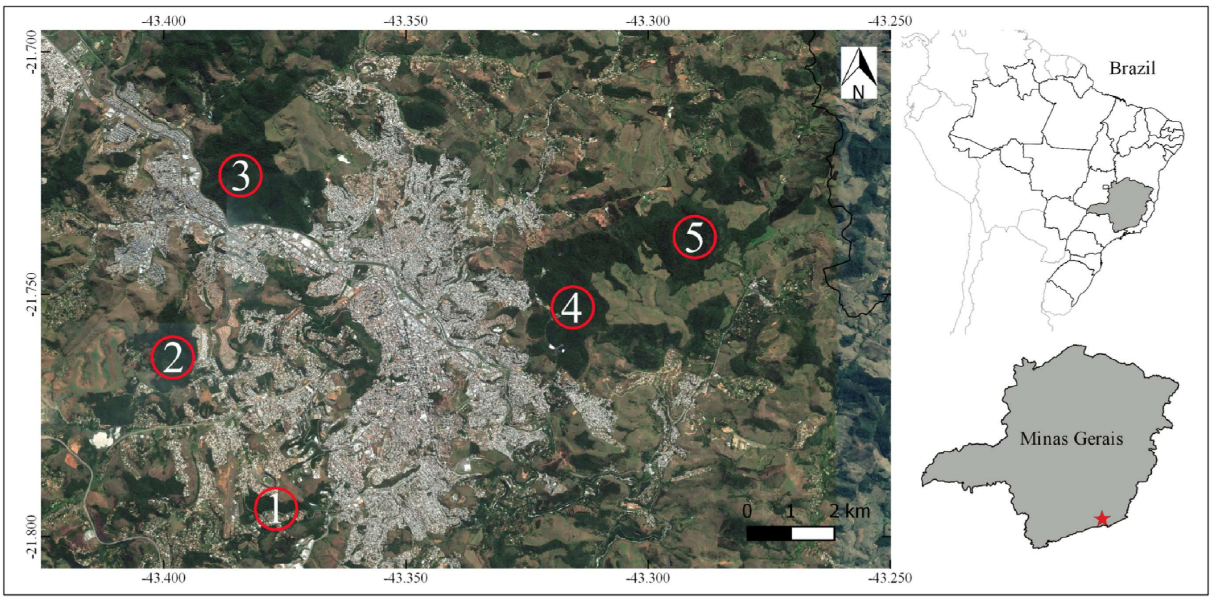

Figure 1. Geographic location of Juiz de Fora municipality (red star) in the Minas Gerais state, southeastern Brazil. Numbers indicate urban fragments: (1) Parque Natural Municipal da Lajinha, (2) Reserva Biológica Municipal de Santa Cândida, (3) Área de Proteção Ambiental Mata do Krambeck/Jardim Botânico da UFJF, (4) Reserva Biológica Municipal do Poço D'Anta, and (5) Fazenda Floresta.

Data collection

To generate the anurans species list, we analyzed the specimens deposited in the Coleção de Anfíbios da Universidade Federal de Juiz de Fora (CAUFJF; Appendix 1). This regional collection has specimens collected in Juiz de Fora municipality from 1970, with a total of 1,717 specimens deposited until 2015. Most individuals were captured during research projects conducted by students of the Laboratório de Anfíbios at the Universidade Federal de Juiz de Fora. All specimens were carefully checked to confirm their identification by experts to avoid misleading information. Moreover, the checklist was complemented by fieldwork from 2006 to 2011 in five urban fragments. Three lines of fence (100 meters each) interspersed with a pitfall and funnel trap arranged every 10 meters were allocated in five urban fragments of Juiz de Fora municipality: (1) Parque Natural Municipal da Lajinha (14 months), (2) Reserva Biológica Municipal de Santa Cândida (eight months), (3) Área de Proteção Ambiental Mata do Krambeck/Jardim Botânico da UFJF (six months), (4) Reserva Biológica Municipal do Poço D'Anta (eight months), and (5) Fazenda Floresta (eight months) (Figure 1). In total, 1500 meters of fence with 90 pitfall traps and 75 pairs of funnels were allocated. We also performed sporadic active searches to collect arboreal species, which were not covered using passive method (pitfall and funnel traps) (Collection License ICMBio 22961-1 / 17746-1).

We checked the conservation status of each species recorded according to the list of threatened species in the state of Minas Gerais (COPAM 2010), the Brazilian list of threatened species (ICMBio 2016), and the red list of threatened species of the International Union for Conservation of Nature and Natural Resources (IUCN 2017).

RESULTS

We recognized 46 species, distributed in 11 families (Table 1): Brachycephalidae (n = 7, Figure 2a-c), Bufonidae (n = 1, Figure 2d), Craugastoridae (n = 1), Cycloramphidae (n = 2, Figure 2e), Eleutherodactylidae (n = 1, Figure 2f), Hylidae (n = 20, Figure 2g-h and 3a-c), Hylodidae (n = 1, Figure 3d), Leptodactylidae (n = 7, Figure 3e), Microhylidae (n = 3, Figure 3f-g), Odontophrynidae (n = 2, Figure 3h), and Ranidae (n = 1). One species (*Lithobates catesbeianus*) is considered exotic and 53.4% of species are endemic to the AF. Hylidae showed the greatest number of species (43.5%), followed by Leptodactylidae (15.2%). Three species, *Adelophryne meridionalis, Ischnocnema verrucosa*, and *Scinax fuscovarius*, were described based on specimens collected in Juiz de Fora (type-locality). Thirty-eight out of the 46 species were registered in urban fragments. The higher species richness (n = 26) was recorded in the Area de Proteção Ambiental Mata do Krambeck.

Table 1. Anurans species recorded in Juiz de Fora municipality, Minas Gerais state, Brazil. Urban fragments were amphibian species were recorded: (1) Parque Natural Municipal da Lajinha, (2) Reserva Biológica Municipal de Santa Cândida, (3) Área de Proteção Ambiental Mata do Krambeck/Jardim Botânico da UFJF, (4) Reserva Biológica Municipal do Poço D'Anta, and (5) Fazenda Floresta. *Endemic species of the Atlantic Forest according to Haddad *et al*. (2013). **Records derived only from CAUFJF.

Family/ Species	Urban fragments
Brachycephalidae	
Ischnocnema juipoca (Sazima & Cardoso, 1978)*	1, 2, 3, 4, 5
Ischnocnema nasuta (A. Lutz, 1925)*	1, 3
Ischnocnema verrucosa (Reinhardt & Lütken, 1862)*	1, 2, 3, 4, 5
Ischnocnema aff. *guentheri*	1, 2, 3, 4, 5
Ischnocnema gr. *lactea*	**
Ischnocnema gr. *parva* 1	1, 2 ,3 ,4
Ischnocnema gr. *parva* 2	1

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Family/ Species	Urban fragments
Bufonidae	
Rhinella gr. *crucifer*	1, 2, 3, 4, 5
Craugastoridae	
Haddadus binotatus (Spix, 1824)*	1, 2, 3, 4, 5
Cycloramphidae	
Thoropa miliaris (Spix, 1824)*	1, 3, 5
Zachaenus carvalhoi Izecksohn, 1983″1982″*	1, 4, 5
Eleutherodactylidae	
Adelophryne meridionalis Santana, Fonseca, Neves & Carvalho, 2012*	1, 4
Hylidae	
Bokermannohyla gr. *circumdata*	1
Dendropsophus branneri (Cochran, 1948)	3
Dendropsophus decipiens (A. Lutz, 1925)	3
Dendropsophus elegans (Wied-Neuwied, 1824)*	3
Dendropsophus minutus (Peters, 1872)	2, 3
Hypsiboas albomarginatus (Spix, 1824)*	3
Hypsiboas albopunctatus (Spix, 1824)	**
Hypsiboas faber (Wied-Neuwied, 1821)*	2, 3
Hypsiboas pardalis (Spix, 1824)*	1, 3
Hypsiboas polytaenius (Cope, 1870)*	2, 4, 5
Hypsiboas semilineatus (Spix, 1824)*	3, 4
Phasmahyla cochranae (Bokermann, 1966)*	5
Phyllomedusa burmeisteri Boulenger, 1882*	1, 3, 5
Scinax crospedospilus (A. Lutz, 1925)*	3
Scinax eurydice (Bokermann, 1968)*	1, 3
Scinax fuscovarius (A. Lutz, 1925)	**
Scinax hayii (Barbour, 1909)*	**
Scinax luizotavioi (Caramaschi & Kisteumacher, 1989)*	1, 3
Scinax x-signatus (Spix, 1824)	**
Scinax gr. *catharinae*	1, 3
Hylodidae	
Hylodes lateristrigatus (Baumann, 1912)*	1, 5
Leptodactylidae	
Adenomera marmorata (Steindachner, 1867)*	1, 3
Leptodactylus furnarius Sazima & Bokermann, 1978	1
Leptodactylus fuscus (Schneider, 1799)	3
Leptodactylus labyrinthicus (Spix, 1824)	1
Leptodactylus latrans (Steffen, 1815)	3

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Family/ Species	Urban fragments
Leptodactylidae	
Physalaemus cuvieri Fitzinger, 1826	1, 2, 3, 5
Physalaemus signifer (Girard, 1853)*	**
Microhylidae	
Chiasmocleis mantiqueira Cruz, Feio & Cassini, 2007*	1
Elachistocleis cesarii (Miranda-Ribeiro, 1920)	**
Myersiella microps (Duméril & Bibron, 1841)*	1, 2, 4, 5
Odontophrynidae	
Odontophrynus americanus (Duméril & Bibron, 1841)	**
Proceratophrys boiei (Wied-Neuwied, 1825)*	1, 2, 3, 4, 5
Ranidae	
Lithobates catesbeianus (Shaw, 1802)	2

None of the species identified in this study present any degree of threat from lists of endangered species. However, some species are classified as Data Deficient (DD), such as *Zachaenus carvalhoi, Phasmahyla cochranae,* and *Myersiella microps* in Minas Gerais state, as well as *I. verrucosa*, *Z. carvalhoi,* and *Chiasmocleis mantiqueira* at global level.

DISCUSSION

The number of species recorded in this study were similar to those found in nearby areas in the Serra da Mantiqueira, despite the methodological differences, such as in the Serra Negra da Mantiqueira (48 species; Neves *et al*. 2017), in the Parque Estadual da Serra do Brigadeiro (47 species, Moura *et al*. 2012) and the Parque Estadual do Ibitipoca (36 species; Cruz *et al.* 2009). Also, they were higher than that found in the Serra do Relógio (17 species; Gomides & Sousa 2012). Most of those areas show a relatively high number of species, which is one of the prominent characteristic of highlands in the AF (Cruz & Feio 2007). Differences in species richness among these areas might be related to methodology, sampling effort or to the degree of the conservation status of the areas.

In this study, urban fragments of the Juiz de Fora municipality housed a considerable number of anuran species present in the city (83%). The importance of cities for biodiversity conservation grows with the increase of urbanization (Kowarik 2011). Landscapes where cities are inserted usually are highly fragmented and composed for a mosaic of land-uses types that vary from fragments of native forests to buildings. Urban fragments are repositories of current and future biodiversity, offering refuge for numerous animal species, but also are generally under direct control by humans (Faeth *et al.* 2011, Souza-Campana *et al*. 2016). This is the case of *Adelophryne meridionalis*, a diminutive species that currently is only known from the Parque Natural Municipal da Lajinha (type locality), in Juiz de Fora (ca. 880 m a.s.l.) (Santana *et al.* 2012).

Hylodes lateristrigatus has its distribution in southeastern Brazil, occurring in few localities in Espírito Santo, Rio de Janeiro, and Minas Gerais states (Salles *et al*. 2012, Moura *et al.* 2012, Vrcibradic *et al.* 2014). In the State of Minas Gerais, the species is only known to occur in the Parque Estadual da Serra do Brigadeiro (Moura *et al.* 2012). In this study, we provided a second record for this species in the state.

Belonging to a problematic taxonomic group, *Ischnocnema* sp. (aff. *guentheri*) presents morphological characteristics similar to *Ischnocnema guentheri* (Steindachner, 1864), which is considered endemic of the Parque Nacional da Floresta da Tijuca, in the State of Rio de Janeiro (Gehara *et al.* 2013). In a recent molecular study, Gehara *et al.* (2013) identified a probable new and cryptic species (*candidate species 3*) in the Juiz de Fora

municipality, as well as in the Serra do Itatiaia, both located within the Serra da Mantiqueira. Cryptic species (*i.e.,* two or more distinct species that are classified as a single species) are numerous to amphibians, and usually appears to be a single, nominal widespread species that may be comprised of morphologically similar but geographically restricted species (Bickford *et al*. 2007). The two species of this study belong to *Ischnocnema parva* group and *I.*

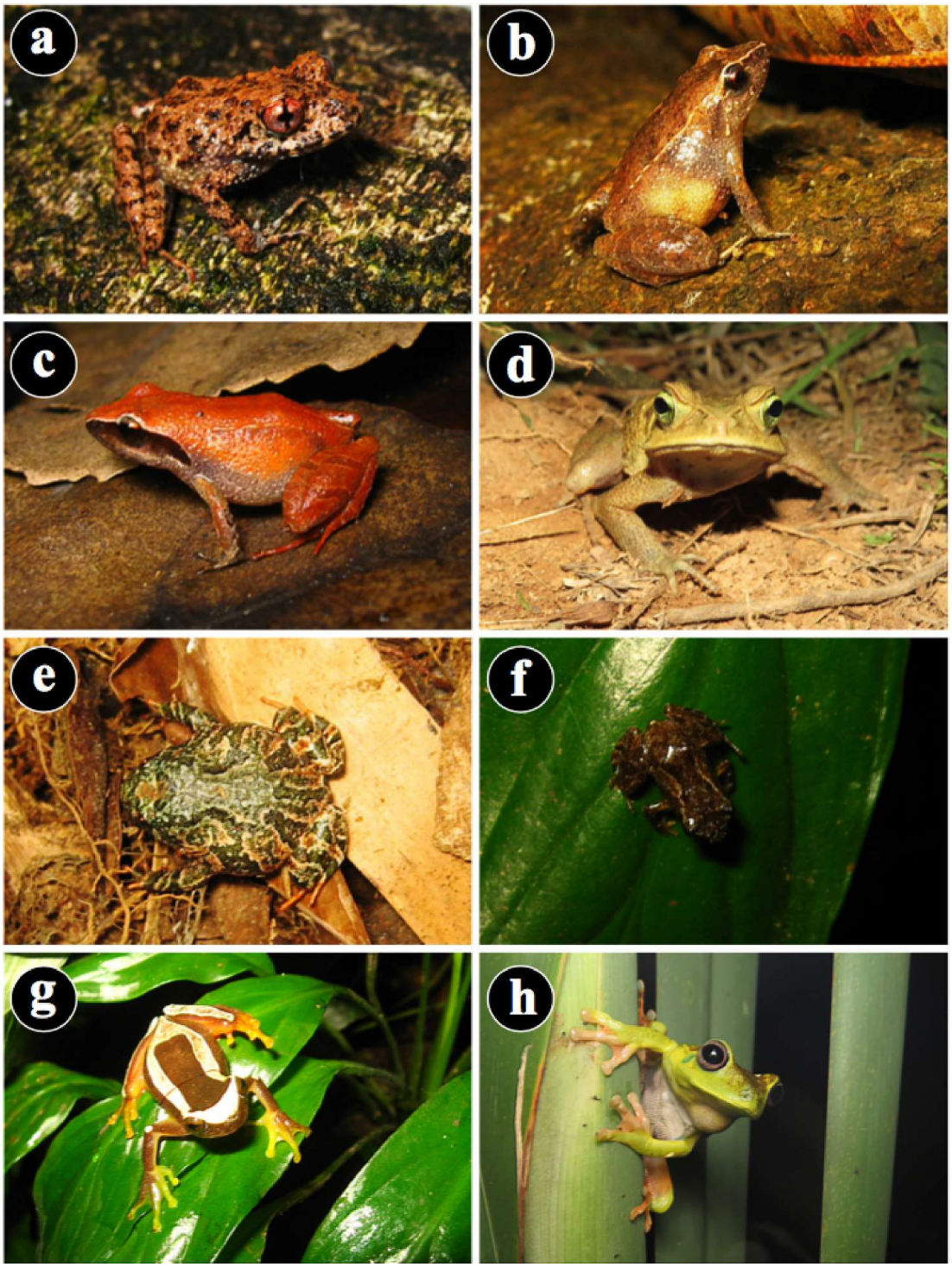

Figure 2. Anuran amphibians from Juiz de Fora, Zona da Mata of Minas Gerais state, Brazil: Family Brachycephalidae: (a) *Ischnocnema verrucosa,* (b) *Ischnocnema* gr. *parva* 1, (c) *Ischnocnema* gr. *parva* 2; Family Bufonidae: (d) *Rhinella* gr. *crucifer;* Family Cycloramphidae: (e) *Zachaenus carvalhoi*; Family Eleutherodactylidae: (f) *Adelophryne meridionalis*; and Family Hylidae: (g) *Dendropsophus elegans*; (h) *Hypsiboas albomarginatus.*

lactea group that are taxonomically complex and difficult to identify. Recently, Gehara *et al*. (2017) demonstrate that *I. parva* comprises six species and the nominal *I. parva* is the lineage found at the type-locality in State of Rio de Janeiro. The specimen attributed to *I. lactea* from CAUFJF did not show the necessary characters for a correct diagnosis due to the long time since it was collected.

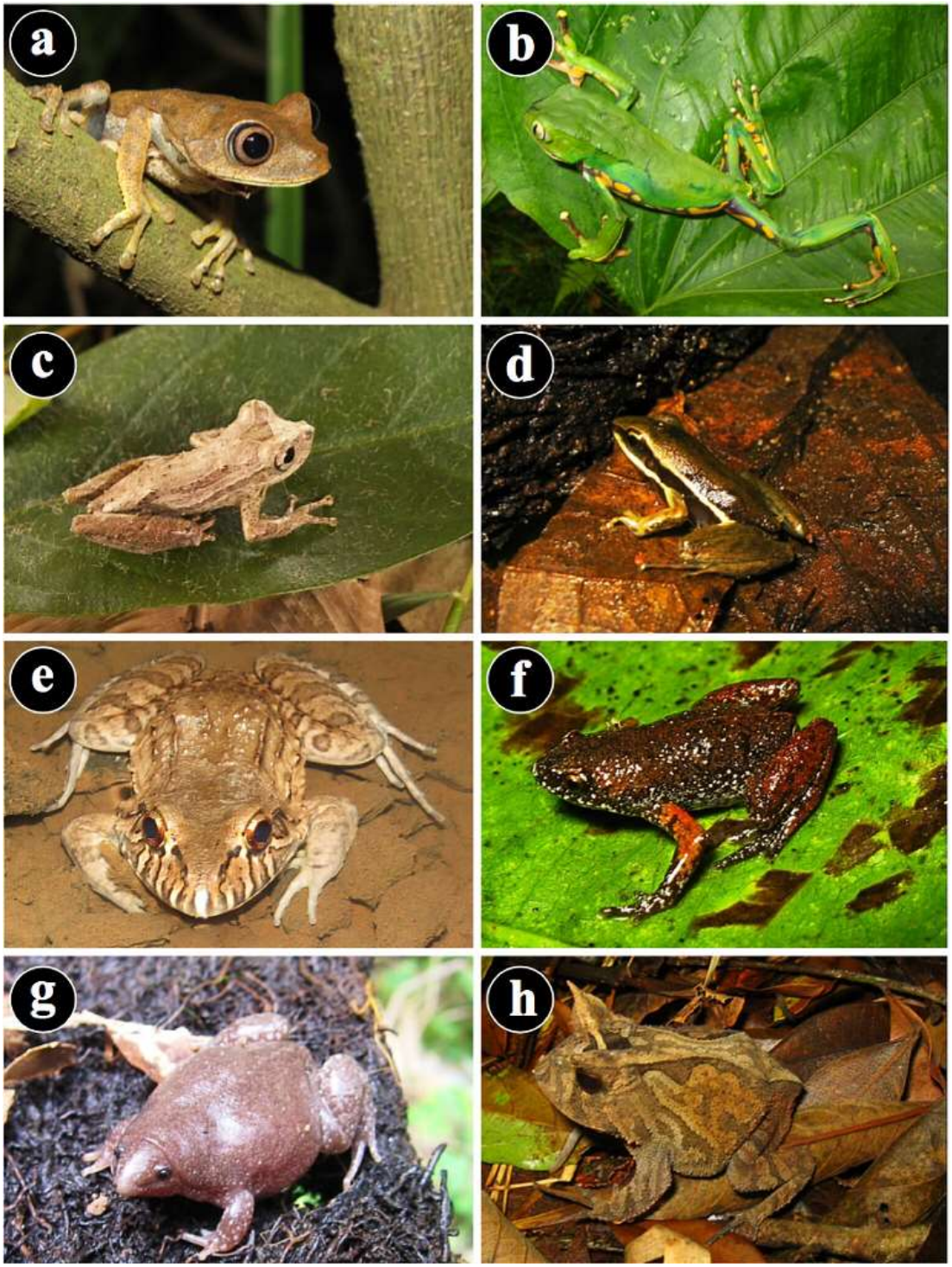

Figure 3. Anuran amphibians from Juiz de Fora, Zona da Mata of Minas Gerais state, Brazil: Family Hylidae: (a) *Hypsiboas semilineatus*, (b) *Phyllomedusa burmeisteri,* (c) *Scinax luizotavioi*; Family Hylodidae: (d) *Hylodes lateristrigatus*; Family Leptodactylidae:(e) *Leptodactylus labyrinthicus*; Microhylidae: (f) *Chiasmocleis mantiqueira*, (g) *Myersiella microps*; and Family Odontophrynidae: (h) *Proceratophrys boiei*. Credit: Flávia Mól Lanna (c).

In the Serra da Mantiqueira complex, *Rhinella* gr. *crucifer* species are identified as *R. crucifer* (Parque Nacional do Itatiaia by IBDF 1982), *R. pombali* (Parque Estadual da Serra do Brigadeiro by Moura *et al.* 2012) or *R. ornata* (Serra Negra da Mantiqueira by Neves *et al.* 2017). However, in Juiz de Fora, the species identified as *Rhinella* gr. *crucifer* presents features of both *R. crucifer* and *R. ornata*. Juiz de Fora is close to the extreme of the distribution of these two species and hybridization might be a common occurrence, which would make it difficult to distinguish these species (see map at Thomé *et al.* 2010). Moreover, Thomé *et al*. (2010) put in doubt the taxonomic status of *R. pombali* from a phylogenetic point of view. Given all these arguments, we prefer keep the species collected in Juiz de Fora under *Rhinella* gr. *crucifer*.

Lithobates catesbeianus is a North American species introduced in many countries around the world (Lowe *et al.* 2000, Lever 2003). This species stands out for its high likelihood of becoming an invasive species in environments where it is introduced (Kats & Ferrer 2003, Ficetola *et al.* 2007). In fact, this species is considered one of the 100 worst invasive species in the world (Lowe *et al.* 2000). It is already a widespread species in Brazil, where its invasion began in the 1930's due to the release from aquaculture farms (Both *et al.* 2011, Fontanello & Ferreira 2016). In Juiz de Fora, this species occurs only at Reserva Biológica Municipal de Santa Cândida. However, there is no information to date about its actual impacts on the native anurofauna in Juiz de Fora, although its potential impacts on Brazilian anurans are widely known and alarming (Lowe *et al*. 2000, Boelter *et al*. 2012, Both & Grant 2012, Silva *et al.* 2016).

Aplastodiscus cavicola had its confirmed occurrence for the Área de Proteção Ambiental Mata do Krambeck through the registration of its advertisement call. However, as the specimen was recorded vocalizing buried, it was not possible to find it (no voucher). Thus, we prefer not to incorporate it into Juiz de Fora species list, although Cruz & Peixoto (1985) have registered the species for the municipality.

Faunal inventories are essential to the understanding of biodiversity and consequently for conservation planning strategies (Haddad 1998, Provete 2015). Although none of the species recorded in this study are considered endangered, Juiz de Fora harbors some poorly known species, such as *Ischnocnema verrucosa*, *Zachaenus carvalhoi, Adelophryne meridionalis, Phasmahyla cochranae, Myersiella microps,* and *Chiasmocleis mantiqueira.* There is a lack of basic information on these species (*e.g*., population size and natural history), preventing the assessment of their threatened status. Many times, studies with poorly known species are hampered due to the restricted distribution of the species and/or difficulty to access the area where the species occur, or even due to the species secretive behavior (Morais *et al.* 2013). We further highlight the need of more studies dedicated to these species to better understand their actual conservation status.

The lack of data on anurans along with the importance of these species and the region where they occur for conservation emphasizes the importance of studies for the understanding and preservation of the fauna of Minas Gerais. There is also the need for long-term studies of the assemblages and populations to assess possible declines and threats to amphibians of the state. The results generated here are of most importance for future conservation strategies and species assessments to protect and maintain this biodiversity over time. Still, the present study demonstrates that even small and disturbed areas harbor important, threatened species, and may help to fill the knowledge gaps about the diversity in the state of Minas Gerais.

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APPENDIX

Appendix 1. Voucher specimens: *Ischnocnema juipoca* – CAUFJF 892; *Ischnocnema nasuta* – CAUFJF 750, 1031; *Ischnocnema verrucosa* – CAUFJF 1231, 1232; *Ischnocnema* sp. (aff. *guentheri*) – CAUFJF 1513, 1515; *Ischnocnema* gr. *lactea* – CAUFJF 54; *Ischnocnema* gr. *parva* 1 – CAUFJF 1567, 1568; *Ischnocnema* gr. *parva* 2– CAUFJF 991, 992; *Rhinella* gr. *crucifer* – CAUFJF 695, 696, 1077, 1097; *Haddadus binotatus* – CAUFJF 1200, 1201; *Thoropa miliaris* – CAUFJF 917, 1037; *Zachaenus carvalhoi* – CAUFJF 1220, 1221; *Adelophryne meridionalis* – CAUFJF 783, 784; *Bokermannohyla* gr. *circumdata* – CAUFJF 1125, 1206; *Dendropsophus branneri* – CAUFJF 1174, 1175; *Dendropsophus decipiens* – CAUFJF 1532, 1533; *Dendropsophus elegans* – CAUFJF 1529, 1530; *Dendropsophus minutus* – CAUFJF 1021, 1022; *Hypsiboas albomarginatus* – CAUFJF 1016, 1017; *Hypsiboas albopunctatus* – CAUFJF 311, 312; *Hypsiboas faber* – CAUFJF 1106, 1139; *Hypsiboas pardalis* – CAUFJF 1156, 1205; *Hypsiboas polytaenius* – CAUFJF 1166, 1167; *Hypsiboas semilineatus* – CAUFJF 1517, 1518; *Phasmahyla cochranae* – CAUFJF 791; *Phyllomedusa burmeisteri* – CAUFJF 1012, 1013; *Scinax crospedospilus* – CAUFJF 1572, 1573, 1574; *Scinax eurydice* – CAUFJF 1069, 1207; *Scinax fuscovarius* – CAUFJF 403, 608; *Scinax hayii* – CAUFJF 56, 57; *Scinax luizotavioi* – CAUFJF 1114, 1577; *Scinax x-signatus* – CAUFJF 623, 624; *Scinax* gr. *catharinae* – CAUFJF 891; *Hylodes lateristrigatus* – CAUFJF 907, 908; *Adenomera marmorata* – CAUFJF 1153, 1157; *Leptodactylus furnarius* – CAUFJF 122,1152; *Leptodactylus fuscus* – CAUFJF 1044, 1045; *Leptodactylus labyrinthicus* – CAUFJF 611, 1163; *Leptodactylus latrans* – CAUFJF 1172, 1173; *Physalaemus cuvieri* – CAUFJF 1183, 1512; *Physalaemus signifer* – CAUFJF 120; *Chiasmocleis mantiqueira* – CAUFJF 893, 1507; *Elachistocleis cesarii* – CAUFJF 64; *Myersiella microps* – CAUFJF 933, 942;*Odontophrynus americanus* – CAUFJF 591; *Proceratophrys boiei* – CAUFJF 1185, 1186; *Lithobates catesbeianus* – CAUFJF 256, 257.