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SPECIES COMPOSITION, CONSERVATION STATUS, AND SOURCES OF THREAT OF ANURANS IN MOSAICS OF HIGHLAND GRASSLANDS OF SOUTHERN AND SOUTHEASTERN BRAZIL

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ABSTRACT

Amphibians are the most threatened vertebrate group in the world, with about 32% of species under some category of threat. Conservation strategies depend on basic data, such as species distribution and natural history, which are largely lacking for endemic species inhabiting mosaics of highland grasslands and forest patches of Southern and Southeastern Brazil. Highland grassland fields occur in the Serra do Mar ecoregion and harbor an endemic anuran fauna associated to rocky outcrops and open fields interspersed among *Araucaria*, Rain and Cloud Forests. Here, we assembled occurrence records of anurans from mosaics of highland grasslands and forest patches in Brazil from the literature. We also compiled the conservation status of those species, including the spatial distribution of richness and endemism. We found that 75 species occur in this environment, of which about 46% are endemic. Highland grassland areas in and around Protected Areas in the Serra do Mar and Serra da Mantiqueira are under strong pressure, including criminal fire, forestry, and mining. Additionally, anurans from high altitude areas are apparently more prone to get infected by the chytrid fungus, whose growth is favored in cool and humid weather. Since anuran species inhabiting such seasonal environments have behavioral and life history adaptations, gathering data on how these disturbances affect anuran populations is urging in order to better inform conservation practices and landscape management plans.

Keywords: amphibians; biodiversity; Brazilian Atlantic Forest; open fields; Protected Area Network.

INTRODUCTION

We are currently facing a global biodiversity crisis caused by the increasing impact of human activities on natural environments, especially deforestation and conversion of natural habitats for agriculture (Dirzo & Raven 2003, Dirzo *et al.* 2014). Human activities have unprecedentedly accelerated the rate of species loss of different groups (De Vos *et al.* 2015), including amphibians (Houlahan *et al.* 2000). The worldwide decline in amphibian populations has been documented since the early 90s (Alford & Richards 1999), but this remains a complex issue, since their causes are multifaceted and may be context dependent (reviewed in Blaustein & Kiesecker 2002, Collins & Storfer 2003). Additionally, another major drawback in amphibian conservation is the lack of basic data on species distribution (Bini *et al.* 2006) and population trends (Houlahan *et al.* 2000), especially in the Tropics.

Despite the recent improvement in conservation actions and spatial prioritization for Brazilian anurans, with the proposal of a national conservation action plan (Verdade *et al.* 2012), there are still a lack of studies on some ecosystems with an endemic anuran fauna. One of these regions are the highland grasslands (*campos de altitude*; *sensu* Safford 1999a) of the Atlantic Forest (Morellato & Haddad 2000). These are vegetation formations covering peaks of high mountains formed during the Tertiary in southeastern and southern Brazil (Vasconcelos 2011). The vegetation is largely composed of grasses, herbs, and shrubs, including hygrophilous forests, and cloud forests (Ribeiro & Freitas 2010, Vasconcelos 2011).

There is evidence suggesting that highland grasslands of Southeastern Brazil had similar climate to the Andes in the past (Safford 1999a). This similarity in climate, along with climatic changes during the Pleistocene, may have determined phytogeographic similarity between the two regions, influencing species distribution of plants (Safford 2007), mammals (Percequillo *et al.* 2011), birds (Sick 1984), and amphibians (Lynch 1979). For example, these two regions share about one third of plant genera (Safford 2007). However, highland grasslands are poorly known in terms of species composition of several taxa, assessment of the impacts of fire, grazing, and other anthropogenic pressures. There is also a lack of population viability studies for endemic and threatened taxa.

The knowledge about species distribution of anurans in the Atlantic Forest has increased in the past few years, with about 570 species being known in this biome (Haddad *et al.* 2013). Additionally, recent studies have identified hotspots within the Atlantic forest that harbor a distinct anuran fauna with many endemics (Villalobos *et al.* 2013). Specifically, the Serra do Mar between São Paulo and Rio de Janeiro contains a high richness of small-ranged species, and was classified as a distinct biogeographic domain for anurans (Vasconcelos *et al.* 2014). Both past climatic and geologic factors seem to have played a larger role in driving this richness pattern (da Silva *et al.* 2014, Thomé *et al.* 2014). However, the processes determining the distribution of the anuran fauna of specific environments, such as highland grasslands remain poorly known, since the information on species distribution in those environments is anecdotal and fragmentary at best (*e.g.*, Garey *et al.* 2014). Specially, studies evaluating population trends and threats as well as their correlates are lacking. Such data is crucial to inform better conservation plans.

Herein, we present (i) a species list of anurans occurring in mosaics of highland grasslands and forest patches and their conservation status; and (ii) a comment on potential threats to anurans and suggest possible actions for their conservation. The data provided here may help in designing both future research projects and conservation plans.

MATERIAL AND METHODS

Study region

Highland grasslands are part of the tropical and subtropical moist broadleaf forests biome (Olson *et al.* 2001), in the ecoregion of Serra do Mar (Olson *et al.* 2001), of the Atlantic Forest (Morellato & Haddad 2000). The Atlantic Forest is one of 25 global biodiversity hotspots (Myers *et al.* 2000) and is currently highly fragmented, with estimates of remaining vegetation between 11.7% and 16% (Ribeiro *et al.* 2009). Due to the lack of consensus in the classification of highland grasslands and rocky fields, in this study we adopt the proposal by Safford (1999a) and Vasconcelos (2011). Highland grasslands are associated with outcrops of igneous or metamorphic rocks, with varying extents of bare rock, cliffs, and rocky peaks that occur sparsely in mountaintops of the Serra do Mar and Mantiqueira (Safford 1999a) in the Atlantic Forest of southeastern and southern Brazil. The vegetation of highland grasslands consists of a mosaic of grasses, herbaceous, and shrubby plants, and forest patches with short trees (Safford 1999a, Martinelli 2007, Mocochinski & Scheer 2008).

Highland grasslands occur in the states of Espírito Santo, Minas Gerais, Rio de Janeiro, São Paulo, Paraná, and Santa Catarina (Safford 1999a, Mocochinski & Scheer 2008; Table 1), but specifically along the Serra do Mar and Mantiqueira *sensu lato*, with an estimated area of 350 km^2 (Safford 1999a). This formation is usually found above 1,500 m (Safford 1999b), except those in the Curucutu section of the Serra do Mar State Park, which occur up to 750 m (Garcia & Pirani 2003) and in the state of Paraná, up to 1,000 m (Mocochinski & Scheer 2008). About 90% of highland grassland areas are inside Protected Areas (Aximoff 2011).

Data on species records

The list of anuran species occurring in highland grasslands was obtained by searching the scientific literature and unpublished dissertations. We searched for species lists of anurans in Protected Areas that harbor highland grasslands in the extent of the study region. Search was conducted from June to August 2014 in the Web of Science (ISI; www.webofknowledge.com), Scientific Electronic Library Online (SciELO; www.scielo.br), and Google Scholar (www.scholar.google.com) using different terms, such as the name of protected areas along with the words "Amphibia" or "Anura". We then checked each article for any information stating that a given species occurred in highland grassland environments. Species with uncertain identification that were not collected by us were not considered.

To determine the geographic distribution and endemicity, we consulted AmphibiaWeb (2014) and Amphibian Species of the World (Frost 2014), besides checking for information in the articles. Species were then classified as (i) restricted endemic, occurring at a single locality; (ii) endemic species that occur in more than one locality, but only in highland grasslands; (iii) widespread species. The threat category for each species was obtained by consulting IUCN (2014) and the Brazilian National red list (Brasil 2014).

RESULTS

We recorded 75 species occurring in highland grassland environments (Table 2). The highest richness was found in the Serra do Mar State Park, Serra da Bocaina National Park, and Itatiaia National Park, with 22, 21, and 20 species respectively (Figure 1). *Bokermannohyla ahenea, B. gouveai, Brachycephalus ferruginus, B. izecksohni, B. pernix, B. pombali, Crossodactylus grandis*, *Cycloramphus bandeirensis, C. carvalhoi, C. organensis, Fritziana* sp., *Holoaden bradei, Hylodes glaber, H. ornatus*, *H. regius, Ischnocnema concolor, I. melanopygia, I. paranaensis, Paratelmatobius gaigeae, P. lutzii, Physalaemus barrioi, Proceratophrys gladius,* and *Thoropa petropolitana* are microendemic species that only

Table 1. Location of the highland grasslands in Brazil, with information about amphibian species richness (S), number of restricted endemic species (Ser), and number of species richness under some degree of threat according to IUCN (Sut), and according to the Brazilian red list of threatened species (Sbl).

Region	Protected Area	S	Ser	Sut	Sbl	Geographic coordinates
Serra da Bocaina	Parque Nacional da Serra da Bocaina	21	6	0	0	22º44'S; 44°36'W
Serra dos Órgãos	Parque Nacional da Serra dos Órgãos	12	2	1	1	22°52'S; 42°09'W
Serra dos Órgãos	Parque Estadual dos Três Picos	6	1	0	0	22º26'S; 42º55'W
Serra dos Órgãos	Reserva Biológica de Araras	0	0	0	0	22º30'S; 43º18'W
Serra de Paranapiacaba	Parque Estadual da Serra do Mar, núcleo Curucutu	22	0	0	0	23°56'S; 46°39'W
Serra Ibitiraquire	Parque Estadual do Pico do Paraná	2	1	0	0	25°14'S; 48°48'W
Serra do Marumbi	Parque Estadual do Pico do Marumbi	1	1	0	0	25°27'S; 48°55'W
Morro do Anhangava	Parque Estadual Serra da Baitaca	1	1	0	1	25°26'S; 49°05' W
Serra da Igreja	APA de Guaratuba	1	1	0	0	25º40'S; 48º51'W
Serra da Prata	Parque Nacional Saint-Hilaire Lange	0	0	0	0	25°43'S; 48º38'W
Serra da Farinha Seca	Parque Estadual da Graciosa	0	0	0	0	25°23'S; 48°55W
Serra do Gigante	APA Guaraqueçaba	0	0	0	0	25°04'S; 48°19'W
Pedra Branca do Araraquara	APA Guaratuba	0	0	0	0	25º56'S; 48º52'W
Serra da Mantiqueira	Parque Estadual de Campos do Jordão	12	0	0	1	22°40'; 45°27'W
Serra do Papagaio	Parque Estadual da Serra do Papagaio	3	0	1	0	22°10'S; 44°43'W
Serra de Itatiaia	Parque Nacional de Itatiaia	20	8	2	2	22°20'S; 41°35'W
Serra do Caparaó	Parque Nacional do Caparaó	5	2	0	0	22°20'S; 41°45'W
Serra do Desengano	Parque Estadual do Desengano	1	0	0	0	21°45'S; 41°41'W
Serra Fina	APA Mantiqueira	1	0	1	0	22°25'S; 44°47'W

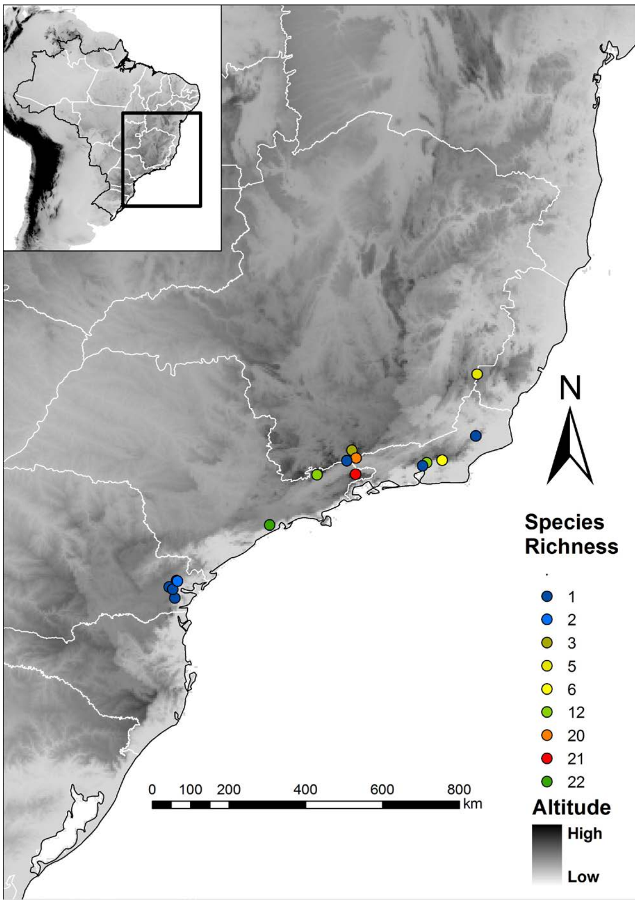

Figure 1. Map with species richness of each locality of highland grasslands in southeastern and southern Brazil, along with altitude. Data from the literature.

occur in one locality in the study extent. These represent about 32% of the species in our list. Most of species (46%) occur only in the Atlantic Forest, about 13% are wide-spread in Brazil or South America, and 8% only occur in highland grasslands (Table 2). The Itatiaia and Serra da Bocaina National Parks had the highest richness of microendemic species, with eight and six species, respectively.

The majority of species (46.6%) are classified as Least Concern (LC), with Data Deficient (DD) comprising 30.6% of species, only one species is NT, another one is CR, and one is VU (Table 2). Only five species (6.66 %) species from highland grasslands appear in the Brazilian National red list (Table 2). The status of about 14 species (18.6%) has not yet been evaluated, since have been described in the past five years (Table 2). Furthermore, three species (*Thoropa petropolitana*, *Holoaden bradei*, and *Melanophryniscus moreirae*) are under some category of threat (3%), in either IUCN or Brazilian red lists. For example, *H. bradei* and *T. petropolitana* are Critically Endangered (CR) in both National and IUCN red lists. Conversely, *Paratelmatobius lutzii* is DD in the IUCN list, but is listed as CR in the Brazilian list.

DISCUSSION

Anuran species richness and composition

We found 75 anuran species occurring in the study extent, which correspond to 7.6% of the anuran species known to occur in Brazil (Segalla *et al.* 2014), and 13.5% of the species known to occur in the Atlantic Forest (Haddad *et al.* 2013). The data gathered in this manuscript represent the first effort to organize the knowledge about anuran species richness in highland grasslands. However, our approach suffers from a number of shortcomings, but mainly the lack of systematic field surveys in many areas, especially in Paraná. As a result, there is a high variation in species richness among the areas (one to 22 species). Moreover, the sampling effort was not standardized among localities, so the high species richness and number of endemics species could be biased towards well-known places, such as Serra do Mar State Park, Itatiaia National Park, and Serra da Bocaina. This reinforces the need to increase samplings in poorly-known areas.

Our data show that about 15% of the species known to occur in the Atlantic Forest are endemic of the highland grasslands. The high number of endemic species found here may also be overestimated due to the lack of surveys in some areas. However, previous studies have already found a high level of endemism for vascular flora in the Southern tip of the Brazilian highland grasslands (*e.g.*, Iganci *et al.* 2011) and for passerine birds for the Serra do Mar (Cardoso da Silva *et al.* 2004), which includes areas of highland grasslands.

Threats to anuran species

There are records of population declines of some anurans in mosaics of highland grasslands

Table 2. Species list of anurans occurring in highland grasslands. Areas: APAP = Area de Proteção Ambiental de Petrópolis; MA = Morro do Anhangava; PECJ = Parque Estadual de Campos do Jordão; PED = Parque Estadual do Desengano; PESMC = Parque Estadual da Serra do Mar, núcleo Curucutu; PESP = Parque Estadual da Serra do Papagaio; PC = Pico Caratuva; PI = Pico da Igreja; PEPP = Parque Estadual Pico Paraná; PM = Pico do Marumbi; PNSC = Parque Nacional Serra do Caparaó; PNI = Parque Nacional Itatiaia; PNSB = Parque Nacional Serra da Bocaina; PETP = Parque Estadual dos Três Picos; PNSO = Parque Nacional Serra dos Órgãos; SF = Serra Fina; Distribution: RE = microendemic; CA = only in highland grasslands; MA = restricted to the Atlantic Forest; NE = wide spread. Conservation status according to IUCN (2014). The asterisk (*) marks the species listed in the Brazilian red list of threatened species (ICMBio 2014).

Family/species	Occurrence	Distri-bution	Conservation status	Reference
Brachycephalidae				
Brachycephalus brunneus Ribeiro, Alves, Haddad & Reis 2005	PEPP; PC	CA	DD	Ribeiro *et al*. (2005)
Brachycephalus ferruginus Alves, Ribeiro, Haddad & Reis 2006	PM	RE	NE	Alves *et al*. (2006)
Brachycephalus garbeanus Miranda-Ribeiro 1920	PETP	MA	NE	Siqueira *et al*. (2011)
Brachycephalus izecksohni Ribeiro, Alves, Haddad & Reis 2005	PC	RE	DD	Ribeiro *et al*. (2005)
Brachycephalus pernix Pombal Jr, Wistuba & Bornschein 1998	MA	RE	DD*	Pombal Jr *et al*. (1998)
Brachycephalus pombali Alves, Ribeiro, Haddad & Reis 2006	PI	RE	DD	Alves *et al*. (2006)
Ischnocnema concolor Targino, Costa & Carvalho-e-Silva 2009	PNI	RE	NE	Targino *et al*. (2009)
Ischnocnema guentheri (Steindachner 1864)	PETP; PNSO PESMC	MA	LC	Siqueira *et al*. (2011), Malagoli (2013), Folly *et al*. This volume
Ischnocnema holti (Cochran 1948)	PNI; PNSO	CA	DD	Targino & Carvalho-e-Silva (2008), Folly *et al*. This volume
Ischnocnema melanopygia Targino, Costa & Carvalho-e-Silva 2009	PNI	RE	NE	Targino *et al*. (2009)
Ischnocnema nasuta (Lutz 1925)	PNSC; PNSO	MA	LC	Heyer (1984), Folly *et al*. This volume
Ischnocnema paranaensis (Langone & Segalla 1996)	PEPP	RE	DD	Langone & Segalla (1996)
Ischnocnema parva (Girard 1853)	PETP; PNSO	MA	LC	Siqueira *et al*. (2011), Folly *et al*. This volume
Ischnocnema vizottoi Martins & Haddad 2010	PNSB; PECJ	CA	NE	Martins & Haddad (2010), Garey *et al*. (2014)
Ischnocnema sp. (aff. *melanopygia*)	PNSB	-	NE	Garey *et al*. (2014)
Bufonidae				
Dendrophryniscus brevipollicatus Jiménez de la Espada 1870	PESMC	MA	LC	Malagoli (2013)
Melanophryniscus moreirae (Miranda-Ribeiro 1920)	PNI; PESP; SF;	CA	NT	Bokermann (1967c), Marques *et al*. (2006),Weber *et al*. (2007)

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Family/species	Occurrence	Distri-bution	Conservation status	Reference
Rhinella icterica (Spix 1824)	PNI; PECJ; PNSO; PNSB; PESMC	NE	LC	Orrico *et al*. (2007), Gomes (2009), Malagoli (2013), Garey *et al*. (2014), Folly *et al*. This volume
Rhinella ornata (Spix 1824)	PESMC	MA	LC	Malagoli (2013)
Craugastoridae				
Haddadus binotatus (Spix 1824)	PESMC	MA	LC	Malagoli, (2013)
Holoaden bradei Lutz 1958	PNI	RE	CR*	Lutz (1958), Caramaschi & Pombal (2006)
Holoaden luederwaldti Miranda-Ribeiro 1920	PECJ	CA	DD*	Caramaschi & Pombal Jr (2006)
Cycloramphidae				
Cycloramphus bandeirensis Heyer 1983	PNSC	RE	DD	Heyer (1983)
Cycloramphus carvalhoi Heyer 1983	PNI	RE	DD	Heyer (1983)
Cycloramphus granulosus Lutz 1929	PNSB	MA	DD	Garey *et al*. (2014)
Cycloramphus organensis Weber, Verdade, Salles, Fouquet & Carvalho-e-Silva 2011	PNSO	RE	NE	Weber *et al*. (2011)
Thoropa miliaris (Spix 1824)	PNI; PNSO; PNSC	MA	LC	Feio *et al*. (2006)
Thoropa petropolitana (Wandolleck 1907)	PNSO; APAP	RE	VU*	Aximoff (2011)
Hemiphractidae				
Fritziana sp. nov.	PNSO	RE	NE	Folly *et al*. This volume
Fritziana ulei (Miranda-Ribeiro 1926)	PNSB	MA	NE	Folly *et al*. (2014), Garey *et al*. (2014)
Gastrotheca ernestoi Miranda-Ribeiro 1920	PETP; PNSO	MA	DD	Siqueira *et al*. (2011), Folly *et al*. This volume
Hylidae				
Aplastodiscus perviridis Lutz 1950	PNSB; PECJ	MA	LC	Gomes (2009), Garey *et al*. (2014)
Bokermannohyla ahenea (Napoli & Caramaschi 2004)	PNSB	RE	DD	Garey *et al*. (2014)
Bokermannohyla circumdata (Cope 1871)	PNSB; PECJ; PESMC	MA	LC	Gomes (2009), Malagoli (2013), Garey *et al*. (2014)
Bokermannohyla carvalhoi (Peixoto 1981)	PNSC; PED; PNSO	MA	LC	Peixoto, (1981), Frost (2014), Folly *et al*. This volume

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Family/species	Occurrence	Distri-bution	Conservation status	Reference
Bokermannohyla gouveai (Peixoto & Cruz 1992)	PNI	RE	DD	Orrico *et al*. (2007)
Dendropsophus elegans (Wied-Neuwied 1824)	PNSB; PESMC	MA	LC	Malagoli (2013), Garey *et al*. (2014)
Dendropsophus microps (Peters 1872)	PNSB; PECJ	MA	LC	Gomes (2009), Garey *et al*. (2014)
Dendropsophus minutus (Peters 1872)	PNSB; PESMC	NE	LC	Malagoli (2013), Garey *et al*. (2014)
Hypsiboas albomarginatus (Spix 1824)	PESMC	MA	LC	Malagoli (2013)
Hypsiboas albopunctatus (Spix 1824)	PESMC	MA	LC	Malagoli (2013)
Hypsiboas bandeirantes Caramaschi & Cruz 2013	PNSB; PESMC	MA	NE	Malagoli (2013), Garey *et al*. (2014)
Hypsiboas bischoffi (Boulenger 1887)	PESMC	MA	LC	Malagoli (2013)
Hypsiboas latistriatus (Caramaschi & Cruz 2004)	PNI; PECJ	MA	NE	Caramaschi & Cruz (2004), Gomes (2009)
Hypsiboas pardalis (Spix 1824)	PESMC	MA	LC	Malagoli (2013)
Hypsiboas prasinus (Burmeister 1856)	PECJ	MA	LC	Gomes (2009)
Hypsiboas stenocephalus (Caramaschi & Cruz 1999)	PESP	MA	DD	Santos *et al*. (2009)
Phyllomedusa distincta Lutz 1950	PESMC	MA	LC	Malagoli (2013)
Scinax alter (Lutz 1973)	PESMC	MA	LC	Malagoli (2013)
Scinax duartei (Lutz 1951)	PNI	NE	LC	Lutz (1951), Orrico *et al*. (2007)
Scinax sp. (aff. *duartei*)	PNSB	-	NE	Garey *et al*. (2014)
Scinax eurydice (Bokermann 1968)	PNSB	MA	LC	Garey *et al*. (2014)
Scinax fuscovarius (Lutz 1925)	PNSB; PETP; PESMC	NE	LC	Siqueira *et al*. (2011), Malagoli (2013), Garey *et al*. (2014)
Scinax obtriangulatus (Lutz 1973)	PNI	MA	LC	Lutz (1973)
Scinax squalirostris (Lutz 1925)	PNSB	NE	LC	Garey *et al*. (2014)
Scinax hayii (Barbour 1909)	PNSB; PESMC	MA	LC	Malagoli (2013), Garey *et al*. (2014)
Hylodidae				
Crossodactylus gaudichaudii Duméril & Bibron 1841	PNI	MA	LC	Carnaval *et al*. (2006)
Crossodactylus grandis Lutz 1951	PNI	RE	DD	Lutz (1951)
Hylodes charadranaetes Heyer & Cocroft 1986	PNSO	MA	DD	Folly *et al*. This volume

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Family/species	Occurrence	Distri-bution	Conservation status	Reference
Hylodes glaber (Miranda-Ribeiro 1926)	PNI	RE	DD	Izecksohn & Gouvêa (1983)
Hylodes ornatus (Bokermann 1967)	PNI	RE	LC	Bokermann (1967b)
Hylodes regius Gouvêa 1979	PNI	RE	DD	Gouvêa (1979)
Hylodes vanzolinii Heyer 1982	PNSC	RE	NE	Heyer (1982)
Leptodactylidae				
Leptodactylus furnarius Sazima & Bokermann 1978	PNSB; PESMC	NE	LC	Malagoli (2013), Garey *et al*. (2014)
Leptodactylus jolyi Sazima & Bokermann 1978	PESMC	MA	DD	Malagoli (2013)
Leptodactylus latrans (Steffen 1815)	PNSB; PESMC	NE	LC	Malagoli (2013), Garey *et al*. (2014)
Paratelmatobius cardosoi Pombal Jr & Haddad 1999	PESMC	MA	DD	Malagoli (2013)
Paratelmatobius gaigeae (Cochran 1938)	PNSB	RE	DD	Cochran (1938)
Paratelmatobius lutzii Lutz & Carvalho 1958	PNI	RE	DD*	Lutz & Carvalho (1958)
Physalaemus barrioi Bokermann 1967	PNSB	RE	DD	Garey *et al*. (2014)
Physalaemus cuvieri Fitzinger 1826	PNSB; PECJ; PESMC	NE	LC	Gomes (2009), Malagoli (2013), Garey *et al*. (2014)
Physalaemus jordanensis Bokermann 1967	PESP; PECJ	CA	DD	Bokermann (1967a), Tolledo *et al*. (2009)
Odontophrynidae				
Odontophrynus americanus Duméril & Bibron 1841	PNI	NE	LC	Orrico *et al*. (2007)
Proceratophrys gladius Mângia, Santana, Cruz & Feio 2014	PNSB	RE	NE	Mângia *et al*. (2014)
Proceratophrys melanopogon (Miranda-Ribeiro 1926)	PETP	MA	LC	Siqueira *et al*. (2011)
Ranidae				
Lithobates catesbeianus (Shaw 1802)	PECJ	NE	LC	Gomes (2009)

and forest patches in southeastern Brazil (Eterovick *et al.* 2005), including *Melanophryniscus moreirae* (Guix *et al.* 1998), *Cycloramphus granulosus* (Heyer *et al.* 1988), *Paratelmatobius lutzii* (Heyer *et al.* 1988), and *Thoropa petropolitana* (Heyer *et al.* 1988). The lack of records of declines in other localities may suggest that these populations are more stable, but more long-term studies on population dynamics are needed.

The main threats to anurans in highland grasslands seem to be: erosion and soil instability due to anthropogenic activities, deforestation, biological invasion, fire, removal of ornamental plants, mining, urban expansion, climate change, installation of power transmission lines (Martinelli 2007, Mocochinski & Scheer 2008). Based on our field experience and on the recent literature (*e.g.*, Leivas *et al.* 2012, Rodriguez *et al.* 2014), "[apparently the main threats for anuran fauna in highland grasslands seem to be: fire, disease, expansion of disturbed areas associated with human activities] MV Garey (personal communication)".

Fire

Fire is a major threat in areas of highland grasslands (Aximoff 2011), especially the man-made ones that are also the most frequent (Safford 2001). Man-made fire is used to clear and regrowth of vegetation used as pasture (Aximoff 2011, Aximoff & Rodrigues 2011), but its real impact depends on frequency and intensity. Thus, preventing fire is an essential measure for the conservation and maintenance of biodiversity in these ecosystems.

The immediate response of animals to fire is to escape and search for shelter, but not all individuals can escape, resulting in injuries and even death (Smith 2000). Several studies indicate that the animals most impacted by fire are those with low dispersal ability (*e.g.*, Abreu *et al.* 2004, Koproski *et al.* 2006). Anurans have a permeable skin and their eggs are susceptible to dehydration, which increases their vulnerability to fire (Wells 2007). Furthermore, their chance to survive to fires is reduced, since anurans have low dispersal ability in average, and population sizes can be strongly reduced after fire (Papp & Papp 2000, Rocha *et al.* 2008). Besides, fire could also affect anuran diet by decreasing prey availability (Rocha *et al.* 2008). Fire has also the potential to affect community structure, as observed in the Chaco, where fire promoted a decrease in species richness of amphibians (Cano & Leynaud 2010). The lack of such studies in highland grasslands prevents a better evaluation of the impact of fire on anurans. Long-term studies that use temporal asymmetrical designs to detect environmental disturbances (Underwood 1994) are urging.

Fires are frequent during the dry season in highland grasslands. Currently, the number of fires recorded in the Serra da Bocaina and Itatiaia National Parks are higher than areas of Cerrado, where natural fire is more frequent (Aximoff 2011). Furthermore, fires can occur with a lower frequency in the Araras Biological Reserve and in the Serra dos Órgãos National Park (Aximoff 2011). These data show that fire is a real threat to anurans in those Parks. For example, some endemic and threatened species could potentially be impacted by fire, such as *Physalaemus barrioi*, which is endemic to highland grasslands of the Serra da Bocaina (Provete *et al.* 2012, Garey *et al.* 2014), *Melanophryniscus moreirae*, *Holoaden bradei* and *Paratelmatobius lutzii* of the Parque Nacional do Itatiaia, and *Thoropa petropolitana* of the Parque Nacional da Serra dos Órgãos e Área de Proteção Ambiental de Petrópolis (Aximoff 2011). Therefore, fire suppression in these environments should be a priority action to conserve flora and fauna (Aximoff 2011).

Diseases

One of the major threats to amphibians is emerging diseases. Chytridiomycosis is an emergent disease caused by the fungus *Batrachochytrium dendrobatidis* that has caused the decline and local extinction of over 200 amphibian species worldwide (Martel *et al.* 2013). Specifically, the fungus has been recorded in at least 18 anuran species occurring in highland grasslands: *Ischnocnema guentheri* (Gründler *et al.* 2012), *Rhinella icterica* (Toledo *et al.* 2006), *R. ornata* (Toledo *et al.* 2006), *Haddadus binotatus* (Gründler *et al.* 2012), *Aplastodiscus perviridis* (Gründler *et al.* 2012), *B. circumdata* (Toledo *et al.* 2006), *Bokermannohyla gouveai* (Carnaval *et al.* 2006), *Dendropsophus microps* (Gründler *et al.* 2012), *D. minutus* (Becker & Zamudio 2011), *Hypsiboas albopunctatus* (Toledo *et al.* 2006), *H. pardalis* (Gründler *et al.* 2012), *H. prasinus* (Gründler *et al.* 2012), *Scinax hayii* (Gründler *et al.* 2012), *Hylodes magalhaesi* (Gründler *et al.* 2012), *Thoropa miliaris* (Toledo *et al.* 2006), *Leptodactylus latrans* (Herrera *et al.* 2005), and *Lithobates catesbeianus* (Toledo *et al*. 2006). Due to the wide distribution and eminent risks associated with contamination by the fungus, monitoring studies of threatened populations are necessary.

Agriculture and exotic species

The conversion of natural landscapes into a forestry matrix affects biodiversity by changing resource availability, shading, allelopathic effects, changes in soil, and water body's physico - chemical characteristics (Richardson 1998, Bustamante & Simonetti 2005). Highland areas in Southeastern Brazil are commonly converted into forestry systems, using exotic species mainly *Pinus* and *Eucalyptus*. The introduction of exotic species has multiple impacts on natural ecosystems and native species (Stohlgren & Jarnevich 2009). Forestry may influence anuran species distribution (Parris & Lindenmayer 2004), community structure (Machado *et al.* 2012), and the ecosystem functioning by altering nutrient cycling and trophic interactions (Bustamante & Simonetti 2005). For example, *Pinus* has colonized areas outside plantations both in typical highland grasslands and nearby natural forests in Paraná (Mocochinski & Sheer 2008), Serra da Bocaina (pers. obs.), and Curucutu section of the Serra do Mar State Park (Malagoli 2013). The expansion of these cultures into natural grasslands may affect anurans negatively. Key actions to minimize the impacts of forestry involve the gradual removal, and the effective management of plantations in and at the edge of grasslands (Malagoli 2013). Furthermore, enforcement of land use regulations preventing *Pinus* plantation in highland grasslands is essential.

Exotic animals are also a threat to anurans of highland grasslands. The introduction of animal species in an environment may reduce and even eliminate prey populations and inferior competitors, alter the trophic structure, and nutrient cycling (Mack *et al.* 2000). The only area of highland grasslands where there are records of an exotic species (*Lithobastes catesbeianus*) is the Campos do Jordão State Park in the Serra da Mantiqueira (Gomes 2009). This species has been introduced in many localities in Brazil for commercial purposes (Both *et al*. 2011) and has many negative impacts on native anuran populations by competing (Kupferberg 1997) with preying (Leivas *et al.* 2012) upon native species and transmitting pathogens (Schloegel *et al.* 2010), which promoted the decline of some amphibian populations (Kats & Ferrer 2003). This species was also recorded in areas of Montane Rain Forest (between 700 and 800 m) of the Curucutu section of the Serra do Mar State Park (Malagoli 2013), which suggest the imminent risk to anurans in this region. Additionally, niche modeling studies have found that *L. catesbeianus* has the potential to invade other areas of highland grasslands (Giovanelli *et al*. 2007), reinforcing the need to control populations of this species. Management actions may involve the active removal of these organisms.

Mining

Mining activities damage ecosystems mainly by the contamination of soil, water, and air. Contamination may occur by acid mine drainage (AMD), when the mineral or metal of interest is associated with sulfides (Mello & Abrahão 1998, Soares & Borma 2002). Moreover, mining activities produce heavy metal waste, such as Arsenic, Cadmium, Lead, Chromium, and Mercury, and organic compounds, such as polycyclic aromatic hydrocarbons, phenols, and alkenes (Silva *et al*. 2000, Leonard *et al*. 2004). Heavy metals and organic compounds from mining activities may change cellular and tissue processes, affecting metabolic and physiological condition of animals (Silva *et al.* 2000, Leonard *et al*. 2004), causing malformations and increasing mortality of amphibians (Lannoo 2008). However, the response of anurans to mining varies among species (Mazerolle 2003, Lannoo 2008). Mining has a negative impact on anurans both at the population, since it decreases the availability of aquatic environments, and at the community scale

(Muncy *et al.* 2014), reducing species abundance and richness (Mazerolle 2003, Muncy *et al.* 2014).

Currently, the only area of highland grasslands threatened by bauxite mining is the Serra Fina, within the Environmental Protection Area (APA) of Mantiqueira. Bauxite mining is highly detrimental, because it drastically transforms the environment by the removal of soil and associated biota. Information on species occurrence on the Serra Fina is scarce and systematic surveys are still lacking. The only species known to occur in this area is *Melanophryniscus moreirae* (Marques *et al.* 2006), which is considered Near Threatened by IUCN (2014). In order to conserve the anuran fauna of this locality, mining activities should be restricted or even banned in highland grasslands, due to its impacts on natural environments.

Expansion of urban and semi-urban areas

The primary impact of urban and semi-urban areas on biodiversity is the conversion of natural landscapes, resulting in habitat loss, fragmentation, and disconnection (Becker *et al.* 2007). The expansion of urban and semi-urban areas in mountainous regions, such as the construction of rural smallholdings and installation of telecom transmission towers (*e.g.*, Pico do Caratuva, Serra do Ibitiraquire and Serra da Bocaina) could potentially harm the ecosystem of highland grasslands (Mocochinski & Sheer, 2008, MV Garey personal communication). The expansion of human habitations is a threat to highland grasslands outside Protected Areas, especially in the APA da Mantiqueira and Guaratuba, and the Serra da Bocaina, where a considerable part of the grasslands are outside the National Park boundaries. The supervision of constructions in Protected Areas and those of sustainable use are essential for anuran conservation. Furthermore, environmental education projects aiming to educate people about the need to conserve this unique ecosystem is urging.

Conclusion and prospective research areas

Highland grasslands have been poorly studied historically. In this study, we provided a preliminary list of anuran species occurring in this unique environment, pointing out endemic species and their conservation status. However, our data suffer from a number of shortcomings that prevented us from analyzing it in a more comprehensive way, mainly the lack of systematic surveys in some areas, such as Araras Biological Reserve, Pico do Paraná State Park, Pico do Marumbi State Park, Guaratuba Environmental Protection Area, Saint-Hilaire Lange National Park, Graciosa State Park, Guaraqueçaba Environmental Protection Area, Serra do Papagaio State Park, Caparaó National Park, and Mantiqueira Environmental Protection Area. Long-term field surveys (*e.g.*, Garey *et al*. 2014) should be encouraged if a broad understanding of anuran species distribution in the Atlantic Forest is to be gained.

Due to the difficulty of access, terrain declivity, and severe weather, highland grasslands have historically suffered little interference from human activities compared to lowland areas. Most highland grasslands (approximately 90%) are within protected areas in Brazil (Aximoff 2011), yet these environments are affected by various anthropogenic impacts (Martinelli 2007), such as expansion of urban and semi-urban areas, seasonal and criminal fire, invasion by exotic species and mining. Additionally, anurans from high altitude areas are apparently more prone to get infected by the chytrid fungus, whose growth is favored in cool and humid weather. However, detailed studies testing the impact of such disturbances on the anuran fauna of highland grasslands are lacking. Since anuran species inhabiting such seasonal environments have specific behavioral and life history adaptations, gathering data on these disturbances is urging in order to better inform conservation practices and management plans.

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REFERENCES

Abreu, K. C., Koproski, L. P., & Kuczach, A. M. 2004. Grandes felinos e o fogo no Parque Nacional de Ilha Grande, Brasil. Floresta, 34(2), 163-167.

Alford, R. A., & Richards, S. J. 1999. Global amphibian declines: a problem in applied ecology. Annual Review of Ecology and Systematics, 30(1), 133-165.

Alves, A. C. R., Ribeiro, L. F., Haddad, C. F. B., & Reis, S. F. 2006. Two new species of *Brachycephalus* (Anura: Brachycephalidae) from the Atlantic Forest in Paraná state, southern Brazil. Herpetologica, 62(2), 221-33.

AmphibiaWeb. 2014. Information on amphibian biology and conservation. Retrieved from http://amphibiaweb.org

Aximoff, I. 2011. O que perdemos com a passagem do fogo pelos campos de altitude do Estado do Rio de Janeiro. Biodiversidade Brasileira, 1(2), 180-200.

Aximoff, I., & Rodrigues, R. C. 2011. Histórico dos incêndios florestais no Parque Nacional do Itatiaia. Ciência Florestal, 21(1), 83-92.

Becker, C. G., Fonseca, C. R., Haddad, C. F. B., Batista, R. F., & Prado, P. I. 2007. Habitat split and the global decline of amphibians. Science, 318(5857), 1775-1777.

Becker, C. G., & Zamudio, K. R. 2011. Tropical amphibian populations experience higher disease risk in natural habitats. Proceedings of the National Academy of Sciences, 108(24), 9893-9898.

Bini, L. M., Diniz-Filho, J. A. F., Rangel, T. F. L. V. B., Bastos, R. P., & Pinto, M. P. 2006. Challenging Wallacean and Linnean shortfalls: knowledge gradients and conservation planning in a biodiversity hotspot. Diversity and Distributions, 12(5), 475-482.

Blaustein, A. R., & Kiesecker, J. M. 2002. Complexity in conservation: lessons from the global decline of amphibian populations. Ecology Letters, 5(4), 597-608.

Both, C., Lingnau, R., Santos-Jr, A., Madalozzo, B., Lima, L. P., & Grant, T. 2011. Widespread occurrence of the American Bullfrog, *Lithobates catesbeianus* (Shaw, 1802) (Anura: Ranidae), in Brazil. South American Journal of Herpetology, 6(2), 127-134.

Bokermann, W. C. A. 1967a. Três novas espécies de *Physalaemus* do sudeste brasileiro (Amphibia, Leptodactylidae). Revista Brasileira de Biologia, 27(2), 135-143.

Bokermann, W. C. A. 1967b. Una nueva especie de *Elosia* de Itatiaia, Brasil (Amphibia, Leptodactylidae). Neotropica, 13(42), 135-137

Bokermann, W. C. A. 1967c. Observações sôbre *Melanophryniscus moreirae* (Mir. Rib.) (Amphibia - Brachycephalidae). Anais da Academia Brasileira de Ciências, 39(2), 301-306.

Brasil. 2014. Ministério do Meio Ambiente. Portaria MMA nº444/2014 de 17 de dezembro de 2014. Lista Nacional Oficial de Espécies da Fauna Ameaçadas de Extinção. Retrieved from http://www.icmbio.gov.br/portal/biodiversidade/fauna-brasileira/lista-de-especies.html

Bustamante, R. O., & Simonetti, J. A. 2005. Is *Pinus* radiate invading the native vegetation in central Chile? Demographic responses in a fragmented forest. Biological Invasions, 7(2), 243-249.

Cano, P. D., & Leynaud, G. C. 2010. Effects of fire and cattle grazing on amphibians and lizards in northeastern Argentina (Humid Chaco). European Journal Wildlife Research, 56(3), 411-420.

Caramaschi, U., & Cruz, C. A. G. 2004. Duas novas espécies de *Hyla* do grupo de *H. polytaenia* Cope, 1870 do sudeste do Brasil (Amphibia, Anura, Hylidae). Arquivos do Museu Nacional, 62(3), 247-254.

Caramaschi, U., & Pombal Jr, J. P. 2006. Notes on the type-series of *Holoaden bradei* B. Lutz and *Holoaden luderwaldti* Miranda-Ribeiro (Anura, Brachycephalidae). Revista Brasileira de Zoologia, 23(4), 1261-1263.

Cardoso da Silva, J. M., Cardoso de Sousa, M., & Castelletti, C. H. M. 2004. Areas of endemism for passerine birds in the Atlantic forest, South America. Global Ecology and Biogeography, 13(1), 85-92.

Carnaval, A. C. O. Q., Puschendorf, R., Peixoto, O. L., Verdade, V. K., & Rodrigues, M. T. 2006. Amphibian chytrid fungus broadly distributed in the Brazilian Atlantic Rain Forest. EcoHealth, 3(1), 41-48.

Cochran, D. M. 1938. Diagnoses of new frogs from Brazil. Proceedings of the Biological Society of Washington, 51, 41-42.

Collins, J. P., & Storfer, A. 2003. Global amphibian declines: sorting the hypotheses. Diversity and Distributions, 9(2), 89-98.

Da Silva, F. R., Almeida-Neto, M., & Arena, M. V. N. 2014. Amphibian beta diversity in the Brazilian Atlantic Forest: Contrasting the roles of historical events and contemporary conditions at different spatial scales. Plos One, 9(10), e109642.

De Vos, J. M., Joppa, L. N., Gittleman, J. L., Stephens, P. R., & Pimm, S. L. 2015. Estimating the normal background rate of species extinction. Conservation Biology, 29(2), 452-462.

Dirzo, R., & Raven, P. H. 2003. Global state of biodiversity and loss. Annual Review of Environment and Resources, 28(1), 137-167.

Dirzo, R., Young, H. S., Galetti, M., Ceballos, G., Isaac, N. J. B., & Collen, B. 2014. Defaunation in the Anthropocene. Science, 345(6195), 401-406.

Eterovick, P. C., Carnaval, A. C. O. Q., Borges-Nojosa, D. M., Silvano, D. L., Segalla, M. V., & Sazima, I. 2005. Amphibian declines in Brazil: an overview. Biotropica, 37(2), 166-179.

Feio, R. N., Napoli, M. F., & Caramaschi, U. 2006. Considerações taxonômicas sobre *Thoropa miliaris* (Spix, 1824), com revalidação e redescrição de *Thoropa taophora* (Miranda-Ribeiro, 1923) (Amphibia, Anura, Leptodactylidae). Arquivos do Museu Nacional, 64(1), 41-60.

Folly, M., Hepp, F., Carvalho-e-Silva, S. P., & Duellman, W. E. 2014. Taxonomic status and redescription of *Flectonotus ulei* (Anura: Hemiphractidae), with a key for the species of *Fritziana*. Zoologia, 31(4), 393-399.

Frost, D. 2014. Amphibian species of the world: an Online Reference. Version 6.0. Retrieved from http://research.amnh.or/herpetology/amphibia/index.html

Garcia, R. J. F., & Pirani, J. R. 2003. Revisão sobre o diagnóstico e caracterização da vegetação campestre junto à crista de serras, no Parque Estadual da Serra do Mar, São Paulo, SP, Brasil. Hoehnea, 30(3), 217-242.

Garey, M. V., Provete, D. B., Martins, I. A., Haddad, C. F. B., & Rossa-Feres, D. C. 2014. Anurans from the Serra da Bocaina National Park and surrounding buffer area, southeastern Brazil. Check List, 10(2), 308-316.

Giovanelli, J. G. R., Haddad, C. F. B., Alexandrino, J. 2007. Predicting the potential of distribution of the alien invasive species American bullfrog (*Lithobates catesbeianus*) in Brazil. Biological Invasions, 10(5), 585-590.

Gomes, F. B. R. 2009. Uso de habitat e ecomorfologia de girinos na Serra da Mantiqueira, SP. Instituto de Biociências, Letras e Ciências Exatas da Universidade Estadual Paulista Júlio de Mesquita Filho. p. 92.

Gouvêa, E. 1979. Uma nova espécie de elosiineo da Serra do Itatiaia (Amphibia, Anura, Leptodactylidae). Revista Brasileira de Biologia, 39(4), 855-859.

Gründler, M. C., Toledo, L. F., Parra-Olea, G., Haddad, C. F. B., Giasson, L. O., Sawaya, R. J., Prado, C. P. A., Araujo, O. G., Zara, F. J., & Centeno, F. C. 2012. Interaction between breeding habitat and elevation affects prevalence but not infection intensity of *Batrachochytrium dendrobatidis* in Brazilian anuran assemblages. Diseases of Aquatic Organisms, 97(3), 173-184.

Guix, J. C., Montori, A., Llorente, G. A., Carretero, M. A., & Santos, X. 1998. Natural history and conservation of bufonids in four Atlantic rainforest areas of southeastern Brazil. Herpetological Natural History, 6(8), 1-12.

Haddad, C. F. B., Toledo, L. F., Prado, C. P. A., Loebmann, D., Gasparini, J. L., & Sazima, I. 2013. Guia dos anfíbios da Mata Atlântica: diversidade e biologia. 1ª ed. São Paulo, SP: Anolis Books: p. 545.

Herrera, R. A., Steciow, M. M., & Natale, G. S. 2005. Chytrid fungus parasitizing the wild amphibian *Leptodactylus ocellatus* (Anura: Leptodactylidae) in Argentina. Diseases of aquatic organisms, 64(3), 247-252.

Heyer, W. R. 1982. Two new species of the frog genus *Hylodes* from Caparaó, Minas Gerais, Brazil (Amphibia: Leptodactylidae). Proceedings of the Biological Society of Washington, 95(2), 377-385.

Heyer, W. R. 1983. Variation and systematics of frogs of the genus *Cycloramphus* (Amphibia, Leptodactylidae). Arquivos de Zoologia, 30(4), 235-339.

Heyer, W. R. 1984. Variation, systematics, and zoogeography of *Eleutherodactylus guentheri* and closely related species (Amphibia: Anura: Leptodactylidae). Smithsonian Contributions to Zoology, 402, 1-42.

Heyer, W. R., Rand, A. S., Cruz, C. A. G., & Peixoto, O. L. 1988. Decimations, extinctions, and colonizations of frog populations in southeast Brazil and their evolutionary implications. Biotropica, 20(3), 230-235.

Houlahan, J. E., Findlay, C. S., Schmidt, B. R., Meyer, A. H., & Kuzmin, S. L. 2000. Quantitative evidence for global amphibian population declines. Nature, 404(6779), 752-755.

Iganci, J. R. V., Heiden, G., Miotto, S. T. S., & Pennington, R. T. 2011. Campos de Cima da Serra: the Brazilian subtropical highland grasslands show an unexpected level of plant endemism. Botanical Journal of the Linnean Society, 167(4), 378-393.

IUCN. 2014. The IUCN Red List of Threatened Species. Version 2014.3. Retrieved from www.iucnredlist.org

Izecksohn, E., & Gouvêa, E. 1983. Sobre a identidade de *Elosia glabra* Miranda-Ribeiro (Amphibia, Anura, Leptodactylidae). Arquivos de Universidade Federal Rural do Rio de Janeiro, 6(2), 221-223.

Kats, L. B., & Ferrer, R. P. 2003. Alien predators and amphibian declines: review of two decades of science and the transition to conservation. Diversity and Distributions, 9(2), 99-110.

Koproski, L., Batista, A. C., & Soares, R. V. 2006. Impactos do fogo sobre serpentes (Squamata) no Parque Nacional de Ilha Grande (PR/MS), Brasil. Arquivos Ciência Veterinária, 9(2), 129-133.

Kupferberg, S. J. 1997. Bullfrog (*Rana catesbeiana*) invasion of a California river: the role of competition. Ecology, 78(6), 1736-1751.

Langone, J. A., & Segalla, M. V. 1996. Una nueva especie de *Eleutherodactylus* del Estado de Paraná, Brasil. Comunicaciones Zoológicas del Museo de Historia Natural de Montevideo, 12(185), 1-5.

Lannoo, M. 2008. Malformed frogs: the collapse of aquatic ecosystems. 1st ed. Califórnia. Oakland, CA: University of California Press: p. 288.

Leivas, P. T., Leivas, G. W. T., & Moura, M. O. 2012. Diet and trophic niche of *Lithobates catesbeianus* (Amphibia: Anura). Zoologia, 29(5), 405-412.

Leonard, S. S., Bower, J. J., & Shi, X. 2004. Metal-induced toxicity, carcinogenesis, mechanisms and cellular responses. Molecular and Cellular Biochemistry, 255(1-2), 3-10.

Lutz, B. 1951. Nota prévia sôbre alguns anfíbios anuros do Alto Itatiaia. O Hospital, 39(5), 705-707.

Lutz, B. 1958. Anfíbios novos e raros das Serras Costeiras do Brasil (New or rare frogs from the Coastal Ranges of Brazil). Memórias do Instituto Oswaldo Cruz, 56(2), 372-389.

Lutz, B. 1973. Brazilian Species of *Hyla*. 1st ed. Austin, TX: University of Texas Press: p. 296.

Lutz, B., & Carvalho, A. L. 1958. Novos anfíbios anuros das serras costeiras do Brasil. Memórias do Instituto Oswaldo Cruz, 56(1), 239-249.

Lynch, J. D. 1979. The amphibians of the lowland tropical forests. In: W. E. Duellman (Ed.), The South American herpetofauna: its origin, evolution, and dispersal. pp. 189-215. Lawrence: Museum Natural History Monograph No. 7, University of Kansas.

Machado, I. F., Moreira, L. F., & Maltchik, L. 2012. Effects of pine invasion on anurans assemblage in southern Brazil coastal ponds. Amphibia-Reptilia, 33(2), 227-237.

Mack, R. N., Simberloff, D., Lonsdale, W. M., Evans, H., Clout, M., & Bazzaz, F. A. 2000. Biotic invasions:

causes, epidemiology, global consequences, and control. Ecological Applications, 10(3), 689-710.

Malagoli, L. R. 2013. Diversidade e distribuição dos anfíbios anuros do núcleo Curucutu, Parque Estadual da Serra do Mar, SP. Instituto de Biociências de Rio Claro da Universidade Estadual Paulista. p. 211.

Mângia, S., Santana, D. J., Cruz, C. A. G., & Feio, R. N. 2014. Taxonomic review of *Proceratophrys melanopogon* (Miranda-Ribeiro, 1926) with description of four new species (Amphibia, Anura, Odontophrynidae). Boletim do Museu Nacional, 531, 1-33.

Marques, R. M., Colas-Rosas, P. F., Toledo, L. F., & Haddad, C. F. B. 2006. Amphibia, Anura, Bufonidae, *Melanophryniscus moreirae*: distribution extension. Check List, 2(1), 68-69.

Martel, A., Van Der Sluijs, A. S., Blooi, M., Bert, W., Ducatelle, R., Fisher, M. C., Woeltjes, A., Bosman, W., Chiers, K., Bossuyt, F., & Pasmans, F. 2013. *Batrachochytrium salamandrivorans* sp. nov. causes lethal chytridiomycosis in amphibians. Proceedings of the National Academy of Sciences, 110(38), 15325-15329.

Martins, I. A., & Haddad, C. F. B. 2010. A new species of *Ischnocnema* from highlands of the Atlantic Forest, Southeastern Brazil (Terrarana, Brachycephalidae). Zootaxa, 3(2617), 55-65.

Martinelli, G. 2007. Mountain biodiversity in Brazil. Revista Brasileira Botânica, 30(4), 587-597.

Mazerolle, M. J. 2003. Detrimental effects of peat mining on amphibian abundance and species richness in bogs. Biological Conservation, 113(2), 215-23.

Mello, J. W. V., & Abrahão, W. A. P. 1998. Geoquímica da drenagem ácida. In: E. L. Dias & J. W. V. Mello (Eds.), Recuperação de áreas degradadas. pp. 45-57. Viçosa: Folha de Viçosa.

Mocochinski, A. Y., & Scheer, M. B. 2008. Campos de altitude na serra do mar paranaense: aspectos florísticos. Floresta, 38(4), 625-640.

Morellato, L. P. C., & Haddad, C. F. B. 2000. Introduction: The Brazilian Atlantic Forest. Biotropica, 32(4), 786-792.

Muncy, B. L., Price, S. J., Bonner, S. J., & Barton, C. D. 2014. Mountaintop removal mining reduces stream salamander occupancy and richness in southeastern Kentucky (USA). Biological Conservation, 180(6779), 115-21.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., Fonseca, G. A. B., & Kent, J. 2000. Biodiversity hotspots for conservation priorities. Nature, 403(6772), 853-858.

Olson, D. M., Dinerstein, E., Wikramanayake, E. D., Burgess, N. D., Powell, G. V., Underwood, E. C., D'amico, J. A., Itoua, I., Strand, H. E., & Morrison, J. C. 2001. Terrestrial ecoregions of the world: a new map of life on earth. A new global map of terrestrial ecoregions provides an innovative tool for conserving biodiversity. Bioscience, 51(11), 933-938.

Orrico, V. G. D., Mongin, M. M., & Carvalho-e-Silva, A. M. P. T. 2007. The tadpole of *Hypsiboas latistriatus* (Caramaschi & Cruz, 2004), a species of the *Hypsiboas polytaenius* (Cope, 1870) clade (Amphibia, Anura, Hylidae). Zootaxa, 1531(1531), 25-37.

Papp, M. G., & Papp, C. O. G. 2000. Decline in a population of the treefrog *Phyllodytes luteolus* after fire. Herpetological Review, 31(2), 93-95.

Parris, K. M., & Lindenmayer, D. B. 2004. Evidence that creation of a *Pinus radiata* plantation in south-eastern Australia has reduced habitat for frogs. Acta Oecologica, 25(1-2), 93-101.

Peixoto, O. L. 1981. Nova especie de *Hyla* da Serra dos Órgãos, Estado do Rio de Janeiro, Brasil (Amphibia, Anura, Hylidae). Revista Brasileira de Biologia, 41, 515-520.

Percequillo, A. R., Weksler, M., & Costa, L. P. 2011. A new genus and species of rodent from the Brazilian Atlantic Forest (Rodentia: Cricetidae: Sigmodontinae: Oryzomyini), with comments on Oryzomyine biogeography. Zoological Journal of the Linnean Society, 161(2), 357-390.

Pombal Jr, J. P., Wistuba, E. M., & Bornschein, M. R. 1998. A new species of brachycephalid (Anura) from the Atlantic rain forest of Brazil. Journal of Herpetology, 32(1), 70-74.

Provete, D. B., Garey, M. V., Toledo, L. F., Nascimento, J., Lourenço, L. B., Rossa-Feres, D. C., & Haddad, C. F. B. 2012. Redescription of *Physalaemus barrioi* (Anura: Leiuperidae). Copeia, 2012(3), 507-518.

Ribeiro, K. T., & Freitas, L. 2010. Impactos potenciais das alterações no Código Florestal sobre a vegetação de campos rupestres e campos de altitude. Biota Neotropica, 10(4), 239-246.

Ribeiro, L. F., Alves, A. C. R., Haddad, C. F. B., & Reis, S. F. 2005. Two new species of *Brachycephalus* Günther, 1858 from the state of Paraná, southern Brazil (Amphibia, Anura, Brachycephalidae). Boletim do Museu Nacional, 519, 1-18.

Ribeiro, M. C., Metzger, J. P., Martensen, A. C., Ponzoni, F. J., & Hirota, M. M. 2009. The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. Biological Conservation, 142(6), 1141-53.

Richardson, D. M. 1998. Forestry trees as invasive aliens. Conservation Biological, 12(1), 18-26.

Rocha, C. D. F., Ariani, C., Menezes, V., & Vrcibradic, D. 2008. Effects of a fire on a population of treefrogs (*Scinax* cf. *alter*, Lutz) in a restinga habitat in southern Brazil. Brazilian Journal of Biology, 68(3), 539-543.

Rodriguez, D., Becker, C. G., Pupin, N. C., Haddad, C. F. B., & Zamudio, K. R. 2014. Long-term endemism of two highly divergent lineages of the amphibian-killing fungus in the Atlantic Forest of Brazil. Molecular Ecology, 23(4), 774-787.

Safford, H. D. 1999a. Brazilian Páramos I. An introduction to the physical environment and vegetation of the Campos de Altitude. Journal of Biogeography, 26(4), 693-712.

Safford, H. D. 1999b. Brazilian Páramos II. Macro- and mesoclimate of the Campos de Altitude and affinities with high mountain climates of the tropical Andes and Costa Rica. Journal of Biogeography, 26(4), 713-737.

Safford, H. D. 2001. Brazilian Páramos. III. Patterns and rates of postfire regeneration in the Campos de Altitude. Biotropica, 33(2), 282-302.

Safford, H. D. 2007. Brazilian Páramos IV. Phytogeography of the Campos de Altitude. Journal of Biogeography, 34(10), 1701-1722.

Santos, J. T., Oliveira, E. D., São Pedro, V. A., Monteiro-Leonel, A. C., & Feio, R. N. 2009. Amphibia, Anura, *Hypsiboas stenocephalus*: Distribution extension and geographic distribution map. Check List, 5(1), 27-31.

Segalla, M. V., Caramaschi, U., Cruz, C. A. G., Grant, T., Haddad, C. F. B., Langone, J. A., & Garcia, P. C. A. 2014. Brazilian amphibians: list of species. Herpetologia Brasileira, 3(2), 37-48.

Schloegel, L. M., Ferreira, C. M., James, T. Y., Hipolito, M., Longcore, J. E., Hyatt, A. D., Yabsley, M., Martins, A. M. C. R. P. F., Mazzoni, R., Davies, A. J., & Daszak, P. 2010. The North American bullfrog as a reservoir for the spread of *Batrachochytrium dendrobatidis* in Brazil. Animal Conservation, 13(6772), 53-61.

Sick, H. 1984. Ornitologia Brasileira. 1ª ed. Brasília, DF: Editora da Universidade de Brasília: p. 827.

Silva, J., Freitas, T. R., Heuser, V., Marinhos, J. R., & Erdtmann, B. 2000. Genotoxicity biomonitoring in coal regions using wild rodent *Ctenomys torquatus* by Comet assay and micronucleus test. Environmental Molecular Mutagen, 35(4), 270-278.

Siqueira, C. C., Vrcibradic, D., Almeida-Gomes, M., Menezes, V. A., Borges-Junior, V. N. T., Hatano, F. H., Pontes, J. A. L., Goyannes-Araújo, P., Guedes, D. M., & Van Sluys, M. 2011. Species composition and density estimates of the anurofauna of a site within the northernmost large Atlantic Forest remnant (Parque Estadual do Desengano) in the state of Rio de Janeiro, Brazil. Biota Neotropica, 11(4), 131-137.

Smith, J. K. 2000. Wildland fire in ecosystems: effects of fire on fauna. General Technical Report RMRS-GTR-42-volume 1; p. 83. Ogden: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Retrieved from www.fs.fed.us/rm/pubs/rmrs_gtr042_1.pdf

Soares, P. S. M., & Borma, L. D. S. 2002. Drenagem ácida e gestão de resíduos sólidos de mineração. In: R. B. E. Trindade & O. Barbosa Filho (Eds.), Extração de Ouro: princípios, Tecnologia e Meio Ambiente. pp. 253-276. Rio de Janeiro: CETEM, Centro de Tecnologia Mineral, Ministério da Ciência e Tecnologia.

Stohlgren, T. J., & Jarnevich, C. S. 2009. Risk assessment of invasive species. In: M. N. Clout & P. A. Williams (Eds.), Invasive species management: a handbook of techniques. pp. 19-35. Oxford: Oxford University Press.

Targino, M., & Carvalho-e-Silva, S. P. 2008. Redescription of *Ischnocnema holti* (Amphibia, Anura). Revista Brasileira de Zoologia, 25(4), 716-723.

Targino, M., Costa, P. N., & Carvalho-e-Silva, S. P. 2009. Two new species of the *Ischnocnema lactea* species series from Itatiaia highlands, southeastern Brazil (Amphibia, Anura, Brachycephalidae). South American Journal of Herpetology, 4(2), 139-150.

Thomé, M. T. C., Zamudio, K. R., Haddad, C. F. B., & Alexandrino, J. 2014. Barriers, rather than refugia, underlie the origin of diversity in toads endemic to the Brazilian Atlantic Forest. Molecular Ecology, 23(24), 6152-6164.

Toledo, L. F., Britto, F. B., Araújo, O. G. S., Giasson, L. M. O., & Haddad, C. F. B. 2006. The occurrence of *Batrachochytrium dendrobatidis* in Brazil and the inclusion of 17 new cases of infection. South American Journal of Herpetology, 1(3), 185-191.

Tolledo, J., Oliveira, E. F., Feio, R. N., & Weber, L. N. 2009. Amphibia, Anura, Leiuperidae, *Physalaemus jordanensis* Bokermann, 1967: Distribution extension and geographic distribution map. Check List, 5(3), 422-424.

Underwood, A. J. 1994. On Beyond BACI: sampling designs that might reliably detect environmental disturbances. Ecological Applications, 4(1), 3-15.

Vasconcelos, M. F. 2011. O que são campos rupestres e campos de altitude nos topos de montanha do Leste do Brasil? Brazilian Journal of Botany, 34(2), 241-246.

Vasconcelos, T. S., Prado, V. H., Silva, F. R., & Haddad, C. F. B. 2014. Biogeographic distribution patterns and their correlates in the diverse frog fauna of the Atlantic Forest hotspot. PLoS One, 9(8), e104130.

Verdade, V. K., Valdujo, P. H., Carnaval, A. C., Schiesari, L., Toledo, L. F., Mott, T., Andrade, G. V., Eterovick, P. C., Menin, M., & Pimenta, B. 2012. A leap further: The Brazilian amphibian conservation action plan. Alytes, 29(1), 28-43.

Villalobos, F., Dobrovolski, R., Provete, D. B., & Gouveia, S. F. 2013. Is rich and rare the common share? Describing biodiversity patterns to inform conservation practices for South American anurans. PLoS One, 8(2), e56073.

Weber, L. N., Procaci, L. S., Salles, R. D. O. L., Silva, S. P., Corrêa, A. L., & Silva, S. P. C. 2007. Amphibia, Anura, Bufonidae, *Melanophryniscus moreirae*: Distribution extension. Check List, 3(4), 346-347.

Weber, L. N., Verdade, V. K., Salles, L., De Oliveira, R., Fouquet, A., & Carvalho-e-Silva, S. P. 2011. A new species of *Cycloramphus* Tschudi (Anura: Cycloramphidae) from the Parque Nacional da Serra dos Orgãos, Southeastern Brazil. Zootaxa, 2737, 19-33.

Wells, K. D. 2007. The ecology and behavior of amphibians. 1st ed. Chicago, IL: University of Chicago Press, p. 1400.

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