

## Impact of fire on anurans of rupestrian grasslands (campos rupestres): a case study in the Serra do Espinhaço, Brazil

LEANDRO DE OLIVEIRA DRUMMOND<sup>1,2</sup>, FILIPE RODRIGUES MOURA<sup>1</sup> & MARIA RITA SILVÉRIO PIRES<sup>1</sup>

<sup>1</sup>) Universidade Federal de Ouro Preto, Pós-Graduação em Ecologia de Biomas Tropicais. Campos Morro do Cruzeiro, s/n, Bauxita, CEP 35400-000, Ouro Preto, MG, Brazil

<sup>2</sup>) Universidade Federal do Rio de Janeiro, Departamento de Ecologia, Laboratório de Vertebrados. CP 68020, Ilha do Fundão. CEP 21941-901, Rio de Janeiro, RJ, Brazil

Corresponding author: LEANDRO DE OLIVEIRA DRUMMOND, e-mail: barrocolod@hotmail.com

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**Abstract.** The rupestrian grasslands of the Serra do Espinhaço (Espinhaço Mountain Range) are mainly a savanna vegetation complex with a high degree of anuran endemism. Although this fire-prone vegetation is frequently burned by natural and anthropogenic fires, there is no information about how populations of the anurans of this ecosystem respond to such an impact. Aiming to evaluate the effect of fire on the anuran composition of a typical rupestrian grasslands environment, a high-elevation temporary pond of about 500 m<sup>2</sup> (Lagoa Seca) in Parque Estadual do Itacolomi was monitored during three different one-year time periods: Pre-fire (PrF), immediately Post-fire (PoF) and Seven Years Post-fire (7PoF). Surveys took place every two weeks throughout each study period. An increase in anuran species richness was found immediately after the fire event. The species present during the periods when the vegetation was in advanced stages of regeneration (PrF and 7PoF) were not eliminated by the fire event. Additionally, five species were recorded at low densities exclusively in the PoF period. The factors that may provide fire resistance to anuran of rupestrian grasslands and the implications of the results for fire management plans, a conservation measure previously treated as a taboo by many Brazilian conservation managers, are discussed.

**Key words.** Amphibians, altitudinal grasslands, conservation, fire effect, rocky fields, savanna, Espinhaço Mountain Range.

### Introduction

Fire is recognized as an important factor in the formation of savanna and grassland landscapes (HOFFMANN & MOREIRA 2002, MIRANDA et al. 2002). In fact, according to COUTINHO (2006), natural fire is an ecological factor that can determine the structure of an entire ecosystem, mainly through selecting ecophysiological, morpho-anatomical and physiognomical-structural characteristics of the flora. The historical relationship between fire and highly fire-resistant plant species is one of the factors responsible for the structural and taxonomic diversification in savannas, like those of the Cerrado morphoclimatic domain (SIMON et al. 2009).

Despite the importance of fire in shaping natural environments, its impact on anurans remains poorly known (CONSTIBLE et al. 2001, CANO & LEYNAUD 2010, WARRENTHOMAS et al. 2013), and most of the existing information deals with observations in temperate regions (e.g. MOSELEY et al. 2003, MEANS et al. 2004, SCHURBON & FAUTH 2004, HOSSACK & PILLIOD 2011, GRUNDEL et al. 2015). Fire may change population dynamics of anurans both directly,

by causing the death of individuals, and indirectly, through alteration of habitat (GRESSWELL 1999). Fire can significantly alter an environment by altering the humidity and temperature of the soil, the structure of the vegetation, the depth of the leaf litter, the rate of soil erosion and the hydroperiod of aquatic habitats (CAIN et al. 1998, SCHURBON & FAUTH 2003).

Studies evaluating the effects of fire on Brazilian fauna are scarce, particularly for anurans (FRIZZO et al. 2011). This is surprising since Brazil harbors the richest anuran fauna in the world (SEGALLA et al. 2016) and possesses several biomes adapted to different fire regimes. Tropical forests in the Amazon and Atlantic Forest morphoclimatic domains, for example, have evolved under a low to nearly nonexistent fire regime (HARDERSTY et al. 2005). In fact, PAPP & PAPP (2000) and ROCHA et al. (2008) found fire to have negative effects on diet and population density of frogs associated with bromeliads of coastal sandbanks (restingas) of the Atlantic Forest morphoclimatic domain. On the other hand, MORAIS et al. (2011) found no effects of fire on the pattern of co-occurrence of anuran species in the only study carried out to date in the fire-prone sa-

vanna formations of the Cerrado morphoclimatic domain. It seems clear that, as far as anurans are concerned, much needs to be understood regarding the effects of fire on local fauna. This understanding is particularly important for properly designing and implementing conservation and management plans, such as the use of prescribed-fire or fire prevention and suppression measures.

Rupestrian grasslands (Campos rupestres in Portuguese) are vegetation complexes that occur above 900 m in elevation throughout the Serra do Espinhaço (Espinhaço Mountain Range) in central Minas Gerais State to northern Bahia State, and sparsely throughout some other mountainous areas of central Brazil (ALVES et al. 2014). This diverse and fire-prone mountainous mosaic of vegetation encompasses phytophysiognomies from grasslands to shrublands on shallow soils of quartzitic-sandstone and iron-ore with numerous rocky outcrops (GIULIETTI & PIRANI 1988, GIULIETTI et al. 1997, SCHAEFER et al. 2016). Both the flora and fauna of rupestrian grasslands are structurally very similar to that of the Cerrado, but with some influence from the Atlantic Forest and Caatinga, and some of the highest rates of endemism among phytophysiognomies in Brazil (GIULIETTI & PIRANI 1988, HEYER 1999).

Although rupestrian grasslands are frequently burned by natural and anthropogenic fires, there have been no studies on the effect of fire on its highly endemic anuran fauna (LEITE et al. 2008).

The present study evaluates the effect of fire on the anuran composition of a typical rupestrian grasslands environment in the state of Minas Gerais in southeastern Brazil. Sampling efforts targeted an isolated temporary pond and surveyed its anuran fauna before, after, and seven years after a fire event.

## Materials and methods

The study took place in Parque Estadual do Itacolomi (PEIT), a conservation unit encompassing an area of 7543 ha in the municipalities of Mariana and Ouro Preto, Minas Gerais, Brazil (Fig. 1). The park is in the transition zone between the Atlantic Forest and Cerrado morphoclimatic domains in the southern limit of the Serra do Espinhaço. The vegetation of the approximately 40% lowest elevations of the conservation unit is semideciduous seasonal rainforest, while the remaining higher areas, usu-

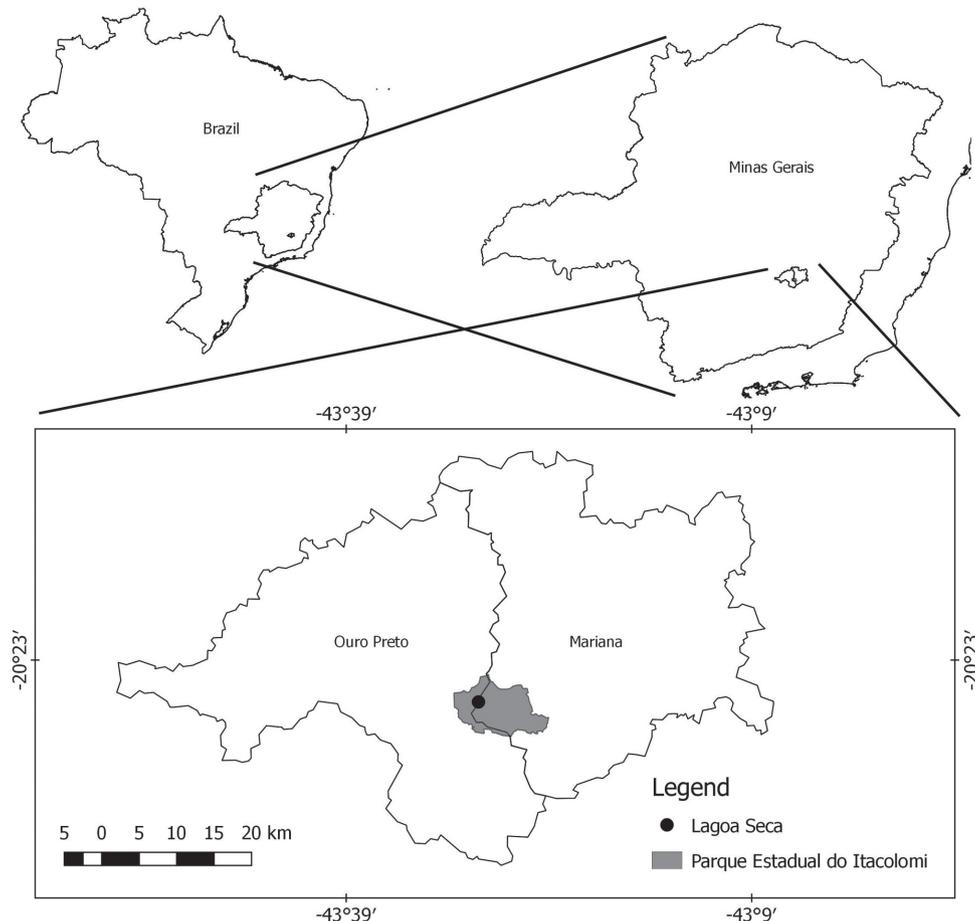


Figure 1. Geographic location of Parque Estadual do Itacolomi (shaded area) and the study site (Lagoa Seca, black dot), in the municipalities of Mariana and Ouro Preto, Minas Gerais State, Brazil.

ally above 1200 m, contain the complex of phytophysiognomies that comprise rupestrian grasslands (COSER et al. 2010, PEDREIRA & SOUZA 2011).

According to the Köppen classification, the study site has a mesothermic climate with dry winters and hot, rainy summers (Cwb; KOTTEC et al. 2006). The elevation varies from 700 m to 1772 m, the average annual rainfall is 2017 mm and is concentrated from November to March, while the average annual temperature is 21°C, with a maximum of 32°C and minimum of 8°C (COSER et al. 2010). The study site, Lagoa Seca, is a temporary pond of about 500 m<sup>2</sup> and maximum depth of 90 cm when completely full, located at an elevation of 1610 m (20°25'52" N, 43°29'12" W; WGS 84) near Pico do Itacolomi, the highest point in the park. Lagoa Seca is situated among typical rupestrian grasslands vegetation with abundant rocky outcrops (Fig. 2), and contains 21 species of macrophytes (ESKINAZI-SANT'ANNA et al. 2011), with a predominance of the emergent species *Juncus microcephalus*.

Fire events occur frequently in the vicinity of PEIT, but mainly towards the end of dry seasons. Most of these fires have both accidental or intentional anthropic origin,

such as to remove native vegetation in order to increase and improve pasture areas (FUJACO et al. 2010). Recently, the development of fire prevention and control programs has dramatically reduced the number of fire events within PEIT (FUJACO et al. 2010). Nonetheless, in early October 2007, a large anthropogenic fire burned almost the entire area of rupestrian grassland vegetation of PEIT. The fire burnt all macrophytes and much of the herbaceous and shrubby vegetation of the area surrounding Lagoa Seca.

Visits to Lagoa Seca were made every two weeks during three distinct one-year periods, for a total of seventy-two visits (24 each year; Fig. 2): (i) Pre-fire (PrF) – between the months of October 2004 and September 2005, when there had not been a fire event recorded at Lagoa Seca or its surroundings for at least 10 years; (ii) Post-fire (PoF) – October 2007 to October 2008, immediately after the fire event; and (iii) Seven Years Post-fire (7PoF) – November 2014 to October 2015, after complete regeneration of the burned vegetation.

Anurans were surveyed by direct search guided by male breeding activity and vocalization. During each visit, the



Figure 2. Studied temporary pond, Lagoa Seca, during four different periods: (A) Before the fire event (February 2006); (B) just after the fire event (October 2007); (C) One year after the fire event (October 2008); (D) Seven years after the fire event (December 2014).

pond, as well as the marginal vegetation to 10 meters from the high-water mark of the pond, were inspected. Individuals of all species of anurans active between 18:00 and 23:00 h were recorded.

Air temperature was measured with a mercury thermometer at the beginning and end of each survey. Daily rainfall data was provided by the environmental control area of the company Novelis do Brasil LTDA. for the PrF and PoF periods, and from Centro Nacional de Monitoramento e Alerta de Desastres Naturais for the 7PoF period. Variation in temperature and rainfall among the three study periods are presented in Figure 3.

Voucher specimens were killed with 5% xylocaine, fixed with 10% formalin, preserved in 70% alcohol and deposited in the Coleção Herpetológica of the Laboratório de Zoologia dos Vertebrados (LZV) of the Universidade Federal de Ouro Preto (Appendix I).

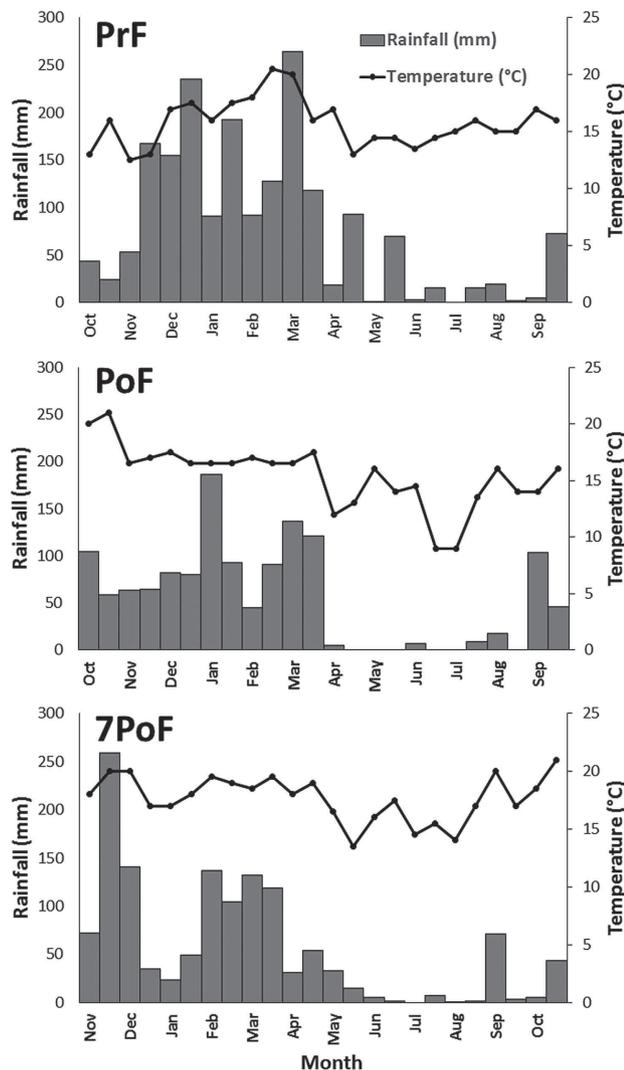


Figure 3. Annual variation of temperature and rainfall in the pre-fire (PrF), post-fire (PoF), and seven-year post-fire (7PoF) periods.

For all analyses, species presence/absence data for each field day were used. To assess the stability of community composition among the studied periods, species were classified according to their proportion of occurrence among field days for each study period: constant = observed on more than 50% of the field days; occasional = 25–50%; and rare = less than 25%. Sampling efficiency was evaluated using species accumulation curves produced by the program EstimateS version 9.1.0 (COLWELL 2013).

To test for differences in species composition of the anuran community among three study periods a PERMANOVA (Permutational Multivariate Analysis of Variance) was performed. PERMDISP was used to test for homogeneity of multivariate dispersion between each period, since PERMANOVA has the implicit assumption that dispersion is roughly constant across groups. PERMDISP results can also be useful for determining whether within-period temporal variation in assemblage structure differed among study periods (i.e. there were greater seasonal fluctuation in species composition in one period than in others?) (ANDERSON & WALSH 2013). Both analyses were made using the Vegan package (OKSANEN et al. 2015) in the R environment (R Core Team 2016) with a significance level of 0.05.

## Results

A total of fifteen species of anurans were recorded over the three study periods. The greatest species richness was recorded in the Post-fire period (PoF = 15 spp.), followed by the Pre-fire period (PrF = 10 spp.) and the Seven Years Post-fire period (7PrF = 8 spp.). Five species were exclusively recorded in PoF, each being recorded during a single field day: *Leptodactylus cunicularius*, *L. furnarius*, *L. fuscus*, *Rhinella crucifer*, and *Scinax fuscovarius*. All of these exclusive PoF species were represented by only a single individual, except for *Scinax fuscovarius*, which was represented by two. Additionally, all these exclusive PoF species were recorded performing reproductive activity, except by *Rhinella crucifer*. Two species, *Dendropsophus minutus* and *Physalaemus cuvieri*, were present only in the PrF and PoF periods, having seemingly disappeared by the 7PoF period (Table 1).

Sampling efficiency (i.e. the potential of not encountering a new species) differed among the three study periods as indicated by species accumulation curves. The curve for the 7PoF period stabilized on the 19<sup>th</sup> day of sampling, while the curve for the PrF period stabilized on the 22<sup>nd</sup> day of sampling. The curve of the PoF period failed to stabilize, and was continuing to increase through the last day of sampling, indicating that new species could be encountered with additional sampling effort during this period (Fig. 4).

During the PrF period, four rare and five occasional species were recorded (Table 1). After the fire, the number of rare species increased to nine. Most of these rare species were new records (5 spp.), but the frequency of *Ischnocnema juipoca*, previously considered common, decreased drastically enough for it to become rare. At 7PoF, there

## Impact of fire on anurans of rupestrian grasslands

Table 1. Frequency of occurrence of each species recorded at Lagoa Seca in the three study periods and their classification according to this frequency.

Species	Frequency			Classification		
	Pre-fire	Post-fire	7 Post-fire	Pre-fire	Post-fire	7 Post fire
<i>Ischnocnema juipoca</i>	38%	4%	38%	occasional	rare	occasional
<i>Dendropsophus minutus</i>	17%	38%	–	rare	occasional	–
<i>Pithecopus ayeaye</i>	21%	21%	25%	rare	rare	occasional
<i>Scinax curicica</i>	42%	54%	63%	occasional	constant	constant
<i>Scinax squalirostris</i>	38%	38%	29%	occasional	occasional	occasional
<i>Scinax rogerioi</i>	21%	33%	13%	rare	occasional	rare
<i>Scinax fuscovarius</i>	–	4%	–	–	rare	–
<i>Leptodactylus latrans</i>	46%	38%	75%	occasional	occasional	occasional
<i>Leptodactylus jolyi</i>	29%	25%	38%	occasional	occasional	occasional
<i>Leptodactylus furnarius</i>	–	4%	–	–	rare	–
<i>Leptodactylus fuscus</i>	–	4%	–	–	rare	–
<i>Leptodactylus cunicularius</i>	–	4%	–	–	rare	–
<i>Physalaemus cuvieri</i>	13%	21%	–	rare	rare	–
<i>Physalaemus erythros</i>	8%	8%	4%	rare	rare	rare
<i>Rhinella crucifer</i>	–	4%	–	–	rare	–

was an increase in constant species, such as *S. curicica* and *L. latrans*. The species *S. squalirostris*, *L. jolyi* and *P. erythros* maintained their frequency of occurrence throughout all three study periods (Table 2).

The anuran species composition of Lagoa Seca differed slightly, but significantly, among study periods (PERMANOVA,  $R^2=0.07$ ;  $F_{2,52}=2.01$   $p=0.02$ ). This difference occurred between the periods with the highest (PoF) and the lowest (7PoF) species richness ( $R^2=0.09$ ;  $F_{3,36}=3.53$ ;  $p<0.01$ ); PrF not differing from the other two periods. Additionally, there were no differences in intra-annual seasonal variation in species composition among the study periods (PERMDISP,  $F_{2,52}=0.26$ ;  $p=0.77$ ).

### Discussion

When evaluating the impacts of human activities on natural environments, it is essential to differentiate naturally

occurring fluctuations in species richness and abundance from those resulting from the human activities (PECHMANN et al. 1991, PECHMANN & WILBUR 1994). Unfortunately, long-term studies identifying patterns in population fluctuations are virtually absent in Brazil (SILVANO & SEGALLA 2005). Although long-term monitoring has not been performed at the Lagoa Seca, the fact that no species was eliminated from the study area, and that there was temporary settlements of new species after the fire strongly suggests that anurans of rupestrian grasslands possess some resistance to isolated fire events.

However, one thing that must be considered is the simplified environment that resulted from fire, which may have facilitated the visual detection of anurans. If so, this could possibly explain the increase in species richness in the PoF period. Nonetheless, most species and individuals were recorded by acoustic signals, and new species continued to be recorded even at the end of the PoF period, when the vegetation was already well regenerated. Furthermore,

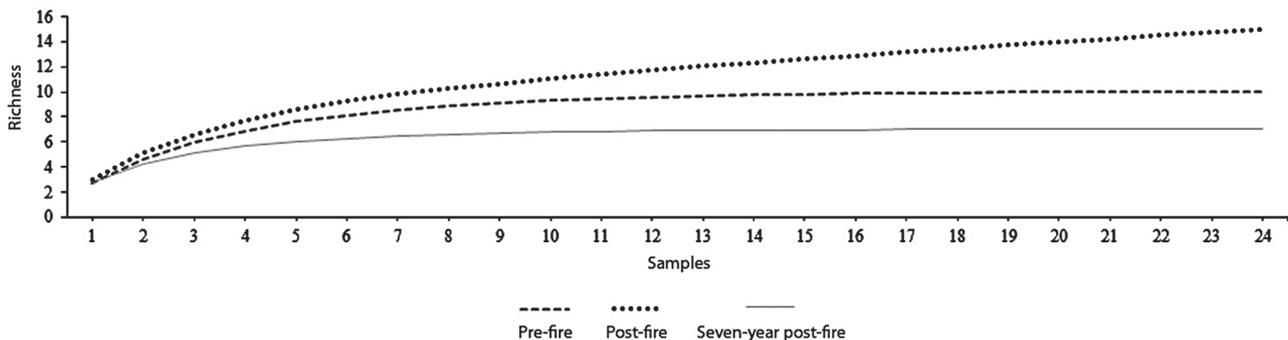


Figure 4. Species accumulation curves for the three study periods.



*cus* can tolerate high water temperatures (SHINYA & NETO 1990) and, consequently, low oxygen levels, a situation that can occur in small ponds in environments with low vegetation cover. ETEROVICK & SAZIMA (2000) state that the same can occur with tadpoles of *L. cunicularius*, *L. furnarius* and *P. cuvieri*. The burrowing capacity of species of *Leptodactylus* from the *L. fuscus* group (*L. fuscus*, *L. cunicularius*, *L. furnarius* and *L. jolyi*) likely provides resistance since during fire the temperature at 5 cm below the soil surface varies as little as 3°C (MIRANDA et al. 1993). Furthermore, these species have foam nests, which are considered adaptations for seasonal environments with unpredictable rainfall because they prevent the dehydration of the eggs (HEYER 1969), in addition to providing a microenvironment with higher thermal stability (DOWNIE 1988, DOBKIN & GETTINGER 1985).

Conversely, *I. juipoca* was recorded with lower constancy and abundance (personal observation) in the PoF period, and was probably the most negatively affected species in the studied environment. According PILLIOD et al. (2003) aquatic amphibians are more resistant to fire events than amphibians whose adults spend some time on dry land. *Ischnocnema juipoca* has direct development and uses bunch grasses as shelter, and vocalization and egg deposition sites (ETEROVICK & SAZIMA 2004, GIARETTA & FACURE 2008). Thus, this species may be susceptible to removal of this microenvironment by fire.

Currently, there is a global perception that fire management is important for the conservation of fire-prone environments (FIGUEIRA et al. 2016). Long periods of fire suppression can lead to dry biomass accumulation resulting in wildfires of greater intensities that eventually affect more sensitive phytophysiognomies that are usually protected from fire, like those associated with rock outcrops and riverine forests (NEVES & CONCEIÇÃO 2010, RIBEIRO & FIGUEIRA 2011, SCHMIDT et al. 2011). In the case of PEIT, the success of the fire suppression methods employed, in the form of fire brigades and environmental education programs, have resulted in a great reduction of fire events when compared to the surroundings (FUJACO et al. 2010). But this complete suppression could result in massive fire events, such as those of the years 2007 and 1997, which burned 20% and 70% of the reserve, respectively, impacting less fire-adapted phytophysiognomies, such as Semideciduous forest (FUJACO et al. 2010). The use of prescribed fires as management tools in rupestrian grasslands can lead to an increase in regional diversity by promoting a mosaic of vegetation types and fire regimes. However, deciding whether to use a specific prescribed fire regime is a complex and dynamic process that must consider temporal, biotic, abiotic, cultural, social, economic and historical factors (FIGUEIRA et al. 2016).

Anuran sensitivity to fire disturbance probably varies among life stages, among populations of the same species in different geographic regions and, certainly, among species that evolved in different fire regimes (PILLIOD et al. 2003). In the case of anurans of rupestrian grasslands, the present study recorded high tolerance to isolated fires at the

study site, which is apparently associated with the timing of the fire event (dry season) and the presence of protected wintering shelters like rock outcrops, burrows and termite mounds. Although this study suggests that fire management can be a good conservation measure for rupestrian grasslands, data for this ecosystem are still too limited, and researches in other areas and with other taxonomic groups are needed to clarify questions regarding the ideal extent, timing and frequency for this type of management.

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### Appendix I

#### Voucher specimens

*Dendropsophus minutus*: LZV1091A; *Ischnocnema juipoca*: LZV1063–64A, 1066A, 1264A, 3039A, 3056A; *Leptodactylus laevis*: LZV1099A; *Leptodactylus cunicularius*: LZV1271A; *Leptodactylus jolyi*: LZV3059A; *Physalaemus cuvieri*: LZV1045A, 1065A; *Physalaemus erythros*: LZV1265A, 3067A; *Rhinella crucifer*: LZV1100A; *Scinax curicica*: LZV1046A, 1130–33A (juvenile), 3057A; *Scinax fuscovarius*: LZV1085A; *Scinax rogerioi*: LZV1087A, 1088–90A (juvenile), 3037–39A; *Scinax squalirostris*: LZV3052–55A.