Herpetological Conservation and Biology 11(2):293–303.
Submitted: 22 December 2015; Accepted: 12 July 2016; Published: 31 August 2016.

AMPHIBIAN SPECIES COMPOSITION AND PRIORITIES FOR REGIONAL CONSERVATION AT THE ESPINHAÇO MOSAIC, SOUTHEASTERN BRAZIL

IZABELA M. BARATA[1,2,5], CAMILA M. CORREIA[2], AND GUILHERME B. FERREIRA[2,3,4]

[1]*Durrell Institute of Conservation and Ecology, School of Anthropology and Conservation, University of Kent, Marlowe Building, Canterbury, Kent, CT2 7NR, UK*
[2]*Instituto Biotrópicos, Praça JK, 25, Centro, Diamantina, Minas Gerais, Brazil*
[3]*Centre for Biodiversity & Environment Research, University College London, Gower Street, London, WC1E 6BT, UK*
[4]*Institute of Zoology, Zoological Society of London, Regent`s Park, London, NW1 4RY, UK*
[5]*Corresponding author, e-mail: ib208@kent.ac.uk*

***Abstract*.—The southern portion of the Espinhaço Range in Brazil is recognized worldwide as a priority area for biodiversity conservation, and it contains a high number of endemic anuran species. We conducted field surveys and compiled published data on amphibian community composition from seven sites within Espinhaço Mosaic (EM; 910,000 ha) to explore the contribution of this area to amphibian species richness in the southern Espinhaço Range. We aimed to describe local and regional community composition and to identify priorities for future amphibian surveys and inventories in the study area. We consider the EM a species-rich area sheltering 73 anuran species, which represents 36.5% of the amphibians known for the state of Minas Gerais, 57.5% of those in the Cerrado biome, and almost 70% of the species in the Espinhaço Range. Unequal sampling effort is a major concern in the study area, and species richness in under-sampled sites might increase as new assessments are conducted. Therefore, sites for which no data are available should be prioritized for species inventories. Although an increase in sampling effort is likely to reduce the proportion of exclusive species (i.e., species known to occur in only one of the seven investigated sites), we conclude that the levels of endemicity indicate a high number of narrowly distributed (micro-endemic) species. We believe anuran community composition and similarities in composition among the sites investigated are influenced by the gradient between the Cerrado and Atlantic Rainforest biomes, which deserves further investigation.**

Key Words.—anurans; biodiversity; cluster analysis; community composition; endemism; Espinhaço Range; species richness

INTRODUCTION

The Brazilian list of amphibians comprises 1,026 living species of the nearly 7,348 known species in the world (Frost, D.R. 2015. Amphibian species of the world: an online reference. Version 6.0. Available from http://research.amnh.org/herpetology/amphibia/index.html. [Accessed 10 May 2015]; Segalla, M.V., U. Caramaschi, C.A.G. Cruz, P.C.A. Garcia, T.L. Grant, C.F.B. Haddad, and J. Langone. 2015. Brazilian amphibians – list of species. Available online at: http://www.sbherpetologia.org.br [Accessed 9 January 2015]), a number that exceeds the latest estimates of amphibian species richness for the country (Pimm et al. 2010). Two biomes of particular interest for biodiversity conservation are the Cerrado and Atlantic Rainforest, both of which have high levels of endemism and are severely threatened by habitat loss (Myers et al. 2000). Valdujo et al. (2012) recorded 209 species from at least one locality within the Cerrado, including 108 endemics (51.7%), whereas Haddad et al. (2013) reported more than 500 amphibian species within the Atlantic Rainforest, and 88% endemism. The Espinhaço Range is the geographical divisor of these hotspots (the Cerrado to the west and Atlantic Rainforest to the east) and its unique geological conditions contribute to a high level of endemism for several taxa (Gontijo 2008), including amphibians (Leite et al. 2008; Leite 2012). According to Valdujo et al. (2012) some endemic anuran species occur only on the western slope and summit (Cerrado) of the Espinhaço Range, while others occur exclusively in a few localities on the eastern slope (Atlantic Rainforest).

The Espinhaço Range is nationally and regionally recognized as a priority area for biodiversity conservation (Projeto de Conservação e Utilização Sustentável da Diversidade Biológica Brasileira/ Ministério do Meio Ambiente [PROBIO/MMA] 2007; Drummond et al. 2005). The southern portion of the Espinhaço Range is a UNESCO Biosphere Reserve, a center of plant diversity (Davis et al. 1995), one of the Global 200 Ecoregions (Olson and Dinerstein 2001), an Important Bird Area for endemic species (Develey and Goerck 2009), and a center for amphibian endemism (Leite et al. 2008). In the southern Espinhaço Range, the landscape is characterized by several fragments of Cerrado and Atlantic Rainforest, some of which are

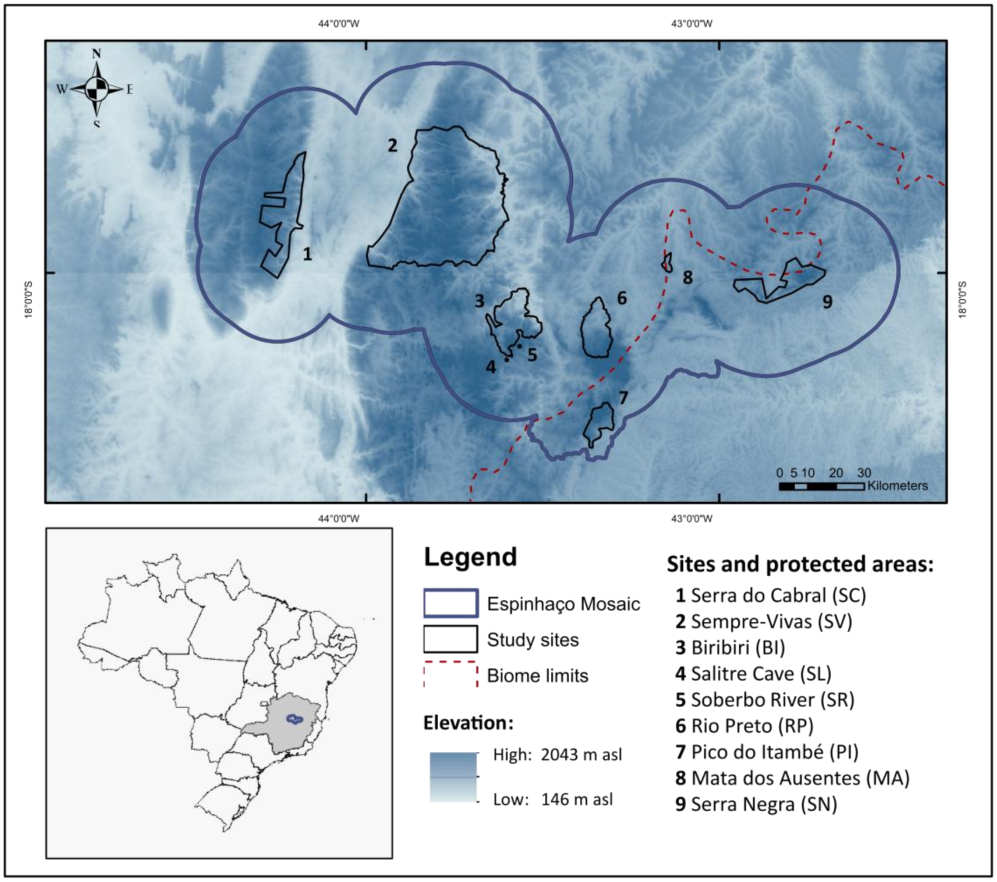

FIGURE 1. Study sites within the Espinhaço Mosaic, at South Espinhaço Range, Minas Gerais State (shaded area on inset map), southeastern Brazil. Sites are numbered; biome boundary (dotted red line) delimits Cerrado biome west of the boundary and Atlantic Rainforest biome to the east. Elevational bands also presented (meters above sea level).

legally protected by state and national authorities, composing a mosaic of protected areas of different sizes and shapes. In 2010 Brazilian authorities recognized the Espinhaço Mosaic in the state of Minas Gerais, southeastern Brazil (Mosaico Espinhaço: Alto Jequitinhonha-Serra do Cabral; hereby EM), which is listed as one of the 20 mosaics in Brazil (Gidsicki 2013).

Due to its level of diversity and threat, a national action plan was recently proposed for the conservation of threatened amphibian and reptile species in the southern Espinhaço Range (PAN Espinhaço 2012). However, an effective conservation plan requires at least some understanding of the target species (Brito 2004), and very often knowledge about biodiversity spatial patterns is crucial to regional conservation planning (Gaston and Rodrigues 2003). Practical decisions are usually made at regional or local scales (Bini et al. 2006), but unfortunately local data are lacking for several regions in the world, especially in the tropics (Collen et al. 2008). Conducting biodiversity surveys in such areas is the only way to overcome this data gap, with the added benefit of potentially finding species new to science and improving the understanding of the geographic distributions of species (Rondinini et al. 2005).

In this study we investigated the amphibian species richness and community composition in the EM. We conducted field surveys and compiled data on amphibian community composition for seven sites (five protected areas and two adjacent natural areas) at southern Espinhaço Range, all within EM. Furthermore, we explored the contribution of studied sites to amphibian species richness within the Espinhaço Range, and we also identified priorities for amphibian surveys and inventories in the state of Minas Gerais, especially in the EM.

MATERIALS AND METHODS

Our study area, the EM, is located at the southern portion of the Espinhaço Range, in the state of Minas Gerais, southeastern Brazil (Fig. 1). It covers an area of 910,000 ha and includes seven protected areas (IUCN categories I and IV; Dudley 2008) that we defined as our study sites. We also included two additional sites, which are not protected areas but are located within EM (Fig. 1; therefore, a total of nine sites within study area). From 2010 to 2015, we surveyed four of the above sites: Sempre-Vivas National Park (SV), Pico do Itambé State Park (PI), Soberbo River (SR) and Salitre Cave (SL).

We followed the Rede ComCerrado sampling protocol (available from www.conservacao.bio.br/comcerrado/protocolos [Accessed 20 May 2014]) to survey anuran species at SV (municipality of Diamantina, Minas Gerais state, southeastern Brazil, 17°52'S, 43°45'W). We selected 10 sampling units and we conducted visual encounter surveys (Crump and Scott 1994) during the wet season, in October 2010 and May 2011 (16 nights). At PI (municipality of Santo Antônio do Itambé, Minas Gerais state, southeastern Brazil, 18°24'S, 43°19'W) we surveyed all available microhabitats from 1,230 to 2,060 m above sea level (asl), using night visual encounter surveys (Crump and Scott 1994) during wet and dry seasons (19 nights, from September 2010 to October 2011). We conducted monthly surveys at SR (municipality of Diamantina, Minas Gerais state, southeastern Brazil, 18°15'S, 43°36'W, 1,113 m asl) from April 2010 to March 2011 (26 nights). At this site we placed linear transects (Heyer et al. 1994) in sections of 100 m along the river, using night visual encounter (Crump and Scott 1994) and acoustic surveys (Zimmerman 1994). We used the same methods to survey anurans at SL (municipality of Diamantina, Minas Gerais state, southeastern Brazil, 18°41'S, 43°11'W) during a rapid assessment in dry and wet seasons (February and June 2015, 15 nights), with the survey effort randomly distributed in 25 sampling units. Specimens are available for examination at the herpetological collection of Museu de Ciências Naturais, Pontifícia Universidade Católica de Minas Gerais (Belo Horizonte, Minas Gerais), and Coleção Herpetológica do Laboratório de Zoologia dos Vertebrados, Universidade Federal de Ouro Preto (Ouro Preto, Minas Gerais). We estimated species richness using Jackknife I and evaluated inventory completeness by plotting species richness observed (SOBS) against sampling effort. We obtained both Jackknife I and SOBS from the software EstimateS (Colwell 2013).

In June 2015 we performed literature searches for publications containing amphibian species lists for the following sites: Biribiri State Park (BI), Rio Preto State Park (RP), Serra do Cabral State Park (SC), Serra Negra State Park (SN), Pico do Itambé State Park (PI), Mata dos Ausentes Ecological Station (MA), and Sempre-Vivas National Park (SV). Our search aimed to list all species recorded for each of these sites. We searched for scientific publications (papers, reviews, and books), but also reports, conference abstracts, management plans, theses, and monographs. We used specific keywords during our search (both in English and Portuguese), combined in different ways: keyword related to taxon (e.g., amphibia, anura, herpetofauna); keyword related to study area (e.g., protected area's name, mosaic name and synonyms, and Espinhaço Range); and (when necessary) a keyword related to our aim (e.g., species list, inventory, species richness, and community composition). We searched peer-reviewed references with the Thomson ISI research tool (Web of Science database, available from http://ipscience.thomsonreuters.com [Accessed 10 February 2015]) with the following parameters: all documents types, all languages, all databases; from 1950–2015, and keywords entered in the title and abstract. We searched for other references using Google Scholar (available from https://scholar.google.co.uk [Accessed 10 February 2015]), and to identify management plans available we contacted protected area managers and state administration offices. We classified all species according to their IUCN category (IUCN. 2015. The IUCN Red List of Threatened Species. Version 2012.2. Available from www.iucnredlist.org [Accessed 1 March 2015]).

We generated a species list for each site, combining our survey and literature search when both sources were available. This approach provided us not only with species richness at each site, but also the regional species pool for the study area. We used this compilation to evaluate the contribution of EM to the anuran species richness for the state of Minas Gerais and for the Espinhaço Range as a whole. To evaluate the similarity between the anuran assemblages at each site, we used hierarchical cluster analysis, which combines similar objects in groups using a similarity or distance measure (Quinn and Keough 2007). We conducted this exploratory analysis in R (R Core Team 2014) using species presence/absence data. We used UPGMA as the linking method and Euclidian distance as the distance measure (Quinn and Keough 2007). To avoid uncertainties in characterizing community composition at each site and to provide a more conservative exploratory analysis, we excluded records from the cluster analysis that were not identified to species level (e.g., *Hypsiboas* sp.), and we followed recent taxonomic reviews that grouped species (e.g., we grouped records of *Elachistocleis* sp. into *Elachistocleis cesarii* according to Caramaschi 2010).

RESULTS

We surveyed four sites (PI, SL, SV, and SR) and compiled data from literature for four sites (BI, PI, RP, and SC). Overall, we gathered data from seven sites within the EM (data from one of the sites came from both surveys and literature), among which five are protected areas. We recorded 15 anuran species in 26 nights at SR, which represents 72.25% of estimated richness (18.8; Fig. 2). We recorded 28 anurans during

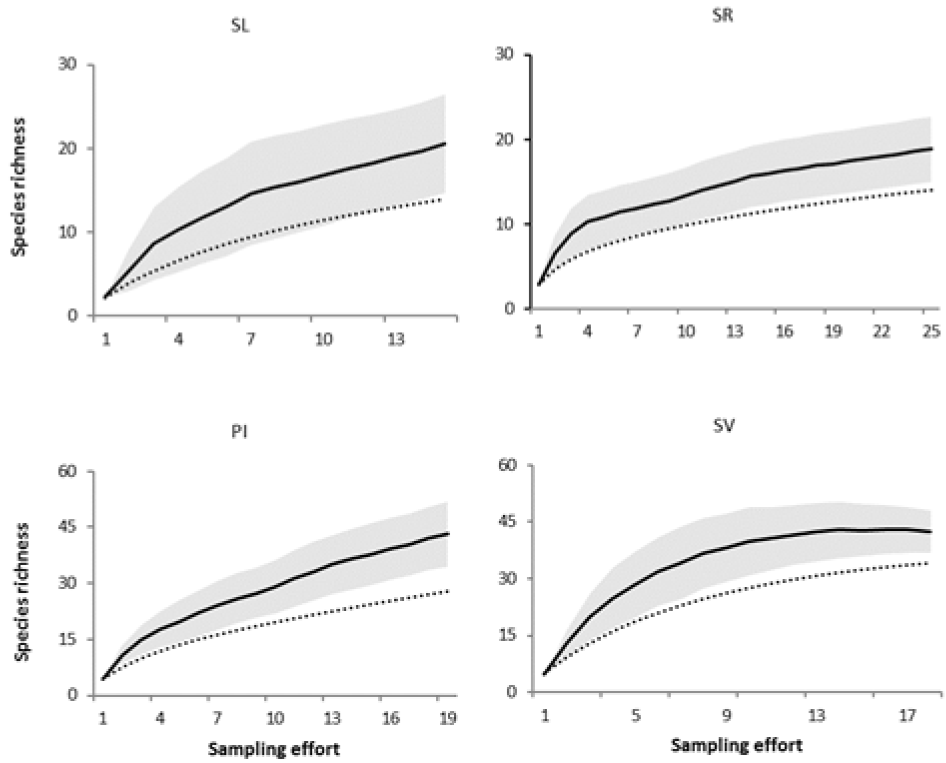

FIGURE 2. Species accumulation curves for surveyed sites: Soberbo River (SR), Pico do Itambe State Park (PI), Sempre-Vivas National Park (SV), and Salitre Cave (SL), Espinhaço Mosaic, Brazil. Estimated species richness (solid line) is shown with its 95% confidence interval (shaded gray). Observed species richness is represented by dotted line. Sampling effort is represented by number of survey nights.

19 sampling nights at PI, adding 11 new species to the list available in the literature. Estimated species richness at this site was 43.16 (considering only sampled data; 65% of estimated species richness; Fig. 2). At SV we recorded 34 species in 16 nights, which represents 80% of estimated richness (42.5; Fig. 2). Our sampling effort at SL was 15 nights and we observed 14 anuran species, representing 68% of those estimated to occur at this site (20.53; Fig. 2).

We found 11 publications containing amphibian species lists for four sites (all protected areas): BI, PI, RP, and SC (Table 1). We had no records or additional information for SV, SN, and MA (Table 1) and, therefore, these sites were not included in our exploratory analysis. Sampling effort (represented as total number of night surveys) differed among sites, as well as total anuran species richness (Table 1). Based on the literature and our inventories, we listed 73 anuran species within the EM; however, nine were not identified to species level (Appendix). If we exclude these species, the total number drops to 64, among which 21 were restricted to only one site (i.e., exclusive species; Fig. 3; Appendix). The highest richness was found at RP with 46 species, followed by PI with 44 species (Table 1; Fig. 3). None of the species recorded are considered in the national or regional lists of threatened amphibians (Machado et al. 2008; Drummond et al. 2008). Only four species were not evaluated by the IUCN (IUCN. 2015. *op. cit.*) and we recorded 10 species designated as Data Deficient by the IUCN (Appendix). Among the latter, six are endemic to the Espinhaço Range and three are known for type locality (Appendix). Two species are considered near threatened (NT): *Bokermannohyla sagarana* and *Hypsiboas cipoensis*. The cluster analysis indicated that our sites form distinct groups according to their anuran community composition (Fig. 4). Our analysis demonstrated that RP and PI harbor similar amphibian communities, whereas SV and SC formed a different group with distinct anuran assemblages, closely positioned to the third group with BI, SL, and SB (Fig. 4).

DISCUSSION

In this study we provide species lists for three previously unsurveyed sites within the Espinhaço Range

TABLE 1. Information and data sources for sites evaluated in the present study of amphibian species richness and community composition at Espinhaço Mosaic, Brazil. Species richness values are from surveys in present study, literature cited, or both combined. Sampling effort is represented by number of nights. Biomes are Cerrado (CE) and Atlantic Rainforest (RF); data not available is given as na.

Code	Study sites	Area (ha)	Biome	Species richness	Sampling effort	References
BI	Biribiri State Park	16,999	CE	24	10	IEF 2004a
MA	Mata dos Ausentes	490	CE	na	na	na
PI	Pico do Itambé State Park	4,696	RF	44	29	Present study; Barata et al. 2013; IEF 2004b
RP	Rio Preto State Park	12,185	RF/CE	46	121	Correia 2015; Oliveira and Eterovick 2009, 2010 Leite et al. 2006; IEF 2004c
SL	Gruta do Salitre	100	CE	14	15	Present study
SC	Serra do Cabral State Park	22,494	CE	34	12	IEF 2015; Drummond et al. 2007; Leite et al. 2011
SN	Serra Negra State Park	13,654	RF/CE	na	na	na
SV	Sempre-Vivas National Park	124,154	CE	34	16	Present study
SR	Soberbo River	na	CE	15	26	Present study

(SV, SL, and SR) and we also complement the species list for Pico do Itambé State Park. Despite the large number of anuran species recorded, our estimates of species richness indicated the need to increase sampling effort, which is also evident from most of the observed richness accumulation curves. This result suggests that further assessments are likely to increase species richness, especially at sites with a lower number of surveys, such as at SR and SL. It is noteworthy though, that at PI, for which our survey results and literature data were both available, the joint species richness is similar to the estimated richness based solely on our field surveys. Uneven surveys are a problem within the entire Espinhaço Range, where the number of species recorded at the northern mountain Range (Bahia State) is less than those recorded in the southern portion (Leite et al. 2008). Even in Minas Gerais, survey effort is concentrated at Serra do Cipó and Quadrilátero Ferrífero (Nascimento et al. 2009). It should thus be a major priority to survey anuran species in Espinhaço sites (protected areas and elsewhere) for which no data are available, such as SN and MA.

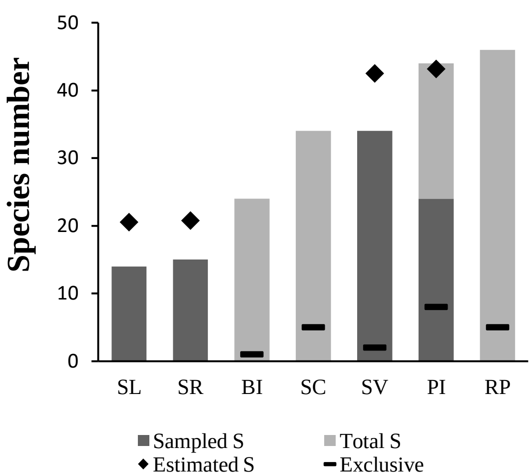

FIGURE 3. Species richness at the seven study sites with data: Salitre Cave (SL), Soberbo River (SR), Biribiri State Park (BI), Serra do Cabral State Park (SC), Sempre-Vivas National Park (SV), Pico do Itambe State Park (PI), and Rio Preto State Park (RP), Espinhaço Mosaic, Brazil. Data are from surveyed sites (Sampled S), literature search and survey data combined (Total S), and number of exclusive species (i.e., species reported for only one site). For surveyed sites, estimated species richness (Estimated S) is also given (black diamonds). Original data are provided in Appendix.

Our results provide a compilation of available data on regional anuran species richness and community composition for the southern portion of the Espinhaço Range (especially at EM). We also contribute to the geographic knowledge of the distribution of several species known to this mountain range. This information can be useful in further assessments of the conservation status of Data Deficient anurans endemic to the Cerrado, which are mainly concentrated in the EM according to Barata et al. (2016). With 73 species recorded, we consider the EM a species-rich area, harboring an amphibian community representative of both the Cerrado and Atlantic Rainforest biomes, and the Espinhaço Range. Approximately 200 amphibian species are recorded from Minas Gerais (Nascimento et al. 2009), among which 127 are reported within the Cerrado (Barata et al. 2016). More than 105 anurans occur in the Espinhaço Range (Leite et al. 2008), although this number might be slightly greater (Leite 2012), and include many endemic species. Therefore,

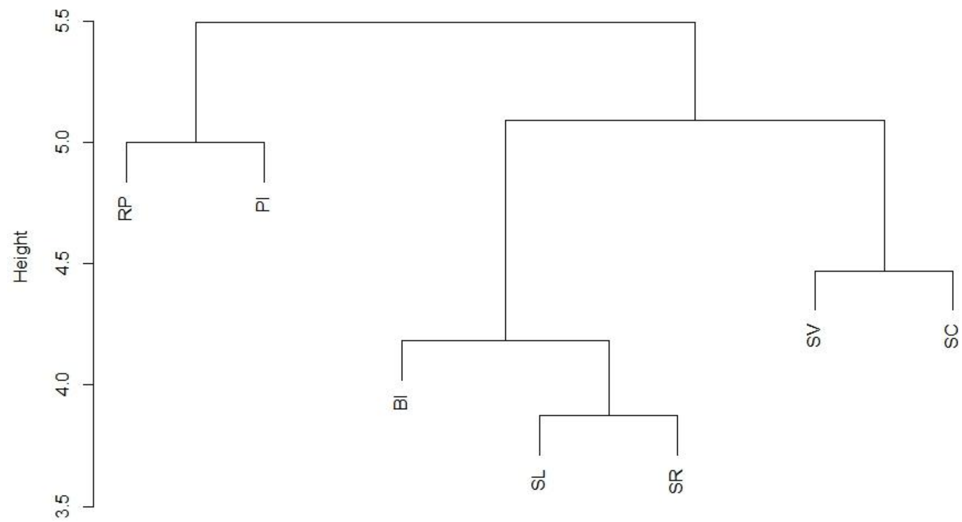

FIGURE 4. Cluster analysis showing similarities in anuran composition among seven study sites: Salitre Cave (SL), Soberbo River (SR), Biribiri State Park (BI), Serra do Cabral State Park (SC), Sempre-Vivas National Park (SV), Pico do Itambe State Park (PI), and Rio Preto State Park (RP), Espinhaço Mosaic, Brazil.

our compilation represents 36.5% of amphibian species from Minas Gerais, 57.5% of the Cerrado in the state, and almost 70% of the species known from Espinhaço Range. Not only is regional diversity high, but also local species richness is high in most sites. For example, RP alone harbors 42% of the amphibian species from Espinhaço Range, which highlights the contribution of this protected area in conserving regional species richness. Although this impressive amphibian diversity is recorded in the EM (mainly inside protected areas), this is not the usual pattern recorded in the state of Minas Gerais, where several Data Deficient endemic anuran species still lack coverage by protected areas (Barata et al. 2016).

We recorded 21 species exclusively at only one of the seven study sites, among which three are widespread in Brazil. Three other species of the 21 are representative of the Cerrado, nine are representative from the Atlantic Rainforest, two are exclusive to the Espinhaço Range, and four are known from type localities only (Appendix). The high proportion of species exclusive to one site (29%) might partially be a consequence of the differences in sampling effort and approaches used; we surveyed some sites intensively during a few days, we surveyed others on different occasions across a period of several months. Although short surveys are efficient for obtaining a general knowledge about the amphibian community, some species may go undetected due to rarity or inactivity during the survey period. Although Heyer et al. (1994) recommend intensive sampling during the wet season, temporal variation can also be a strong factor in determining species distribution in the tropics (Conte and Machado 2005; Borges and Juliano 2007). For example, species with low abundance can be missed at a site if surveys are not well distributed over time (e.g., over a couple of years). A larger effort on site with high levels of endemism, such as the Espinhaço Range, could lead to new discoveries. According to Pimm et al. (2010) unknown species will be rare and threatened with extinction, and science may not discover them before they go extinct. Leite et al. (2008) suggested that the investigation of unexplored areas above 1,700 m elevation could result in the discovery of new species. This idea is corroborated by the recent description of the mountain endemic Itambe's Bromeliad Frog (*Crossodactylodes itambe*; Barata et al. 2013).

Although an increase in sampling effort is likely to reduce the proportion of exclusive species, we believe the levels of endemicity recorded indicate a high number of narrowly distributed species inside the EM region. For example, among the exclusive species, we considered four as micro-endemic because they have been recorded only at the type locality and have highly restricted distributions (small ranged and few known populations): *Bokermannohyla* cf. *diamantina*, *B. sagarana*, *Scinax cabralensis*, and *Crossodactylodes itambe*. Micro-endemic species did not have their geographic distributions extended, demonstrating that the EM, does indeed, hold true micro-endemic species. These species are completely contained within protected reserves (equivalent to IUCN categories I and IV), being more likely to be safeguarded from habitat alteration and land use changes, such as fire and grazing. Although human induced impacts are not expected, species with small ranges are more vulnerable and prone to extinction due to adverse natural events (e.g., such as natural fire and drought; Barata et al. 2013) than wide ranging species. This emphasizes the need for adequate management of protected areas.

Community composition at EM exhibited a pattern of distribution reflecting the Atlantic Rainforest and Cerrado gradient from east to west. The first group is composed of two protected areas located at the east of EM (RP and PI), which experience a higher influence from Atlantic Rainforest habitats when compared to the opposite group (SV and SC) of western protected areas that receive higher influence from the Cerrado. This spatial pattern was evident in our cluster analysis. The number of Cerrado to Rainforest species represented at each site is higher at SV and SC (seven and six species from the Cerrado and zero and four species from the Rainforest, respectively) when compared with RP and PI, which are mainly represented by Rainforest and Espinhaço species (eight and 11 species from the Rainforest, four and eight species from the Cerrado, respectively). By contrast, among the 23 species shared between SV and SC (the Cerrado Group), there are no species characteristic of the Atlantic Rainforest. Of the 28 species shared between RP and PI (the Rainforest Group), only three are Cerrado-related species. According to Valdujo et al. (2012) species occurring in the Cerrado and its domains have a highly structured spatial pattern in which Atlantic Forest species are restricted to southeastern portions of the savanna ecosystem. Therefore, in the Cerrado, it is expected that more species are shared with the Atlantic Rainforest as you move further to its eastern limits.

It could be argued that groups identified in the cluster analysis are strongly influenced by species richness in each site, which for our data would be of some concern due to the uneven sampling effort. Even though species richness may be affecting the clusters, it also indicates a geographic pattern in the anuran communities. Therefore, we believe community composition and similarities between sites are at least partially influenced by the Cerrado-Rainforest gradient. As data from future inventories becomes available, we can improve this exploratory analysis to facilitate understanding of the effects of the ecosystem gradient on anuran community composition within the study region. Furthermore, our data suggest that species richness at less-sampled sites might increase as new assessments are conducted, showing the need to equalize sampling effort in surveyed areas. Implementing these two broad recommendations (i.e., survey new sites and equalize sampling effort) would allow a better understanding of community composition patterns across the Espinhaço Range and the influence of the Cerrado-Rainforest gradient on community composition. Moreover, we suggest that sites with larger sampling effort (such as PI and RP) should be considered for focused-ecological studies, as investing in more species surveys in these sites seems unreasonable when other sites (especially protected areas) in the region do not even have a species list. Investigating species richness of unsurveyed sites can help us to better develop conservation actions and can also facilitate future studies on ecology, distribution, and taxonomy of anuran species in the Espinhaço Range.

Acknowledgments.—We are grateful to all volunteers that helped during field work: Isabela P. Reis, Riccelly C. A. Monteiro, Marco Aurélio C. Pacheco, Guilherme C. Conrado, and Alexsander A. Azevedo. Field surveys were funded by Conselho Nacional de Desenvolvimento Científico e Tecnológico (Proc. 50.6121/2008-09, 457434/2012-0) and Instituto Estadual de Florestas de Minas Gerais (IEF-MG; convênio IEF-MG 2101010400510). Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) provided our research permit (22361-1), and ICMBio and IEF-MG provided logistic support for field activities. Izabela M. Barata and Guilherme B. Ferreira were supported by Ph.D. scholarships from Coordenação e Aperfeiçoamento de Pessoal de Nível Superior (BEX 13153/13-7) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (207195/ 2014-5), respectively. We are grateful to Instituto Biotrópicos for the scholarship offered to Camila M. Correia (convênio IEF-MG 2101010400510). We thank Luciana B. Nascimento, Felipe F. S. Leite, and Maria Rita S. Pires for help with species identification. We are thankful to Maíra F. Goulart and Isabela L. Oliveira who generously contributed on the first draft of the manuscript, and Rob Ward who reviewed the final version of the manuscript.

LITERATURE CITED

Barata, I.M., M.T.T. Santos, F.S.F. Leite, and P.C.A. Garcia. 2013. A new species of *Crossodactylodes* (Anura: Leptodactylidae) from Minas Gerais, Brazil: first record of genus within the Espinhaço Mountain Range. Zootaxa 3731:552–560.

Barata, I.M., V.M. Uhlig, G.H. Silva, and G.B. Ferreira. 2016. Downscaling the gap: protected areas, scientific knowledge and the conservation of amphibian species in Minas Gerais, southeastern Brazil. South American Journal of Herpetology 11:34–45.

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

Borges, F.J.A., and R.F. Juliano. 2007. Distribuição espacial e temporal de uma comunidade de anuros do município de Morrinhos, Goiás, Brasil (Amphibia:

Anura). Neotropical Biology and Conservation 2:21–27.

Brito, D. 2004. Lack of adequate taxonomic knowledge may hinder endemic mammal conservation in the Brazilian Atlantic Forest. Biodiversity and Conservation 13:2135–2144.

Caramaschi, U. 2010. Notes on the taxonomic status of *Elachistocleis ovalis* (Schneider, 1799) and description of five new species of *Elachistocleis* Parker, 1927 (Amphibia, Anura, Microhylidae). Boletim do Museu Nacional 527:1–20.

Collen, B., M. Ram, T. Zamin, and L. McRae. 2008. The tropical biodiversity data gap: addressing disparity in global monitoring. Tropical Conservation Science 1:75–88.

Colwell, R.K. 2013. EstimateS: statistical estimation of species richness and shared species from samples. Version 9. User's Guide and Application. http://purl.oclc.org/estimates.

Conte C.E., and R.A. Machado. 2005. Riqueza de espécies e distribuição espacial e temporal em comunidade de anuros (Amphibia, Anura) em uma localidade de Tijucas do Sul, Paraná, Brasil. Revista Brasileira de Zoologia 22:940–948.

Correia, C.M. 2015. Estrutura de uma comunidade de anfibios anuros em savana tropical Brasileira: uso dos ambientes e sazonalidade. M.Sc. Thesis, Universidade Federal de Ouro Preto, Minas Gerais, Brazil. 99 p.

Crump M.L., and N.J. Scott Jr. 1994. Visual encounter surveys. Pp. 84–91 *In* Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Heyer, W.R., M.A. Donnelly, R. McDiarmid, L.C. Hayek, and M.S. Foster (Eds.). Smithsonian Institution Press, Washington, D.C., USA.

Davis, S.D., U.H. Heywood, A.C. Hamilton. 1995. Centres of Plant Diversity: A Guide and Strategy for their Conservation, Volume 3: The Americas. The World Wildlife Fund (WWF) and World Conservation Union (IUCN). IUCN Publications Unit, Cambridge, U.K.

Develey, P.F., and J.M. Goerck. 2009. Brazil. Pp. 99–112 *In* Important Bird Areas Americas - Priority Sites for Biodiversity Conservation (No. 16). Devenish, C., D.F. Díaz Fernández, R.P. Clay, I. Davidson, and I. Yépez Zabala (Eds.). BirdLife International, Quito, Ecuador.

Drummond, G.M., A.B.M. Machado, C.S. Martins, M.P. Mendonça, and J.R. Stehmann. 2008. Listas Vermelhas das Espécies de Fauna e Flora Ameaçadas de Extinção em Minas Gerais. Fundação Biodiversitas, Belo Horizonte, Minas Gerais, Brasil.

Drummond, G.M., C.S. Martins, A.B.M. Machado, F.A. Sebaio, and Y. Antonini. 2005. Biodiversidade em Minas Gerais: Um Atlas para sua Conservação. Fundação Biodiversitas, Belo Horizonte, Minas Gerais, Brasil.

Drummond, L.O., D. Baêta, and M.R.S. Pires. 2007. A new species of *Scinax* (Anura, Hylidae) of the *S. ruber* clade from Minas Gerais, Brazil. Zootaxa 1612:45–63.

Dudley, N. (Ed.). 2008. Guidelines for Applying Protected Area Management Categories. IUCN, Gland, Switzerland.

Gaston K.J., and A.S.L. Rodrigues. 2003. Reserve selection in regions with poor biological data. Conservation Biology 17:188–195.

Gidsicki, D. 2013. Protocolo de avaliação de efetividade de gestão de mosaicos de áreas protegidas no Brasil. M.Sc. Thesis, Instituto de Pesquisa da Amazônia, Manaus, Amazonas, Brasil. 88 p.

Gontijo, B.M. 2008. Uma geografia para a Cadeia do Espinhaço. Revista Megadiversidade 4:7–14.

Haddad, C.F.B., L.F. Toledo, C.P.A. Prado, D. Loebmann, J.L. Gasparini, and I. Sazima. 2013. Guia de Anfíbios da Mata Atlântica: Diversidade de Biologia. Anolisbooks, São Paulo, São Paulo, Brasil.

Heyer, W.R., M.A. Donnelly, R. McDiarmid, L.C. Hayek, and M.S. Foster (Eds.). 1994. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C., USA.

IEF (Insituto Estadual de Florestas). 2004a. Plano de Manejo do Parque Estadual do Biribiri. Instituto Estadual de Florestas de Minas Gerais, Belo Horizonte, Minas Gerais, Brasil.

IEF (Insituto Estadual de Florestas). 2004b. Plano de Manejo do Parque Estadual do Pico do Itambé. Instituto Estadual de Florestas de Minas Gerais, Belo Horizonte, Minas Gerais, Brasil.

IEF (Insituto Estadual de Florestas). 2004c. Plano de Manejo do Parque Estadual do Rio Preto. Instituto Estadual de Florestas de Minas Gerais, Belo Horizonte, Minas Gerais, Brasil.

IEF (Insituto Estadual de Florestas). 2015. Plano de Manejo do Parque Estadual da Serra do Cabral. Instituto Estadual de Florestas de Minas Gerais, Belo Horizonte, Minas Gerais, Brasil.

Leite, F.S.F. 2012. Taxonomia, biogeografia e conservação dos anfíbios da Serra do Espinhaço. Ph.D Dissertation, Universidade Federal de Minas Gerais, Belo Horizonte, Minas Gerais, Brasil. 123 p.

Leite, F.S.F., F.A. Juncá, and P.C. Eterovick. 2008. Status do conhecimento, endemismo e conservação de anfíbios anuros da Serra do Espinhaço, Brasil. Revista Megadiversidade 4:1–2.

Leite, F.S.F., T.L. Pezzuti, and L.O. Drummond. 2011. A new species of *Bokermannohyla* from the Espinhaço Range, state of Minas Gerais, southeastern Brazil. Herpetologica 67:440–448.

Leite, F.S.F., T.L. Pezzuti, and P.L. Viana. 2006. Amphibia, *Bokermannohyla nanuzae, Scinax curicica*, *Leptodactylus camaquara*, *Physalaemus evangelistai*, and *Proceratophrys cururu*: distribution extensions. Check List 2:5.

Machado, A.B.M., G.M. Drummond, and A.P. Paglia. 2008. Livro Vermelho da Fauna Brasileira Ameaçada de Extinção – Volume II (Biodiversidade 19). Ministério do Meio Ambiente, Brasília, Distrito Federal, Brasil.

Myers, N., R.A. Mittermeier, C.G Mittermeier., G.A.B. Fonseca, and J. Kent. 2000. Biodiversity hotspots for conservation priorities. Nature 403:853–858.

Nascimento, L.B., F.S.F. Leite, P.C. Eterovick, and R.N. Feio. 2009. Anfíbios. Pp. 221–248 *In* Diagnóstico do Conhecimento Sobre a Biodiversidade no Estado de Minas Gerais - Subsídio para o Programa Biota Minas. Drummond, G. (Ed.). Fundação Biodiversitas, Belo Horizonte, Minas Gerais, Brasil.

Oliveira, F.F.R., and P.C. Eterovick. 2009. The role of river longitudinal gradients, local and regional attributes in shaping frog assemblages. Acta Oecologica 30:1–12.

Oliveira, F.F.R., and P.C. Eterovick. 2010. Patterns of spatial distribution and microhabitat use by syntopic anuran species along permanent lotic ecosystems in the Cerrado of southeastern Brazil. Herpetologica 66:148–160.

Olson, D.M., and E. Dinerstein. 2001. The Global 200: priority ecoregions for global conservation. Annals of the Missouri Botanical Garden 89:199–224.

PAN (Plano de Ação Nacional) Espinhaço. 2012. Plano de Ação Nacional para a Conservação dos Répteis e Anfíbios Ameaçados de Extinção na Serra do Espinhaço: Sumário Executivo. Instituto Chico Mendes de Conservação da Biodiversidade, Ministério do Meio Ambiente, Brasília, Distrito Federal, Brasil.

Pimm, S.L., C.N. Jenkins, L.N. Joppa, C.L. Roberts, and G.J. Russel. 2010. How many endangered species remain to be discovered in Brazil? Natureza & Conservação 8:71–77.

Projeto de Conservação e Utilização Sustentável da Diversidade Biológica Brasileira/ Ministério do Meio Ambiente (PROBIO/MMA). 2007. Mapas de Cobertura Vegetal dos Biomas Brasileiros. Ministério do Meio Ambiente, Brasília, Distrito Federal, Brasil.

Quinn, G.P., and M.J. Keough. 2002. Experimental Design and Data Analysis for Biologists. Cambridge University Press, Cambridge, UK.

R Core Team. 2014. A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at http://www.R-project.org.

Rondinini, C., S. Stuart, and L. Boitani. 2005. Habitat suitability models and the shortfall in conservation planning for African vertebrates. Conservation Biology 19:1488–1497.

Valdujo, P.H., D.L. Silvano, G. Colli, and M. Martins. 2012. Anuran species composition and distribution patterns in Brazilian Cerrado, a Neotropical hotspot. South American Journal of Herpetology 7:63–78.

Zimmerman, B.L. 1994. Audio strip transects. Pp. 92–96 *In* Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Heyer, W.R., M.A. Donnelly, R. McDiarmid, L.C. Hayek, and M.S. Foster (Eds.). Smithsonian Institution Press, Washington, D.C., USA.

IZABELA M. BARATA is a Ph.D. candidate at Durrell Institute of Conservation and Ecology, University of Kent, UK, and member of Instituto Biotrópicos. She works with amphibian conservation ecology, and long term monitoring. She has worked in the Cerrado, Atlantic Rainforest, and Espinhaço Range in Minas Gerais, Brazil. She is currently investigating the effects of climate change on a rare population of an endemic mountaintop frog species. (Photographed by Marcell Soares).

CAMILA M. CORREIA is a Research Biologist and Consultant. Her research interests include ecology, natural history, and conservation of amphibians and reptiles. She received her Master of Science degree in 2015 from the Universidade Federal de Ouro Preto (Brazil), working with ecology of herpetofaunal communities in montane sites of the Brazilian Cerrado. (Photographed by Guilherme Conrado).

GUILHERME B. FERREIRA is member of Instituto Biotrópicos and a Ph.D. student at University College London and the Zoological Society of London, UK. He has conducted biodiversity surveys in more than 10 protected areas in northern Minas Gerais and Espinhaço Mountain Range, southeastern Brazil. Currently, he is studying the effect of protected areas on the large mammal community in the Brazilian Cerrado. (Photographed by Vera Voronova).

Appendix Table. Anuran species occurring at the seven study sites using data from literature (four sites) and field surveys in present study (four sites) within the Espinhaço Mosaic, Brazil: Salitre Cave (SL), Soberbo River (SR), Sempre-Vivas National Park (SV), Rio Preto State Park (RP), Pico do Itambé State Park (PI), Biribiri State Park (BI), and Serra do Cabral (SC). For species occurring exclusively at one site (Exclusive), name of that site is listed. Distribution refers to species occurrence in Brazil: Cerrado biome (CE), Atlantic Rainforest biome (AF), Espinhaço Range (ES), widespread (W), type locality (T). Conservation status according to IUCN: Least Concern (LC), Data Deficient (DD), Near Threatened (NT).

	Study sites							Total			IUCN
Species	SL	SR	SV	RP	PI	BI	SC	sites	Exclusive	Distribution	Status
Brachycephalidae											
Ischnocnema juipoca				x			x	2		CE, RF	LC
Bufonidae											
Rhinella cruficer	x			x	x	x		4		RF	LC
R. mirandaribeiroi			x					1	SV	CE	
R. rubescens	x	x	x	x	x	x	x	7		CE	LC
R. schneideri			x	x			x	3		W	LC
R. sp.				x				1			
Centrolenidae											
Vitreorana eurygnatha					x			1	PI	RF	LC
V. sp.				x				1			
Craugastoridae											
Haddadus binotatus					x			1	PI	RF	LC
Cycloramphidae											
Thoropa megatympanum	x	x	x	x	x	x	x	7		ES	LC
Dendrobatidae											
Ameerega flavopicta							x	1	SC	CE	LC
Hylidae											
Bokermannohyla alvarengai	x	x	x	x	x			5		ES	LC
B. gr. *circumdata*	x			x	x		x	4		RF	LC
B. cf. *diamantina*					x			1	PI	T	DD
B. nanuzae	x	x		x	x	x		5		ES	LC
B. sagarana							x	1	SC	T	NT
B. saxicola		x	x	x	x	x	x	6		ES	LC
B. sp.					x			1			
Dendropsophus branneri					x			1	PI	RF	LC
D. elegans				x	x			2		RF	LC
D. minutus	x		x	x	x	x	x	6		W	LC
D. rubicundulus			x				x	2		CE	LC
Hypsiboas albomarginatus				x				1	RP	RF	LC
H. albopunctatus	x	x	x	x	x	x	x	7		W	LC
H. botumirim		x	x	x	x			4		T	NE
H. cipoensis			x	x				2		ES	NT
H. crepitans			x		x	x	x	4			LC
H. faber				x	x	x		3		CE, RF	LC
H. lundii				x				1	RP	CE	LC
H. polytaenius					x	x		2		RF	LC
H. sp.			x					1			
Phyllomedusa megacephala				x			x	2		T	DD
P. sp.					x			1			
Scinax aff. *berthae*					x			1	PI	W	LC
S. gr. *catharinae*		x		x	x	x	x	5		RF	LC
S. cabralensis							x	1	SC	T	DD
S. curicica		x	x	x	x		x	5		ES	DD
S. aff. duartei				x	x			2		RF	LC
S. eurydice					x			1	PI	RF	LC
S. fuscomarginatus				x	x	x	x	4		W	LC
S. fuscovarius			x	x	x	x	x	5		W	LC
S. aff. machadoi				x				1	RP	ES	LC
S. gr. *ruber*	x		x	x				3		W	LC
S. aff. *similis*							x	1	SC	RF	LC
S. squalirostris			x	x	x		x	4		CE, RF	LC
S. sp.			x		x			2			

Trachycephalus typhonius			x	x			x	3		W	LC
Hylodidae											
Crossodactylus trachystomus				x	x	x		3		ES	DD
Leptodactylidae											
Adenomera sp.					x			1			
Crossodactylodes itambe					x			1	PI	T	NE
Leptodactylus camaquara		x	x	x	x	x		5		ES	DD
L. cunicularius				x		x		2	BI	RF	LC
L. furnarius			x	x		x	x	4		CE, RF	LC
L. fuscus			x	x	x		x	4		W	LC
L. jolyi			x	x	x		x	4		CE, RF	DD
L. labyrinthicus		x	x	x	x	x	x	6		CE, RF	LC
L. latrans		x	x		x	x	x	5		W	LC
L. mystacinus			x	x				2	SV	W	LC
L. syphax				x				1	RP	W	LC
L. sp.					x			1			
Physalaemus centralis			x				x	2		CE	LC
P. cuvieri	x	x	x	x	x	x	x	7		W	LC
P. evangelistai				x				1	RP	ES	DD
P. marmoratus	x		x			x	x	4		CE	LC
P. cf. *signifer*					x			1	PI	RF	LC
Pseudopaludicola mineira	x	x	x	x	x		x	6		ES	DD
Ps. saltica		x	x	x	x	x		5		CE	LC
Ps. murundu				x			x	2	SC	RF	NE
Ps. sp.				x				1			
Microhylidae											
Dermatonotus muelleri			x				x	2		W	LC
Elachistocleis cesari	x		x	x	x	x	x	6		CE	NE
Odontophrynidae											
Odontophrynus americanus	x					x	x	3		W	LC
Proceratophrys cururu			x	x	x			3		ES	DD
TOTAL	14	15	34	46	44	24	34		21		