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ARTICLE

Bird community structure and dynamics in the campos rupestres of southern Espinhaço Range, Brazil: diversity, phenology and conservation

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ABSTRACT: "Campos rupestres" comprises the open vegetation growing above 900 m altitude mainly along the Espinhaço Range, eastern Brazil. We presents the first thorough assessment concerning the bird community structure and dynamics in campos rupestres of southern Espinhaço, in the western slope of Serra do Cipó. We investigated the species richness, composition, abundance, seasonality, and conservation. From 2005 to 2007 we performed visual and acoustic detections and mist-netting. Every species was categorized according to two types of classification schemes that reflect its pattern of occurrence and seasonality: Frequency of Occurrence (FO) and Phenological Category of presence (PC). We recorded 81 species, including endemics, endangered, and new records. The 287 mist-netted individuals showed a multi-modal abundance distribution among species, suggesting that the community has few common and many rare species. The most abundant species was a campos rupestres endemic hummingbird, the Hyacinth Visorbearer *Augastes scutatus*. The same pattern was verified for the FO, with few "Common" (5%) and many "Occasional" (27%) species. Regarding the PC, almost half of the species were categorized as "Residents" (47%), 14% as "Migratory", and 31% as "Occasional visitors". The annual occurrence pattern of the seasonal species differ by "Occasional visitors" being more narrowly concentrated than "Migratory" species. We discuss the occurrence and phenology patterns of species and some threats to the campos rupestres. Although relatively poor in species richness, the Cipó campos rupestres avifauna has a distinct composition, and we suggest that the patterns found here reflect a general dynamic for the campos rupestres habitat as a whole. Our results may be useful in further investigations concerning the existence of distinct ecosystems within "campos rupestres" complex, and may also provide a baseline for future assessments of the conservation status of those threatened ecosystems.

KEY-WORDS: Avian assemblage, highlands, mountaintops, seasonality, Serra do Cipó, Minas Gerais, *Augastes scutatus.*

INTRODUCTION

"Campos rupestres" (rocky fields or rocky grasslands) harbor a wide variety of physiognomies, but is recognized by its typical open vegetation of grasses, herbs and scattered small bushes growing on rocky outcrops and shallow quartzite soils above 900 m (Ribeiro & Walter 1998, Benites *et al*. 2003). This ecosystem occurs mainly along the Espinhaço Range ("Cadeia do Espinhaço"), a mountain range in eastern Brazil that is an important centre of plant diversity (Giulietti *et al*. 1997, Jacobi *et al*. 2007) and animal endemism (Stattersfield *et al*. 1998, Silva & Bates 2002, BirdLife International 2003, Vasconcelos *et al*. 2008a, and references therein). Because of its distinctive flora, degree of endemism and significant anthropic pressures, the Espinhaço Range was recently declared an area of extreme importance for biodiversity conservation (Drummond *et al*. 2005).

Compared to the numerous taxonomic and ecological studies on its flora (Giulietti *et al*. 1997), very little is known about the avifauna assemblages of the campos rupestres of Espinhaço Range. Most of our current knowledge about the bird community is restricted to standard species checklists (*e.g.*, Willis & Oniki 1991, Parrini *et al.* 1999, Melo-Júnior *et al*. 2001, Machado 2005, see detailed revision in Vasconcelos *et al*. 2008a). A recent work shows 205 bird species recorded in the campos rupestres of Espinhaço, predominating wide-ranging species (85.9%), but also Atlantic Forest (7.3%), Caatinga (0.5%), Cerrado (2.9%,) and seven endemic to the open-habitats of southeastern Brazilian mountaintops (3.4%) (Vasconcelos & Rodrigues 2010).

Although the species composition can be the most relevant property on community studies, other parameters like bird species abundance, temporal and spacial distribution remains unknown for this ecosystem. Those parameters provide more substantial data about the local ecological dynamics (Wiens 1989).

We present the first thorough assessment of the bird community structure and dynamics in campos rupestres

of the southern Espinhaço Range, in southeastern Brazil. Here, we focus on species richness, taxonomic composition, relative abundance, frequency of occurrence, seasonality, and conservation status of the species at this highly threatened ecosystem.

MATERIAL AND METHODS

Study Area

The bird community was studied in a campos rupestres area called 'Alto da Boa Vista', hereafter ABV (19°17'- 19°18'S; 43°34'- 43°35'W). This area is the type locality of the Cipó Canastero *Asthenes luizae,* one of the most recently described furnariid (Vielliard 1990). ABV is located on the western slope of the Serra do Cipó mountains, nearby the Parque Nacional da Serra do Cipó, southern portion of Espinhaço Range, in the municipality of Santana do Riacho, state of Minas Gerais, southeastern Brazil (Figure 1). Serra do Cipó region shows little variation in annual and monthly averages temperatures (Madeira & Fernandes 1999, Rodrigues *et al.* 2011) but a high daily amplitude in temperature, a general pattern observed for most campos rupestres (Ribeiro & Walter 1998). Mist is relatively common within the first few hours of the day, but mainly during the rainy season (*pers. obs.*). There is extreme variation in rainfall, with very wet summers (mainly from November to January) and very dry winters (mainly from May to September) (Madeira & Fernandes 1999, Rodrigues *et al.* 2011).

For study site, we selected a 200 ha area with an altitudinal range from 1,180 to 1,360 m a.s.l., largely covered by rock outcrops with typical campos rupestres plants (Giulietti *et al*. 1997). Additionally, there is a portion of open grassland surrounding the rock outcrops, patches of temporary small marshes with a dense cover of scrub along a seasonal stream, and a narrow strip of riparian forest with small trees along of a perennial stream.

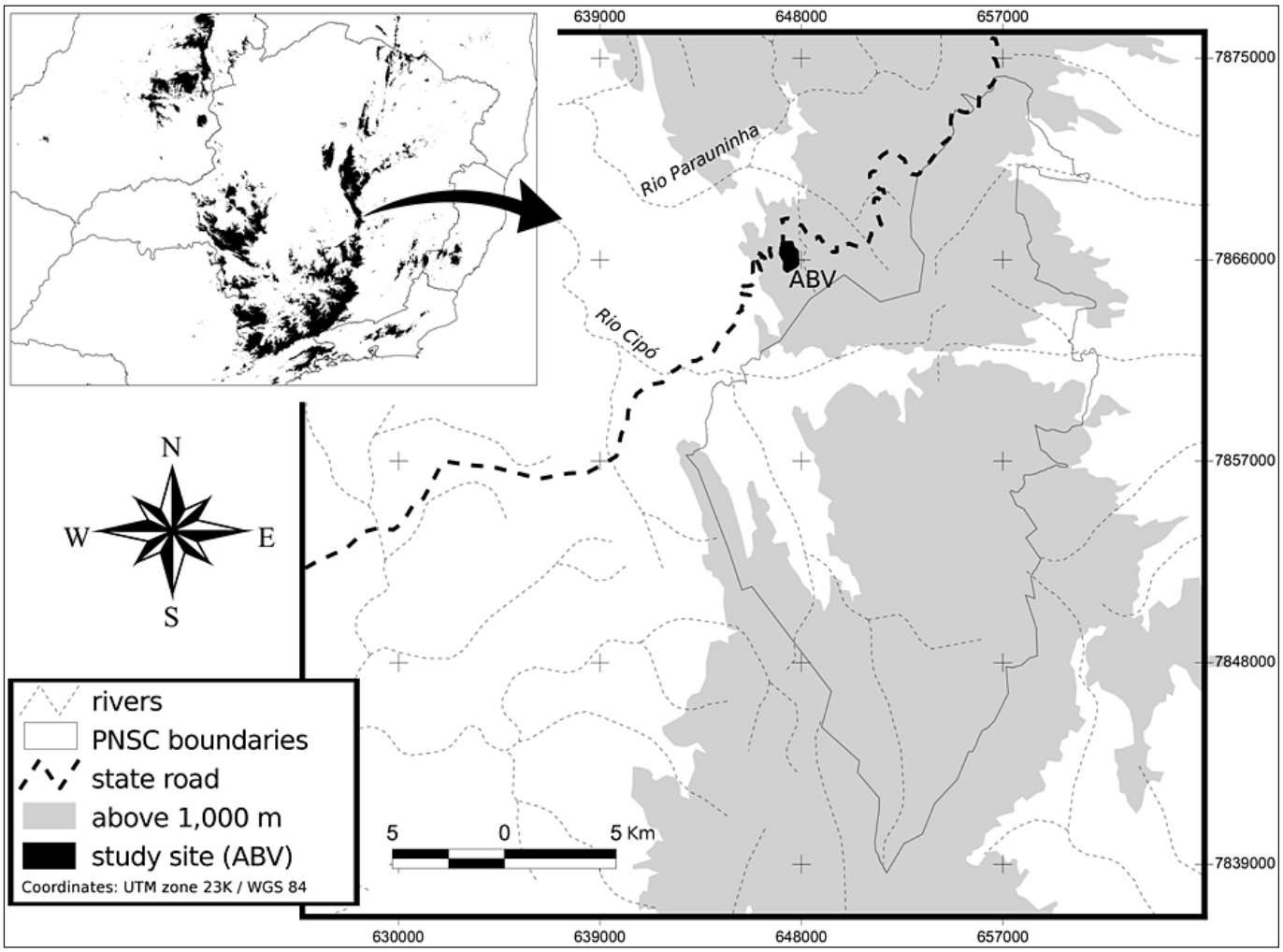

FIGURE 1. Location of 'Alto da Boa Vista' (ABV), nearby the Parque Nacional da Serra do Cipó (PNSC), on the western slope of Espinhaço Range. On the upper left, the location of ABV in Minas Gerais state, southeastern Brazil (dark areas above 1,000 m).

Sampling Methods

Field work period, from July 2005 to August 2007, included 104 days in 22 months. To access the community species richness, composition, relative abundance and seasonality we employed two basic sampling methods: visual and acoustic detections, and mist-netting.

Visual and acoustic detections were performed along slow walking with frequent stops throughout the study site. This method was employed over all 104 field work days in a total sampling effort of *c.* 620 hours. All birds seen or heard were identified using 8x40 binoculars and sound recordings (Sony TCM-5000EV with microphones Sennheiser ME-66).

Mist-netting was carried out in a 25 ha core area of the study site that lies within rocky outcrops cut by a seasonal stream. In that area, we placed 2 to 17 nets per day (12 x 2.5 m, 36 mm mesh) during 45 days along 14 months spread over the field work period, producing a total effort of 72,551 h.m² (computed according to Straube & Bianconi 2003). In each of the 12 months of the year (January - December) the average effort was (mean ± SD) 14.8 ± 10.9 nets or 6,046.6 ± 5,584.6 h.m². Each captured bird was identified and banded with a unique combination of colored plastic leg bands and a metal alphanumeric band (provided by the *Centro Nacional de Pesquisa para Conservação de Aves Silvestres* - CEMAVE/IBAMA), allowing individual recognition.

Analysis

The community species richness and composition were the sum of all species recorded by both methods (visual and acoustic detections and mist-netting; Rodrigues *et al.* 2005). To analyze species richness, we plotted a species discovery curve with sampling days as the unit of effort (Robertson & Liley 2000) and estimated the predicted species richness with extrapolation using a first-order jackknife estimator. Calculations were made using 'EstimateS' software with 95% confidence intervals (Colwell 2005).

Species abundances were estimated based on the number of individuals captured on mist-nets, excluding recaptures. We recognize that sampling with nets can be biased because only some species can be captured. Nonetheless, those data provide a rough estimate of the relative proportion of individuals, bringing information about the most abundant species and about the equitability from this subset of the community. To analyze the relative abundances of species we constructed a rank-abundance diagram, ordering the species from the most to the least captured. We divided the total number of captured individuals by the total of captured species, finding a hypothetical number of individual birds per species that represents the maximal value of equitability or diversity (evenness). We then analyze the proportion of species above and below this number.

Every recorded species during all field work period (104 days) was assigned to two types of classification schemes designed to reflect its pattern of occurrence and seasonality: Frequency of Occurrence (FO) and Phenological Category of presence (PC). Those analyses were based mostly on visual and acoustic detections, but we also addressed a category to two species that were recorded exclusively by mist-netting only a single time (see results).

FO was based on the proportion of effort units (days) in which a given species was detected. Six categories of FO were used, being five adapted from Naka *et al.* (2002) and Rodrigues *et al.* (2005): 'Common', recorded 75-100% of the visits; 'Fairly common', 50-74 %; 'Uncommon', 25-49%; 'Rare', 6-24%; 'Occasional', less than 5% of the visits. An additional category, 'Single record', was used for species only recorded on a single day.

For the PC classification we first calculate the monthly Pattern of Frequency of species (adapted from Figueira *et al.* 2006). Every species records were clustered throughout a hypothetical year in order to estimate the number of months (1-12) a particular species was present in the area. Based on the results, we assigned to species one of the following phenological categories (according to suggestions of Donatelli *et al.* 2004): 'Residents', species with at least one record during each period of four consecutive months; 'Migratory', species having at least four consecutive months without records in the area, but with at least three months of recorded occurrence overall; 'Occasional visitors', species recorded in only one or two months throughout the year; and 'Undefined', those that do not match any of those categories.

The taxonomy used here follows CBRO (2011). Endemic status for Cerrado, eastern Brazilian mountaintops, and campos rupestres follow Silva & Bates (2002) and Vasconcelos (2008). Regional and global conservation status follow Machado *et al.* (1998) and BirdLife International (2012).

RESULTS

Species richness

Eighty-one species of 30 families and 13 orders were recorded (Appendix). Most species belong to the families Tyrannidae (14 species), Trochilidae, and Emberizidae (eight species each). Passeriformes was the richest order (46 species, 57% of the total richness) followed by Apodiformes (nine species, 11%) and Accipitriformes (five species, 6%). A Jackknife first-order estimate predicted that 93.88 ± 3.64 bird species are likely to appear in the sampling area (Figure 2).

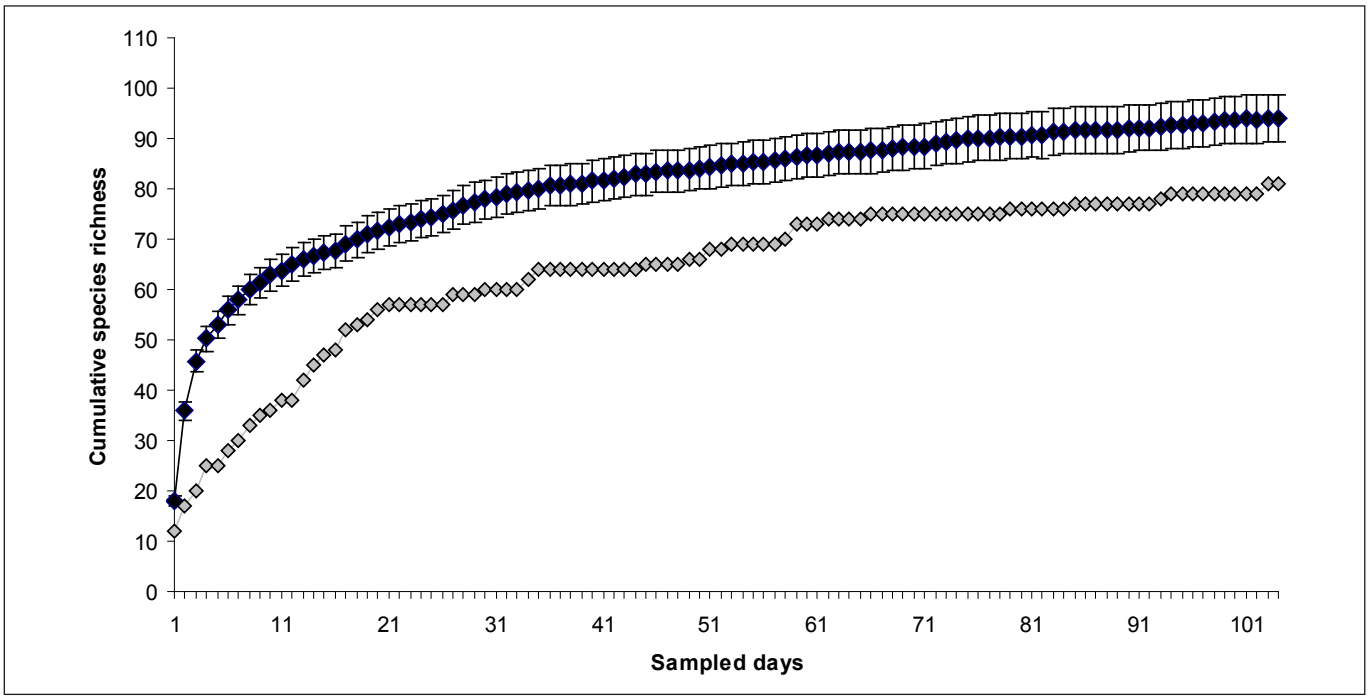

FIGURE 2. Species discovery curve of observed (gray) and estimated (black) bird species during 104 sampled days from July 2005 to August 2007 at 'Alto da Boa Vista', a campos rupestres area of the Serra do Cipó mountains, Brazil. Vertical lines represent 95% confidence intervals around the mean.

Species composition

Ten percent of the species recorded in ABV are endemic to some restricted area (Appendix). Four species are considered endemic to the Cerrado (*Cyanocorax cristatellus, Saltatricula atricollis, Porphyrospiza caerulescens,* and *Poospiza cinerea*), four are endemic to the eastern Brazilian mountaintops (*Augastes scutatus, Asthenes luizae, Polystictus superciliaris* and *Embernagra longicauda*). *Augastes scutatus* and *A. luizae* are restricted to campos rupestres of the southern portion of Espinhaço Range.

Six percent of all recorded birds are of conservation concern, recognized as threatened (*P. cinerea* – Vulnerable) or near-threatened species (see Appendix). *Asthenes luizae* and *P. cinerea* are also regionally threatened in Minas Gerais.

Seven of the species observed in this work were recorded for the first time in campos rupestres of the Serra do Cipó (Willis & Oniki 1991, Melo-Júnior *et al.* 2001, Vasconcelos & Rodrigues 2010, Rodrigues *et al.* 2011). *Chrysolampis mosquitus* and *Turdus flavipes* were not recorded even in other habitats of Serra do Cipó (Rodrigues *et al.* 2005, Mesquita *et al.* 2008). *Hydropsalis parvula* and *Veniliornis mixtus* were not recorded in any other locality of campos rupestres of Espinhaço Range (Vasconcelos & Rodrigues 2010) (Appendix).

Abundance

We mist-netted 287 individuals of 40 species, belonging to 16 families and five orders. These species represents 49% of the total richness that we recorded at ABV. In this subset of species, the richest families were the same of the whole community: Tyrannidae (eight species, 20% of total captures), Trochilidae and Emberizidae (seven species each, 18%). Belonging to those families, are also the most abundant species in ABV: *A. scutatus*, with 68 mist-netted individuals (24% of the captured birds), *Elaenia cristata* (34 individuals, 12%), and *Zonotrichia capensis* (28 individuals, 10%).

With the total numbers of individuals and species captured, we would find 7.2 individual birds per species if the number of captured individuals was evenly distributed amongst the species (maximum equitability). Considering this estimate, nine species (22.5%) are more abundant than predicted (> 7.2 birds) and 31 (77.5%) are less abundant (< 7.2 birds). Sixteen (40%) species were mist-netted only once (Figure 3), including the only two species that were not recorded by visual or acoustic detections: *Amazilia lactea* and *Turdus flavipes* (Appendix).

Frequency of Occurrence and Phenology

The number of species by FO category tends to increase from "Common" (four species, 5%) to

"Occasional" (22 species, 27%; Figure 4). Additionally, thirteen species (16%) were recorded only once in ABV (FO "Single record"), such as *Heterospizias meridionalis*, *Zenaida auriculata*, and *Pitangus sulphuratus.* The only few Common species were the same of the most captured (*A. scutatus*, *Elaenia cristata*, and *Z. capensis*) plus *Schistochlamys ruficapillus* (Appendix)

The analysis of the monthly Pattern of Frequency revealed that most species appeared in ABV either throughout the year (11 to 12 months, 30%) or during just a small part of the year (1 to 2 months, 30%). However, 13 (87%) of the 15 species only found in one month are those recorded only once (FO of "Single record"). When these are excluded from the analysis,

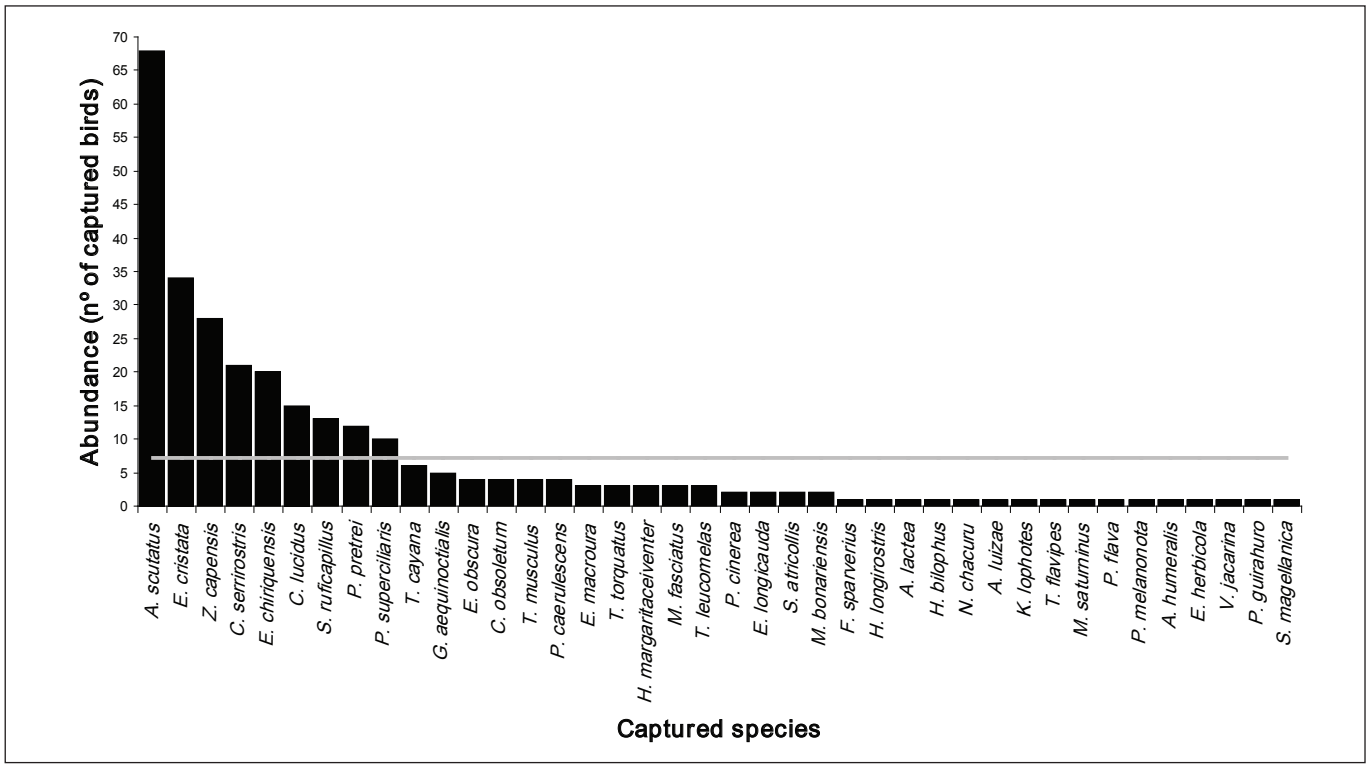

FIGURE 3. Rank-abundance diagram of mist-netted bird species during 45 sampling days from July 2005 to August 2007 at 'Alto da Boa Vista', a campos rupestres area of the Serra do Cipó mountains, Brazil. The gray line indicates the most homogeneous abundance (7.2 individuals per species; see text for details).

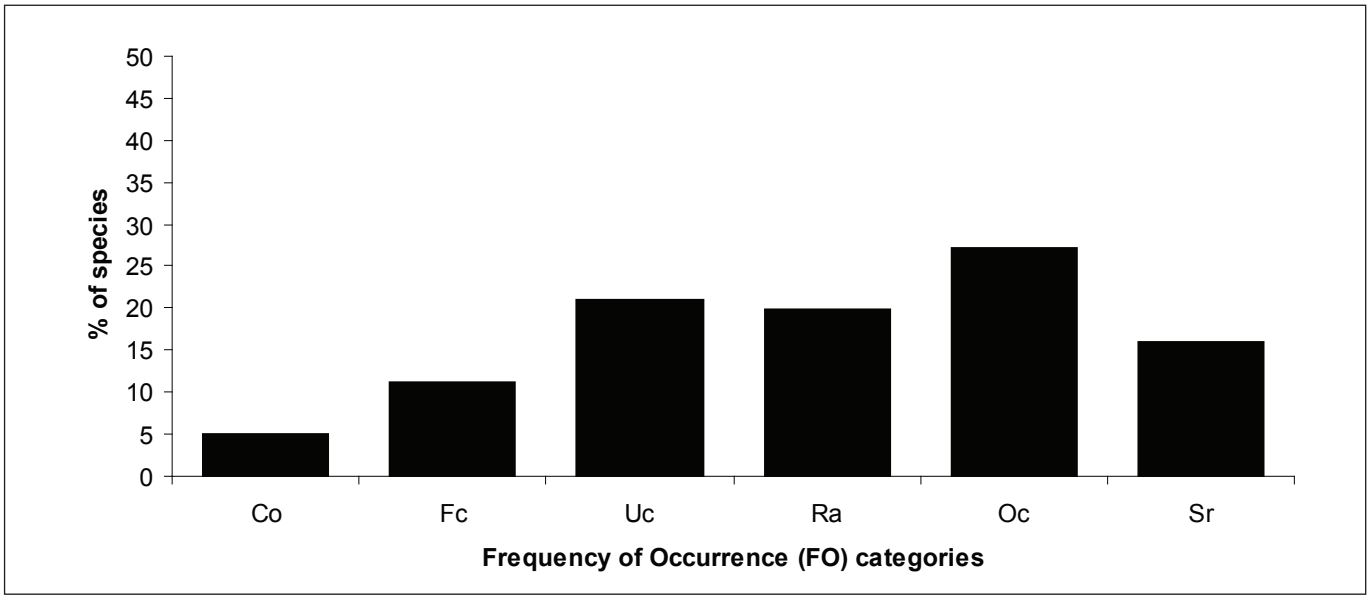

FIGURE 4. Distribution of the Frequency of Occurrence (FO) categories of bird species recorded from July 2005 to August 2007 at 'Alto da Boa Vista', a campos rupestres area of the Serra do Cipó mountains, Brazil. Percentage of species by categories: Co, "Common"; Fc, "Fairly common"; Uc, "Uncommon"; Ra, "Rare"; Oc, "Occasional"; Sr, "Single record". See text for details.

more than one third of the remaining species appear in ABV throughout the year (35%) and only a few occur during just a few months (18%; Figure 5).

Almost half (38 species, 47%) of the species recorded were categorized according to the PC as "Residents' at ABV (Figure 6). Eleven species were "Migratory" (14%) and 25 "Occasional visitors" (31%); but 13 of "Occasional visitors" species (52%) were those categorized as "Single record". However, even after excluding these species from the analysis, "Occasional visitors" remains the second richest PC of the community (Figure 6).

Most of the species considered as "Migratory" and "Occasional visitors" show a very similar monthly pattern throughout the year, occurring from mid-winter until the end of summer, with a peak of record in August (Table 1). Analysis of these PC categories separately indicates a slight difference in the monthly pattern of "Migratory" and "Occasional visitors" species, with the presence of the later falling sharply during the summer months (Figure 7).

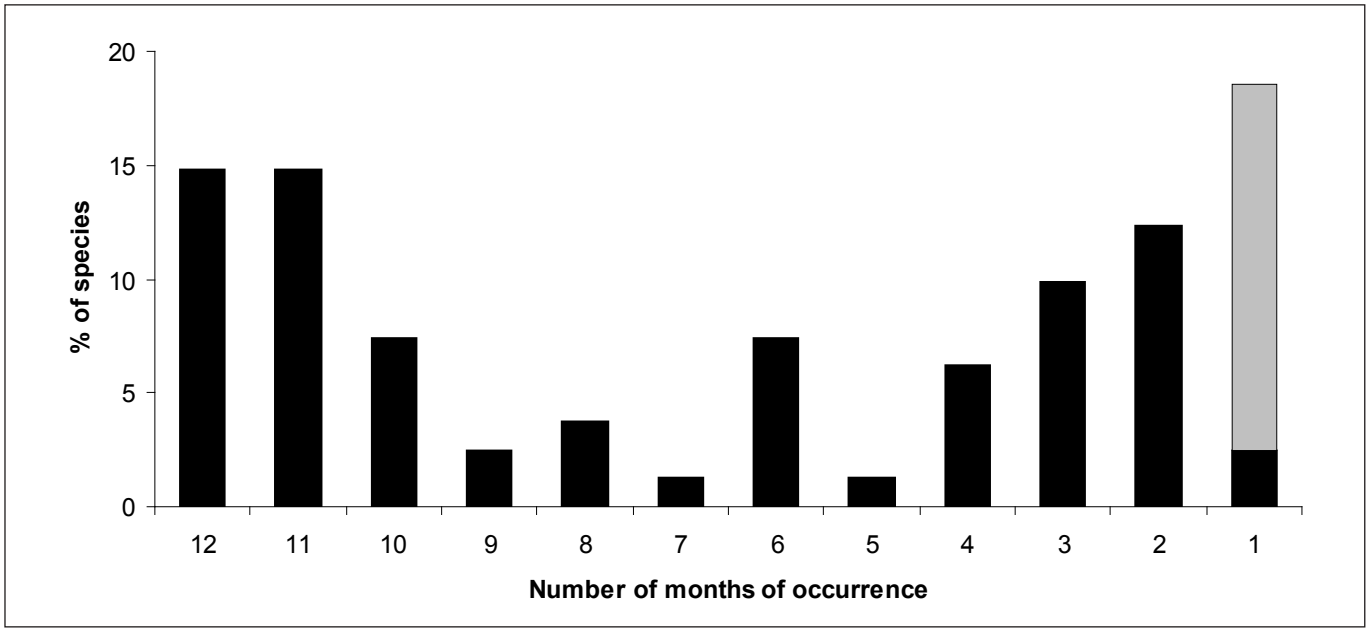

FIGURE 5. Monthly Pattern of Frequency of bird species recorded from July 2005 to August 2007 at 'Alto da Boa Vista', a campos rupestres area of the Serra do Cipó mountains, Brazil. Percentage of species according to the number of months of occurrence within a hypothetical year. This analysis was used for calculate the Phenological Category of presence (PC). The grey area represents species with FO 'Single record'. See text for details.

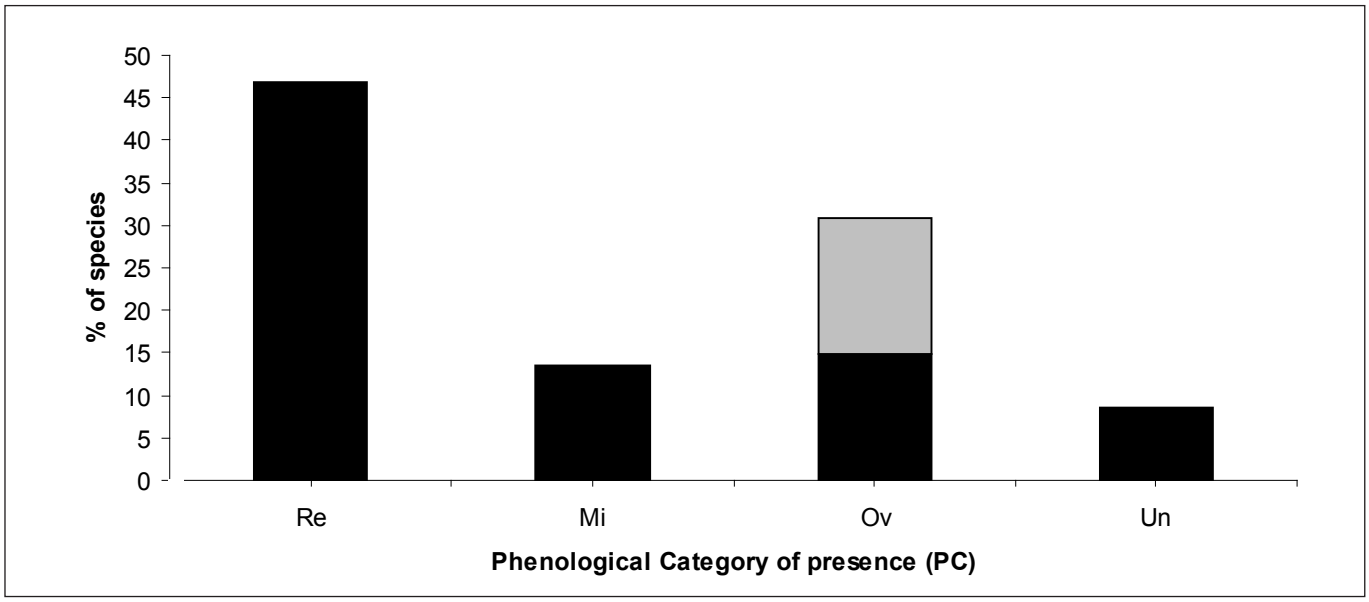

FIGURE 6. Distribution of the Phenological Category of presence (PC) of bird species recorded from July 2005 to August 2007 at 'Alto da Boa Vista', a campos rupestres area of the Serra do Cipó mountains, Brazil. Percentage of species by categories: Re, "Residents"; Mi, "Migratory"; Ov, "Occasional visitors"; Un, "Undefined". The grey area represents species with FO 'Single record'. See text for details.

TABLE 1. List of the seasonal bird species - Phenological Category (PC) of "Migratory" and "Occasional visitors" - recorded from July 2005 to August 2007 at 'Alto da Boa Vista', a campos rupestres area of the Serra do Cipó mountains, Minas Gerais state, Brazil, indicating months of occurrence in the monthly Pattern of Frequency analysis (see text for details).

	Seasonal species	Months of occurrence											
		J	F	M	A	M	J	J	A	S	O	N	D
Migratory	*Nothura maculosa*		X						X	X	X	X	
	Herpetotheres cachinnans							X	X		X		
	Elaenia chiriquensis	X	X					X		X	X	X	X
	Tyrannus melancholicus									X	X	X	
	Knipolegus nigerrimus					X		X	X				
	Stelgidopteryx ruficollis							X	X	X			
	Turdus leucomelas							X	X	X	X	X	X
	Ammodramus humeralis							X	X	X	X	X	X
	Sicalis citrina		X		X								X
	Molothrus bonariensis						X		X	X	X	X	X
	Sporagra magellanica										X	X	X
Occasional visitors	*Sarcoramphus papa*							X	X				
	Heterospizias meridionalis [1]			X									
	Rupornis magnirostris [1]								X				
	Buteo albonotatus								X	X			
	Patagioenas cayennensis								X				
	Zenaida auriculata [1]								X				
	Piaya cayana [1]		X										
	Hydropsalis parvula [1]										X		
	Chrysolampis mosquitus [1]		X										
	Amazilia lactea [1]	X											
	Veniliornis mixtus											X	X
	Synallaxis albescens [1]								X				
	Elaenia flavogaster [1]												X
	Pitangus sulphuratus [1]										X		
	Tyrannus savana								X	X			
	Knipolegus lophotes [1]									X			
	Xolmis velatus							X	X				
	Cyclarhis gujanensis							X					
	Cyanocorax cristatellus [1]								X				
	Turdus flavipes [1]					X							
	Cypsnagra hirundinacea					X		X					
	Pipraeidea melanonota						X			X			
	Emberizoides herbicola					X		X					
	Volatinia jacarina									X	X		
	Gnorimopsar chopi	X							X				

[1] Indicates that the species has a Frequency of Occurrence (FO) "Single record".

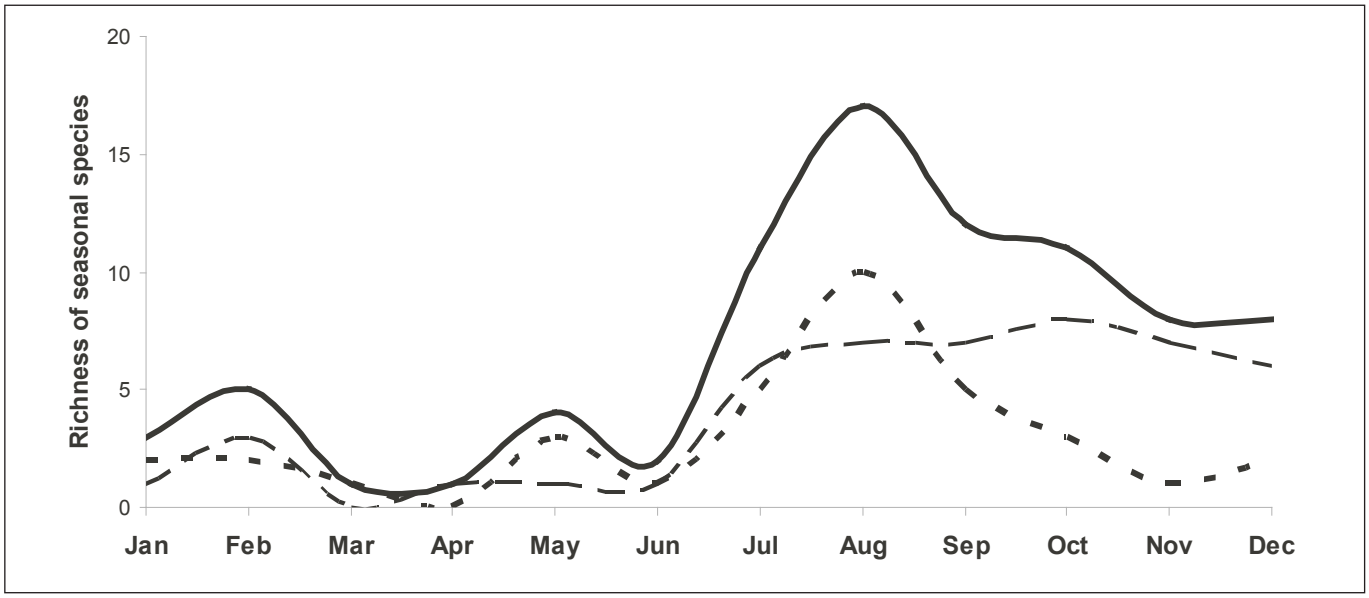

FIGURE 7. Distribution of "Migratory" and "Occasional visitors" bird species within a hypothetic year at 'Alto da Boa Vista', a campos rupestres area of the Serra do Cipó mountains, Brazil. The solid line shows the general pattern of occurrence for these species, whereas the traced line shows "Migratory" species and the dotted line the "Occasional visitors".

DISCUSSION

Species richness

The species richness estimated by us suggests that no more than 98 bird species coexist in the 200 ha area sampled in ABV. The species discovery curve shows a plateau, suggesting that most species occurring in ABV were recorded. The plateau was reached after approximately 60 days of sampling, which was completed after almost one year of field work, probably due the phenology of some species.

There are few previous studies of the avifauna of Serra do Cipó mountains that include sampling at higher altitudes. Willis & Oniki (1991) found 165 bird species in the Serra do Cipó region, most (131 species, 79%) found at higher altitudes, with less than half (63 species, 38%) appearing in campos rupestres. Melo-Júnior *et al*. (2001) recorded 269 bird species in the region (although they exhibit a number of 273 species in the paper, their table contains only 269 species), with nearly the same proportion (99 species, 37%) found in campos rupestres. A recent survey conducted at 'Alto do Palácio', an area located in the highlands at the eastern slope of Serra do Cipó, found 151 bird species (Rodrigues *et al.* 2011), with only 39 species (26%) recorded on rock outcrops habitat. Accordingly, ABV holds *c.* 36-59% of the bird richness recorded on previous surveys at Serra do Cipó, and at least 99% of the total bird richness found in campos rupestres of this region. Also, ABV represents *c.* 48% of the total bird richness found in the campos rupestres for the whole Espinhaço Range (Vasconcelos & Rodrigues 2010).

When one considers campos rupestres as part of the Cerrado domain, ABV includes no more than 11% of the 856 species recorded for this domain (Silva & Santos 2005). A survey carried out in the Cerrado lowlands of Serra do Cipó recorded 226 bird species (Rodrigues *et al*. 2005). Thus, ABV includes only *c.* 43% of the species richness of this nearby lower altitude locality. These comparisons indicate that the avian assemblages in campos rupestres are depauperate in terms of species richness when compared to other Cerrado physiognomies (*e.g.,* Bagno 1998, Marini 2001, Tubelis & Cavalcanti 2001, Lopes & Braz 2007). This contrasts sharply with patterns of plant communities (Giulietti & Pirani 1988), maybe due several micro-habitats that harbor high concentration of narrow endemic plant species (Rapini *et al*. 2008).

Species composition

Some species recorded at ABV are new records for Serra do Cipó, or for the campos rupestres of this region, or even for the whole Espinhaço Range. Most of these new records at ABV were categorized by their FO as "Single record" (43%) and included into the PC "Occasional visitors" (71%). Only *Hemitriccus margaritaceiventer* and *Poospiza cinerea* were more constant in the study area, with an FO "Uncommon" and a PC "Resident". Despite Serra do Cipó being a comparatively well-studied site, new bird species additions have been recently made at nearby highland localities, including some noteworthy records (Costa *et al*. 2008, Freitas *et al*. 2008, Vasconcelos *et al*. 2008b).

Although relatively poor in species richness, the campos rupestres avifauna has a composition distinct, but influenced by adjacent habitats (Vasconcelos & Rodrigues 2010). In particular, ABV includes 21% of the bird species considered endemic to the Cerrado domain, 57% of the endemics to the eastern Brazilian mountaintops, 50% of the endemics to the campos rupestres of Espinhaço, and all of endemics to the Espinhaço's south-central sub-area of endemism (Silva & Bates 2002, Vasconcelos 2008, Vasconcelos *et al*. 2008a). It is noteworthy that the highlands on the eastern slope of Serra do Cipó, otherwise, present also many species endemic to Atlantic Forest or typically related to forested habitats (Rodrigues *et al*. 2011).

Most species of global conservation concern in ABV are near-threatened. Recently, *Asthenes luizae* was downlisted from Vulnerable to Near-threatened, while *Polystictus superciliaris* was downlisted from Near-threatened to Least Concern (BirdLife International 2012). The number of species of conservation concern in ABV corresponds to 10% of the total number of threatened birds in the Cerrado region (Marini & Garcia 2005). All the threatened or near-threatened species of the ABV assemblage are also endemic to a biome domain (40%) or restricted to a particular habitat (60%). Habitat loss is the main threat to all of these species (BirdLife International 2012). Two species, *A. luizae* and *P. cinerea*, are also thought to be threatened by invasive species, by brood-parasitism of the Shiny Cowbird *Molothrus bonariensis*, and by further habitat shifting and alteration due climate change (BirdLife International 2012). All of the endemic or threatened bird species recorded at ABV - except for *Cyanocorax cristatellus* - are residents and were regularly observed, breeding in the area (*e.g.*, Costa & Rodrigues 2007, Gomes & Rodrigues 2010, Costa 2011).

Abundance

The large number of rare species and few very abundant species captured at ABV fits the general pattern found elsewhere in the tropics (Putman 1994, Macedo 2002, Donatelli *et al*. 2004). However the high abundance of *A. scutatus* was surprising. It has been

previously suggested that hummingbirds can be the most abundant non-passerine species in particular areas of the Amazon (Sick 1997). But we do not know of any area studied so far in the Neotropics where a hummingbird is the most abundant bird species, as we found in ABV. Trochilinae species have high flight capacity and frequency, low site fidelity and generalist feeding habit, factors that can increase the capture rate (Remsen & Good 1996). Another explanation lies in known seasonal movements of hummingbirds for seasonal floral resources (Terborgh *et al*. 1990, Sick 1997, Macedo 2002). Most plant species in the Espinhaço range are animal-pollinated, especially by birds (Machado *et al*. 2007, Rapini *et al*. 2008). Hummingbird broader dispersal to riparian forests during the dry season has been suggested for Cerrado (Macedo 2002), but there is no data supporting this hypothesis in ABV. It would be valuable, then, to explore if this species is so abundant in other campos rupestres areas, as also if the congeneric species *A. lumachella* is also so well represented in the bird communities of northern Espinhaço, in Bahia state.

The second and third most abundant species, *E. cristata* and *Z. capensis*, on the other hand, are also common in the nearby lowlands (Rodrigues *et al*. 2005) as well as in other areas within the Cerrado domain (Donatelli *et al*. 2004). *Zonotrichia capensis* is also very common at higher altitudes in all of southeastern Brazil (Sick 1997). There is evidence that part of *E. cristata* populations migrate locally within the Cerrado region (Alves 2007). It is possible that ABV receives some of these migratory individuals from the adjacent lowlands.

We recognized that estimate relative abundances by mist-netting can be biased, but we provided data that can be used to develop some testable hypotheses for future work. The three most captured species were also the most frequently observed (FO "Common"), so we expect some partial correlation between both methods. Observation of color-banded individuals helped us to determine that, for most cases, our estimates of abundance fit well or approximates to our observed abundances. For example, we captured and observed only a few more individuals of *Schistochlamys ruficapillus* that might be predicted by a previous study at the same locality (more than 13, against nine birds; Domingues & Rodrigues 2007). The abundance of captured *Poospiza cinerea* (two birds) is the very same of that observed at the study site (Costa & Rodrigues 2006), corroborating with its supposed rarity (Machado *et al*. 1998). However, we captured only two individuals of *Embernagra longicauda* recognizing that its abundance in ABV is underestimated, but only a few additional non-banded birds were observed. As it seems to be very abundant and may select wetter habitats on the eastern slope of Serra do Cipó (Freitas & Rodrigues 2012), its density can be distinct among the slopes, since those habitats are less common on the drier western slope.

Frequency of Occurrence and Phenology

The FO analysis showed that few species occur frequently and many are rare or occasional, *i.e.*, the same pattern found in the analysis of absolute abundance. The distribution of the species on FO categories at ABV differ of that found at Cerrado lowlands of Serra do Cipó where most species have high FO (Rodrigues *et al*. 2005), but is similar to other bird communities elsewhere on Cerrado and Atlantic Forest (Donatelli *et al*. 2004, Curcino *et al*. 2007). It is desirable to further investigate if the FO pattern found at ABV also occurs in other campos rupestres areas.

The PC analysis showed that many species are found in ABV throughout the year (approximately half of species were "Residents"), but also that many only occur over the course of a few months (approximately one third of species were "Occasional visitors"). Excluding those recorded only once, "Occasional visitors" species appear to be using the area regularly, since most were recorded more than once on the same month(s) of consecutive years (*e.g. Veniliornis mixtus, Tyrannus savana,* and *Volatinia jacarina*).

Four of the species categorized as "Migratory" in this study, *Nothura maculosa, Herpetotheres cachinnans*, *Turdus leucomelas,* and *Ammodramus humeralis*, are not recognized as such in literature (Silva 1995, Stotz *et al*. 1996, Sick 1997, Alves 2007). *Nothura maculosa* and *A. humeralis* are typically terrestrial species that are recorded when they explosively take flight as the observer approaches (Sick 1997). As we did not record these species in such a situation during other seasons of the year, we are confident with the seasonal status assigned to them, at least into sampled area in ABV. *Turdus leucomelas* is certainly 'migratory' in ABV, since it is an easily observed species and its winter call is frequently heard throughout the year in other localities. It is known that other *Turdus* species are at least partially migratory and most make short scale altitudinal movements in other regions of Brazil (Sick 1997, Macedo 2002, Alves 2007).

It appears that there is a distinct seasonal effect in the ABV area that is relatively well marked by the emergence of "Migratory" and "Occasional visitors". This should reflect the seasonal nature of some resources present in study site, as well as in surrounding habitats (*e.g.*, food and water availability). Observation of these species starts in July and August just before the beginning of the breeding season for most birds in Brazil (September to January; Sick 1997), which can be considered as a time of transition between wintering and breeding areas (Alves 2007). The ABV seems to be a breeding area at least for some of the "Migratory" species, such as *Elaenia chiriquensis*, *T. leucomelas*, *Sicalis citrina,* and *Molothrus bonariensis*. Breeding records for all of which were made in the area (Vasconcelos & Endrigo 2008, Gomes

& Rodrigues 2010, L. M. C. & M. R. *unpubl. data*). Species classified as "Occasional visitors", which have a narrower occurrence period, are considered to be passing through ABV during altitudinal or latitudinal migrations, maybe using the area as a stopover site. In fact, of these species in particular, *V. mixtus*, *Xolmis velatus, Tyrannus savana,* and *Volatinia jacarina* have known migratory habits (Sick 1997, Macedo 2002, Alves 2007).

Assemblage of bird species

The species composition of any biotic community is the result of a balance between species addition (colonization and speciation) and loss (emigration and local extinction). Species that can be potentially added to the community are the "pool of species" and are 'selected' for inclusion at various barrier levels, mainly by factors such as (1) dispersal and (2) environmental constraints, and (3) internal dynamics of the assemblage (Diamond 1975, Wiens 1989, Begon *et al*. 2006).

The potential "pool of species" for ABV community includes those that occur in other habitats closest to campos rupestres, adjacent areas of Cerrado and Atlantic forest habitats of lower altitudes. Since ABV is located on the western slope of Serra do Cipó, it is likely that the pool of species is mainly influenced by Cerrado species (*e.g.*, Rodrigues *et al*. 2005). All of the species able to overcome the dispersal barrier (1st factor) could potentially be recorded at ABV. Even those species unable to overcome environmental restrictions (2nd) between these areas might be recorded as 'Single records', soon leaving the area or dying. Species which might overcome the second barrier and that are not restricted by the first, could potentially co-occur naturally with the previously resident species of ABV, even if they are temporarily present and do not participate considerably in the established network of ecological interactions (3rd). This type of species could be recorded as 'Occasional visitors'.

We suggest that all species having a PC of 'Residents' form the core species of campos rupestres assemblage, and can be considered the typical bird community of this ecosystem. Certainly, seasonal fluctuations in resources and even fire can affect the local assemblage in terms of richness, composition and abundance. We anticipate that the pattern at ABV, which has been described here, may be effectively used in future comparison with other bird communities structures elsewhere in Espinhaço Range.

Conservation

Biodiversity conservation of campos rupestres is favored by the low fertility of their shallow soils, which are poorly suited for agriculture. On the other hand, there are many threats that affect this ecosystem, such as mining, cattle ranching, arson, and biological invasion (Vielliard 1990, Giullieti *et al*. 1997, Viana *et al*. 2005, Rodrigues & Costa 2006, Jacobi *et al*. 2007, Medina & Fernandes 2007). Unfortunately, all of these negative impacts occurs in ABV, and can even be found within the officially protected Conservation Unit of the region, the Parque Nacional da Serra do Cipó.

If the density of bird species in campos rupestres is as reduced as the present study suggests, we must assume that even small-scale disturbances can significantly and adversely affect the diversity of this ecosystem. Aside from what we are learning from bird research, additional studies suggest that other biotic elements of campos rupestres must be poorest in species richness and less dense, and highly distinct from those of other habitat types (Giullieti *et al*. 1997, Ribeiro & Fernandes 2000, Rodrigues 2005, Medina & Fernandes 2007).

The Espinhaço Range is an outstanding biogeographical barrier separating two hydrological basins and important biome domains at its southern portion: the dry Cerrado on the western slope (rio São Francisco basin), and the wet Atlantic forest on the eastern slope (rio Doce basin; Giulietti *et al*. 1997). Although campos rupestres occurs on mountaintops along the Espinhaço Range, it is officially included within Cerrado domain (Ribeiro & Walter 1998, Ribeiro *et al*. 2009). However, there are notable differences in soil types, rock arrangement, phytophysiognomy, and humidity between the campos rupestres of both slopes in some regions, the last one primarily because the eastern slope receives moister air from the Atlantic Ocean (Ribeiro *et al*. 2009). Preliminary biodiversity surveys have shown substantial differences also in bird and plant assemblages (see Melo-Júnior *et al*. 2001, Vasconcelos & D'Angelo Neto 2007, Ribeiro *et al*. 2009, Rodrigues *et al*. 2011), and we suggest here that at least two distinct biotic communities may occur on either slope of some regions of the Espinhaço Range, inhabiting different campos rupestres types. At Serra do Cipó, those differences are due mostly to the stationary cloudiness line that lies on eastern slope, coinciding with the hydrological basins limits in some points (Ribeiro *et al*. 2009), where we could found "wet campos rupestres"; contrasted to "dry campos rupestres" on the west. Efforts to refine the delimitation of the frontier Cerrado/Atlantic forest domains has recently started in Serra do Cipó (Ribeiro *et al*. 2009). By containing a distinct fauna and flora and, simultaneously, typical elements from Atlantic forest, Cerrado (at its southern portion) and Caatinga (at its northern portion), we agree with previous authors that it is urgent the recognition of campos rupestres as a biological unit apart those biome domains (Vasconcelos 2008, Ribeiro *et al*. 2009, Vasconcelos & Rodrigues 2010, Rodrigues *et al.* 2011).

We believe that we took the first step to understanding the community structure of campos rupestres birds beyond its species richness and composition. Herein, we presented by means of the categories of abundance, occurrence and phenology, an indication of the probability of finding each species throughout the year within the study area. We also show the core species of this bird community (*i.e.*, 'Resident' species), and two different occurrence patterns of regular visitors (Migratory and Occasional visitors). We hope that our analyses of a bird community structure and dynamics inhabiting campos rupestres on the western slope of the Serra do Cipó can be useful in further comparative investigations elsewhere on Espinhaço Range. We propose two hypotheses that can be further tested with our data: that the communities of campos rupestres differs from those of surrounding biome domains, and that there are distinct ecosystems within what is generally known as "campos rupestres". Further biological inventories that contain community structure and dynamic analyses of both slopes at other Espinhaço regions are urgently needed to better understand those questions, allowing suitable managements dealing with the conservation of the entire campos rupestres.

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APPENDIX

Frequency of occurrence, phenological category of presence, endemic and conservation status of bird species recorded from July 2005 to August 2007 at 'Alto da Boa Vista', a campos rupestres area of Serra do Cipó mountains, Minas Gerais state, Brazil. Endemic status follows Silva & Bates (2002) and Vasconcelos (2008). Conservation status follows Machado *et al*. (1998) and BirdLife International (2012). FO - Frequency of Occurrence*:* Co, "Common"; Fc, "Fairly common"; Uc, "Uncommon"; Ra, "Rare"; Oc, "Occasional"; Sr,"Single record". PC - Phenological Category of presence*:* Re, "Residents"; Mi, "Migratory"; Ov, "Occasional visitors"; Un, "Undefined". END. - Endemism: Ce, endemic to Cerrado domain; Cr, endemic to campos rupestres; Ms, endemic to the eastern Brazilian mountaintops. CON. - Conservation status*:* Re, regionally threatened; Gl, globally threatened (NT, Near-Threatened; VU, Vulnerable).

Orders, Families, and species	FO	PC	END.	CON.
TINAMIFORMES				
Tinamidae				
Rhynchotus rufescens (Temminck, 1815)	Ra	Re		
Nothura maculosa (Temminck, 1815)	Ra	Mi		
CATHARTIFORMES				
Cathartidae				
Cathartes aura (Linnaeus, 1758)	Fc	Re		
Coragyps atratus (Bechstein, 1793)	Oc	Un		
Sarcoramphus papa (Linnaeus, 1758)	Oc	Ov		
ACCIPITRIFORMES				
Accipitridae				
Heterospizias meridionalis (Latham, 1790)	Sr	Ov		
Rupornis magnirostris (Gmelin, 1788)	Sr	Ov		
Geranoaetus albicaudatus (Vieillot, 1816)	Ra	Re		
Geranoaetus melanoleucus (Vieillot, 1819)	Oc	Un		
Buteo albonotatus Kaup, 1847	Oc	Ov		
FALCONIFORMES				
Falconidae				
Caracara plancus (Miller, 1777)	Ra	Re		
Milvago chimachima (Vieillot, 1816)	Uc	Re		
Herpetotheres cachinnans (Linnaeus, 1758)	Oc	Mi		
Falco sparverius Linnaeus, 1758	Uc	Re		
CARIAMIFORMES				
Cariamidae				
Cariama cristata (Linnaeus, 1766)	Ra	Re		
COLUMBIFORMES				
Columbidae				
Patagioenas picazuro (Temminck, 1813)	Uc	Re		
Patagioenas cayennensis (Bonnaterre, 1792)	Oc	Ov		
Zenaida auriculata (Des Murs, 1847)	Sr	Ov		
PSITTACIFORMES				
Psittacidae				
Aratinga aurea (Gmelin, 1788)	Fc	Re		
CUCULIFORMES				
Cuculidae				
Piaya cayana (Linnaeus, 1766)	Sr	Ov		
Guira guira (Gmelin, 1788)	Ra	Re		

Orders, Families, and species	FO	PC	END.	CON.
CAPRIMULGIFORMES				
Caprimulgidae				
Hydropsalis parvula (Gould, 1837) [1]	Sr	Ov		
Hydropsalis longirostris (Bonaparte, 1825)	Uc	Re		
APODIFORMES				
Apodidae				
Streptoprocne zonaris (Shaw, 1796)	Oc	Re		
Trochilidae				
Phaethornis pretrei (Lesson & Delattre, 1839)	Fc	Re		
Eupetomena macroura (Gmelin, 1788)	Uc	Re		
Colibri serrirostris (Vieillot, 1816)	Fc	Re		
Chrysolampis mosquitus (Linnaeus, 1758) [2]	Sr	Ov		
Chlorostilbon lucidus (Shaw, 1812)	Uc	Re		
Amazilia lactea (Lesson, 1832) [3]	Sr	Ov		
Augastes scutatus (Temminck, 1824)	Co	Re	Ms, Cr	Gl (NT)
Heliactin bilophus (Temminck, 1820)	Oc	Un		
GALBULIFORMES				
Bucconidae				
Nystalus chacuru (Vieilloy, 1816)	Ra	Re		
PICIFORMES				
Picidae				
Veniliornis mixtus (Boddaert, 1783) [1]	Oc	Ov		
Colaptes campestris (Vieillot, 1818)	Ra	Re		
PASSERIFORMES				
Thamnophilidae				
Thamnophilus torquatus Swainson, 1825	Uc	Re		
Furnariidae				
Synallaxis albescens Temminck, 1823	Sr	Ov		
Asthenes luizae Vielliard, 1990	Fc	Re	Ms, Cr	Re, Gl (NT)
Rhynchocyclidae				
Hemitriccus margaritaceiventer (d'Orbigny & Lafresnaye, 1837) [4]	Uc	Re		
Tyrannidae				
Camptostoma obsoletum (Temminck, 1824)	Uc	Re		
Elaenia flavogaster (Thunberg, 1822)	Sr	Ov		
Elaenia cristata Pelzeln, 1868	Co	Re		
Elaenia chiriquensis Lawrence, 1865	Uc	Mi		
Elaenia obscura (d'Orbigny & Lafresnaye, 1837)	Uc	Re		
Polystictus superciliaris (Wied, 1831)	Fc	Re	Ms	
Pitangus sulphuratus (Linnaeus, 1766)	Sr	Ov		
Tyrannus melancholicus Vieillot, 1819	Oc	Mi		
Tyrannus savana Vieillot, 1808 [4]	Oc	Ov		
Myiophobus fasciatus (Statius Muller, 1776)	Ra	Re		
Knipolegus lophotes Boie, 1828	Sr	Ov		
Knipolegus nigerrimus (Vieillot, 1818)	Oc	Mi		
Xolmis cinereus (Vieillot, 1816)	Ra	Un		
Xolmis velatus (Lichtenstein, 1823)	Oc	Ov		
Vireonidae				
Cyclarhis gujanensis (Gmelin, 1789)	Oc	Ov		
Corvidae				
Cyanocorax cristatellus (Temminck, 1823)	Sr	Ov	Ce	

Orders, Families, and species	FO	PC	END.	CON.
Hirundinidae				
Pygochelidon cyanoleuca (Vieillot, 1817)	Oc	Un		
Stelgidopteryx ruficollis (Vieillot, 1817)	Oc	Mi		
Troglodytidae				
Troglodytes musculus Naumann, 1823	Fc	Re		
Turdidae				
Turdus flavipes Vieillot, 1818 [2,3]	Sr	Ov		
Turdus leucomelas Vieillot, 1818	Ra	Mi		
Mimidae				
Mimus saturninus (Lichtenstein, 1823)	Uc	Re		
Motacillidae				
Anthus hellmayri Hartert, 1909	Oc	Un		
Thraupidae				
Saltatricula atricollis (Vieillot, 1817)	Uc	Re	Ce	
Cypsnagra hirundinacea (Lesson, 1831)	Oc	Ov		
Tangara cayana (Linnaeus, 1766)	Uc	Re		
Schistochlamys ruficapillus (Vieillot, 1817)	Co	Re		
Pipraeidea melanonota (Vieillot, 1819)	Oc	Ov		
Emberizidae				
Zonotrichia capensis (Statius Muller, 1776)	Co	Re		
Ammodramus humeralis (Bosc, 1792)	Ra	Mi		
Porphyrospiza caerulescens (Wied, 1830)	Uc	Re	Ce	Gl (NT)
Poospiza cinerea Bonaparte, 1850 [4]	Uc	Re	Ce	Re, Gl (VU)
Sicalis citrina Pelzeln, 1870	Ra	Mi		
Emberizoides herbicola (Vieillot, 1817)	Oc	Ov		
Embernagra longicauda Strickland, 1844	Uc	Re	Ms	Gl (NT)
Volatinia jacarina (Linnaeus, 1766)	Oc	Ov		
Cardinalidae				
Piranga flava (Vieillot, 1822)	Oc	Un		
Parulidae				
Geothlypis aequinoctialis (Gmelin, 1789)	Fc	Re		
Icteridae				
Gnorimopsar chopi (Vieillot, 1819)	Oc	Ov		
Pseudoleistes guirahuro (Vieillot, 1819)	Fc	Re		
Molothrus bonariensis (Gmelin, 1789)	Ra	Mi		
Fringillidae				
Sporagra magellanica (Vieillot, 1805)	Ra	Mi		

[1] new records for all campos rupestres of the Espinhaço Range.
[2] new records for the entire Serra do Cipó region.
[3] species recorded only by mist-netting.
[4] new records for the campos rupestres habitats of the Serra do Cipó region.