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Vascular epiphytes in a forest fragment of Serra da Mantiqueira and floristic relationships with Atlantic high altitude areas in Minas Gerais

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Abstract This study presents the results of a vascular epiphytic flora survey in a fragment of the Serra da Mantiqueira, southeastern Brazil, and compares the floristic composition with that of six other altitude areas of this mountainous complex in the Minas Gerais State, using the Jaccard index and the unweighted pair-group method with arithmetic mean algorithm. The survey was performed between September 2010 and January 2012 in the Serra do Cruz (SC), part of the Mantiqueira complex. The survey recorded 135 species, 62 genera, and 16 families. Orchidaceae and Polypodiaceae were the richest families among the angiosperms and ferns, respectively. Some species were recorded for the first time in the flora of Minas Gerais State, including *Cryptophoranthus jordanensis* and *Pleurothallis gehrtii*. Five species are threatened with extinction in Minas Gerais, cited in different categories: *Epidendrum ochrochlorum*, *Hadrolaelia coccinea* and *Pleurothallis cryptophoranthoides* (as Endangered, EN), and *Vriesea penduliflora* and *Oncidium warmingii* (as Vulnerable, VU). The similarity analysis showed that the composition of vascular epiphytes of the SC is more related to that of the Serra Negra and Parque Estadual do Ibitipoca, and that about 60 % of this similarity is due to geographic distance, although with relatively low values of about 0.31–0.35. Although geographically close, the low similarity between the three areas reinforces the need for conservation of all remnant fragments of the Serra da Mantiqueira, to conserve the Minas Gerais flora as a whole.

Keywords Atlantic forest · Biodiversity · *Campo rupestre* · Dense ombrophilous forest · Serra do Cruz

Introduction

The Serra da Mantiqueira encompasses part of four states of the Brazilian southeastern region and is one of the most important mountain ranges in this region, harbouring endemic plant species and/or those threatened with extinction. The area was classified as a priority for biodiversity conservation in Minas Gerais State, due to its high biological richness (Drummond et al. 2005). From the abiotic standpoint, due to several springs, the region is considered the largest provider of mineral water in the world, for its quality and quantity (Lino et al. 2007).

The Serra da Mantiqueira represents an important region for the conservation of Atlantic forest (AF) in Minas Gerais State, protecting about 20 % of the remnants (Soares and Costa 2008). However, despite its ecological importance, the region is extremely threatened by incorrect land use and urban expansion, mineral extraction, and farming, leading to deforestation and environment degradation (Lino et al. 2007).

Epiphytes represent 9–10 % of the vascular flora, comprising between 23,000 and 29,000 species, distributed among 73–84 families (Kress 1986; Gentry and Dodson 1987; Zotz 2013), and they play an important ecological role in the flora of tropical regions (Benzing 1990). In Brazil, there are 49 families of epiphytic species, including Orchidaceae, Bromeliaceae, and Araceae among the richest representatives (Kersten 2010).

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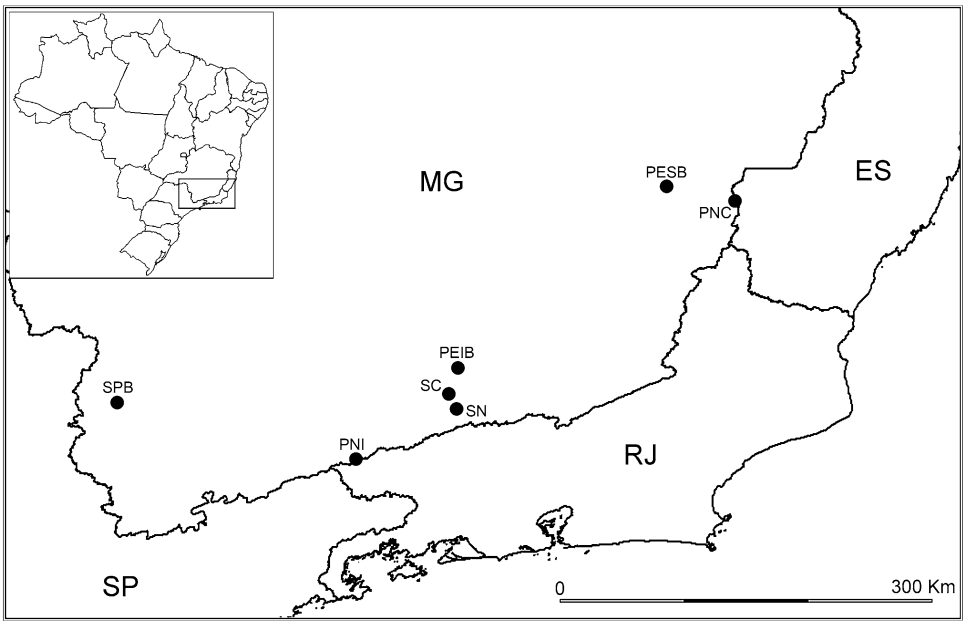

Fig. 1 Location of Serra do Cruz, southeastern of Minas Gerais and of areas used in similarity analysis. *SC* Serra do Cruz, *SN* Serra Negra, *PEIB* Parque Estadual do Ibitipoca, *PNI* Parque Nacional do Itatiaia, *PESB* Parque Estadual da Serra do Brigadeiro, *PNC* Parque Nacional do Caparaó, *SPB* Serra da Pedra Branca

In the last 15 years, the number of studies on epiphytic flora in Brazil has gradually increased, although the majority of studies are concentrated in the southern region of the country (Kersten 2010) and are scarce in Minas Gerais State (Werneck and Espírito Santo 2002; Alves et al. 2008; Menini Neto et al. 2009b).

The aim of this study was to survey the vascular epiphytic species in the Serra do Cruz (SC) and to evaluate the floristic relationships with another six altitude areas in the Serra da Mantiqueira in Minas Gerais State, to extend knowledge concerning the biodiversity of the AF in the Mantiqueira complex region, as well as that concerning the geographic distribution of the families and species recorded.

Materials and methods

Study area

The Mantiqueira complex includes part of the states of Minas Gerais, Espírito Santo, Rio de Janeiro, and São Paulo, and is one of the largest and most important mountain ranges in the Brazilian southeastern region (Soares and Costa 2008).

The SC lies between the municipalities of Olaria, Lima Duarte, and Bom Jardim de Minas (21°51′S, 43°56′W) (Fig. 1), at an altitude between 1,300 and 1,700 m and is part of the ecological corridor of the Serra da Mantiqueira, according to the delimitation proposed by Soares and Costa (2008). This area is also part of a region considered of "very high" biological importance for the conservation of the Minas Gerais flora (Drummond et al. 2005).

The region is part of the Atlantic domain and its vegetation is composed of a mosaic of wet grassland, *campo rupestre* with quartizitic outcrops and white sand, montane seasonal semideciduous forest, and patches of montane and high montane dense ombrophilous forest in the higher areas (pers. obs.).

The climate of the region is Cwb according to the Köppen classification, with a mean annual temperature of 20.6 °C and mean annual rainfall of 1,200–1,500 mm. The landscape is mainly mountainous and its main elevations are the SC, Serra das Flores, and the Serra das Voltas e Serra Negra (IBGE 2012).

Field and laboratory work

To perform the survey of vascular epiphytes in the SC, expeditions were undertaken between September 2010 and January 2012, using random walking method ("método do caminhamento" proposed by Filgueiras et al. (1994)), covering the widest possible area in each expedition.

Only fertile specimens were collected with a hand pruner or trimmer and when necessary, by climbing phorophytes. Plants were photographed and published as a rapid colour guide by "the field museum of Chicago" (http://fm2.fieldmuseum.org/plantguides/guide_pdfs/470%20Ep%EDfitas%20da%20Serra%20do%20Cruz.pdf). The annotation of relevant data was performed in the field.

The specimens were herborized and deposited in the Herbarium Leopoldo Krieger (CESJ) of the Universidade

Federal de Juiz de Fora (Thiers 2012), according to usual methods.

Plant identification was performed by comparison with the CESJ Herbarium collection, via specialized literature and the cooperation of specialists in the recorded families (listed in Table 1). The *red list of flora threatened with extinction of Minas Gerais State* (Biodiversitas 2007) was consulted, to verify the threat status of the recorded species in the SC. Names are according to Lista de Espécies da Flora do Brasil (2013), except regarding to genera *Maxillaria*, *Oncidium*, and *Pleurothallis* (Orchidaceae) due to instability in its circumscription along the last years. The ecological categories were according to Benzing (1990), and the dispersion was obtained in the specialized literature about epiphytes.

Floristic similarity analysis

Due to the scarcity of similar studies with vascular epiphytes in Minas Gerais State, the composition of vascular epiphytes of the SC was compared with general floristic surveys in which the life form of recorded species was noted: Parque Estadual da Serra do Brigadeiro (PESB) (Leoni and Tinte 2004), Parque Estadual do Ibitipoca (PEIB) (Menini Neto et al. 2009a, Forzza et al. 2013), Serra Negra (SN) (Menini Neto et al. 2009a; Souza et al. 2012; Salimena et al. 2013), Serra da Pedra Branca (SPB) (Rezende et al. 2013), Parque Nacional (Parna) do Caparaó (PNC) (Souza 2012; Machado 2012), and Parna do Itatiaia (Condack 2006). Regarding the national parks of Caparaó and Itatiaia, the published checklists (ferns, Bromeliaceae and part of Orchidaceae, to first CU and ferns, to second), were supplemented by data obtained from the website SpeciesLink (www.splink.org.br), which gathers collections of several national and international herbaria. The environmental data for each area (shown in Table 2) were obtained from the respective articles.

All locations are part of the Mantiqueira Complex, characterized by high elevations (the majority above 900 m.s.m.), and vegetation was represented by mosaics of forest (seasonal semideciduous forest, dense ombrophilous forest, and/or mixed ombrophilous forest) and field areas (*campo de altitude* or *campo rupestre*).

A matrix was created, consisting of the presence (1) or absence (0) of species from the cited surveys, comprising a total of 516 vascular epiphytic species. The infraspecific taxa, as well as unidentified taxa at the species level (shown by "cf.," "aff.," or "sp."), were removed from the analysis.

The similarity analysis was conducted via the unweighted pair-group method using the arithmetic averages (UPGMA) algorithm, the Jaccard index and the Mantel test, to evaluate the correlation between floristic similarity and geographic distance among areas. Both

Table 1 List of species of vascular epiphytes recorded in the Serra do Cruz, Minas Gerais

Families and species	EC	Disp	Voucher
Amaryllidaceae—1/1			
Hippeastrum calyptratum Herb.	CHL	An	Alves 206
Araceae—2/5			
Anthurium minarum Sakuragui & Mayo	FHL	Zo	Alves 134
Anthurium scandens (Aubl.) Engl.	CHL	Zo	Alves 67
Philodendron appendiculatum Nadruz & Maio	Hem	Zo	Alves 151
Philodendron minarum Kunth ex Schott	Hem	Zo	Alves 63
Philodendron propinquum Schott	Hem	Zo	Alves 199
Aspleniaceae—1/4			
Asplenium auritum Sw.	CHL	An	Alves 75
Asplenium claussenii Hieron.	FHL	An	Dittrich 1799
Asplenium harpeodes Kunze	FHL	An	Dittrich 1798
Asplenium oligophyllum Kaulf.	Hem	An	Alves 163
Begoniaceae—1/2			
Begonia fruticosa A. DC.	FHL	An	Menini Neto 1141
Begonia rufa Thunb.	AHL	An	Alves 81
Blechnaceae—1/1			
Blechnum binervatum (Poir.) C.V. Morton & Lellinger	FHL	An	Alves 100
Bromeliaceae—6/19			
Aechmea aiuruocensis Leme	FHL	Zo	Alves 54
Aechmea coelestis (K. Koch) E. Morren.	CHL	Zo	Alves 89
Aechmea nudicaulis (L.) Griseb.	CHL	Zo	Alves 36
Aechmea pineliana (Brongn. ex Planch.) Baker	CHL	Zo	Menini Neto 1142
Billbergia distachia (Vell.) Mez	FHL	Zo	Alves 17
Nidularium ferdinando-coburgii Wawra	FHL	Zo	Alves 58
Racinaea aerisincola (Mez) M.A. Spencer & L.B. Sm.	CHL	An	Alves 8
Tillandsia geminiflora Brongn.	CHL	An	Alves 4
Tillandsia recurvata (L.) L.	CHL	An	Alves 85
Tillandsia stricta Lindl.	CHL	An	Alves 32
Tillandsia tenuifolia L.	CHL	An	Alves 211
Tillandsia usneoides (L.) L.	CHL	An	Alves 141
Vriesea bituminosa Wawra	FHL	An	Alves 11
Vriesea friburgensis Mez	FHL	An	Alves 24
Vriesea gradata (Baker) Mez	CHL	An	Alves 79
Vriesea guttata Linden & André	CHL	An	Alves 35
Vriesea heterostachys (Baker) L.B. Sm.	FHL	An	Alves 2

Table 1 continued

Families and species	EC	Disp	Voucher
Vriesea lubbersii (Baker) Mez	CHL	An	Alves 138
Vriesea penduliflora L.B. Sm.	FHL	An	Alves 33
Cactaceae—2/4			
Hatiora salicornioides (Haw.) Britton & Rose	FHL	Zo	Alves 166
Rhipsalis elliptica G. Lindb. ex. Schum	CHL	Zo	Alves 190
Rhipsalis floccosa Salm-Dyck ex Pfeiff.	CHL	Zo	Alves 152
Rhipsalis juengeri Barthlott & N.P. Taylor	CHL	Zo	Alves 164
Commelinaceae—1/1			
Dichorisandra incurva Mart. ex Schult.f.	AHL	Zo	Alves 198
Dryopteridaceae—2/4			
Elaphoglossum glaziovii (Fée) Brade	CHL	An	Alves 120
Elaphoglossum sp. 1	CHL	An	Alves 113
Elaphoglossum sp. 2	CHL	An	Alves 123
Rumohra adiantiformis (G. Forster) Ching	AHL	An	Alves 111
Gesneriaceae—2/2			
Nemathantus strigillosus (Mart.) H.E. Moore	Hem	Zo	Alves 27
Sinningia cooperi Wiehler	CHL	Na	Alves 201
Hymenophyllaceae—4/8			
Hymenophyllum asplenioides (Sw.) Sw.	CHL	An	Alves 121
Hymenophyllum fragile (Hedw.) C.V. Morton	CHL	An	Alves 179
Hymenophyllum polyanthos (Sw.) Sw.	CHL	An	Alves 104
Hymenophyllum sp. 1	CHL	An	Alves 126
Hymenophyllum sp. 2	CHL	An	Alves 127
Polyphlebium angustatum (Carmich.) Ebihara & Dubuisson	CHL	An	Alves 161
Trichomanes anadromum Rosenst.	CHL	An	Alves 71
Vandenboschia radicans (Sw.) Copel.	CHL	Na	Dittrich 1793
Lindsaeaceae—1/1			
Lindsaea botrychioides A. St-Hil.	FHL	Na	Alves 72
Orchidaceae—23/50			
Bifrenaria stefanae V.P. Castro	CHL	An	Alves 74
Bulbophyllum granulosum (Barb.Rodr.) Cogn.	CHL	An	Alves 7
Bulbophylum regnellii Rchb.f.	CHL	An	Alves 130
Campylocentrum linearifolium Schltr. ex Mansf.	CHL	An	Alves 16
Capanemia thereziae Barb.Rodr.	CHL	An	Alves 13

Table 1 continued

Families and species	EC	Disp	Voucher
Cryptophoranthus jordanensis Brade	CHL	An	Alves 170
Dichaea cogniauxiana Schltr.	CHL	An	Alves 34
Encyclia patens Hook.	FHL	An	Alves 173
Epidendrum chlorinum Barb.Rodr.	CHL	An	Alves 136
Epidendrum aff. *chlorinum* Barb.Rodr.	CHL	An	Alves 47
Epidendrum latilabre Lindl.	CHL	An	Alves 23
Epidendrum ochrochlorum Barb.Rodr.	CHL	Na	Alves 116
Epidendrum parahybunense Barb.Rodr.	CHL	Na	Alves 176
Epidendrum rigidum Jacq.	FHL	Na	Alves 177
Epidendrum secundum Jacq.	FHL	An	Alves 118
Eurystyles cotyledon Wawra	CHL	An	Alves 21
Gomesa barkeri (Hook.) Rolfe	CHL	An	Alves 167
Gomesa gomezoides (Barb.Rodr.) Pabst	CHL	An	Alves 193
Gomesa recurva R. Br.	FHL	An	Alves 62
Hadrolaelia coccinea (Lindl.) Chiron & V.P.Castro	FHL	An	Alves 5
Isochilus linearis (R. Br.) Jacq.	CHL	An	Alves 59
Malaxis excavata (Lindl.) Kuntze	AHL	An	Alves 19
Maxillaria bradei Schltr. ex Hoehne	CHL	An	Alves 182
Maxillaria notylioglossa Rchb.f.	CHL	An	Alves 39
Maxillaria picta Hook.	CHL	An	Alves 15
Maxillaria subulata Lindl	FHL	An	Alves 90
Octomeria diaphana Lindl.	CHL	An	Alves 157
Octomeria grandiflora Lindl.	CHL	An	Alves 80
Oncidium gardneri Hook.	FHL	An	Alves 208
Oncidium hookeri Rolfe	CHL	An	Alves 42
Oncidium longipes Lindl.	CHL	An	Alves 31
Oncidium truncatum Lindl.	CHL	An	Alves 139
Oncidium warmingii Rchb.f.	AHL	An	Alves 155
Phymatidium microphyllum (Barb.Rodr.) Toscano	CHL	An	Alves 20
Pleurothallis cryptophoranthoides Loefgr.	CHL	An	Alves 22
Pleurothallis gehrtii Hoehne & Schltr.	CHL	An	Alves 204
Pleurothallis mentigera Kraenzl.	CHL	An	Alves 183
Pleurothallis rubens Lindl.	FHL	An	Alves 131
Pleurothallis saundersiana Rchb.f.	CHL	An	Alves 52
Pleurothallis tricarinata Poepp. & Endl.	CHL	An	Alves 162

Table 1 continued

Families and species	EC	Disp	Voucher
Polystachya estrellensis Rchb.f.	FHL	An	Alves 61
Promenaea xanthina Lindl.	CHL	An	Alves 30
Prosthechea allemanoides (Hoehne) W.E. Higgins	FHL	An	Alves 9
Prosthechea pachysepala (Klotszch.) Chiron & V.P. Castro	FHL	An	Alves 10
Stelis aprica Lindl.	CHL	An	Alves 187
Stelis caespitosa Lindl.	CHL	An	Alves 189
Stelis intermedia Poepp. & Endl.	CHL	An	Alves 44
Stelis megantha Barb.Rodr.	CHL	An	Alves 117
Stelis papaquerensis Rchb.f.	CHL	An	Alves 184
Zygopetalum maxillare Lodd.	CHL	An	Alves 202
Piperaceae—1/8			
Peperomia alata Ruiz & Pav.	FHL	Ep	Alves 197
Peperomia corcovadensis Gardn.	FHL	Ep	Alves 64
Peperomia diaphanoides Dahlst.	FHL	Ep	Alves 38
Peperomia galioides Kunth	FHL	Ep	Alves 174
Peperomia glabella (Sw.) A. Dietr.	FHL	Ep	Alves 146
Peperomia quadrifolia (L.) Kunth	FHL	Ep	Alves 37
Peperomia subrubricaulis C. DC.	FHL	Ep	Alves 129
Peperomia tetraphylla (G. Forst.) Hook. & Arn.	CHL	Ep	Alves 56
Polypodiaceae—12/23			
Alansmia reclinata (Brack.) Moguel & M. Kessler	CHL	An	Alves 122
Campyloneurum acrocarpon Fée	CHL	An	Dittrich 1797
Campyloneurum cf. *aglaolepis* (Alston) de la Sota	CHL	An	Alves 110
Campyloneurum decurrens (Raddi) C. Presl.	FHL	An	Dittrich 1802
Campyloneurum nitidum (Kaulf.) C. Presl.	CHL	An	Alves 26
Cochlidium punctatum (Raddi) L.E. Bishop	CHL	An	Alves 103
Cochlidium serrulatum (Sw.) L.E. Bishop	CHL	An	Alves 99
Lellingeria apiculata (Kunze *ex* Klotzsch) A.R. Sm. & R.C. Moran	CHL	An	Alves 76
Melpomene pilosissima M.Martens & Galeotti) A.R. Sm. & R.C. Moran	CHL	An	Alves 106
Microgramma squamulosa (Kaulf.) de la Sota	CHL	An	Alves 40
Micropolypodium gradatum (Baker) Labiak & F.B. Matos	CHL	An	Alves 108
Niphidium crassifolium (L.) Lellinger	FHL	An	Alves 93
Pecluma recurvata (Kaulf.) M.G. Price	CHL	An	Alves 98
Pecluma truncorum (Lindm.) M.G. Price	CHL	An	Dittrich 1795
Phlebodium pseudoaureum (Cav.) Lellinger	CHL	An	Alves 112
Phlebodium sp.	CHL	An	Alves 92
Pleopeltis astrolepis (Liebm.) E. Fourn.	CHL	An	Alves 96
Pleopeltis hirsutissima (Raddi) de la Sota	CHL	An	Alves 3
Pleopeltis macrocarpa (Bory ex Willd.) Kaulf.	CHL	An	Alves 1
Pleopeltis pleopeltidis (Fée) de la Sota	CHL	An	Alves 105
Serpocaulon catharinae (Langsd. & Fisch.) A.R. Sm.	CHL	An	Alves 12
Serpocaulon fraxinifolium (Jacq.) A.R. Sm.	Hem	An	Alves 132
Serpocaulon latipes (Langsd. & Fisch.) A.R. Sm.	FHL	An	Alves 97
Pteridaceae—2/2			
Polytaenium lineatum (Sw.) J. Sm.	CHL	An	Dittrich 1794
Vittaria sp.	CHL	An	Alves 101

The numbers that follow families are, respectively, genera and species recorded in the Serra do Cruz

EC ecological category (Benzing 1990), *Disp* dispersion form, *CHL* characteristic holoepiphyte, *AHL* accidental holoepiphyte, *FHL* facultative holoepiphyte, *Hem* hemiepiphyte, *An* anemochory, *Zoo* zoochory, *EP* epizoochory. Specialists who assisted in the identification of species: Araceae—Marcus Nadruz; Bromeliaceae—Ana Paula G. Faria and Rafaela C. Forzza; Cactaceae—Diego R. Gonzaga and Daniela Zappi; Gesneriaceae—Luciana P. Carvalho; Piperaceae—Daniele Monteiro; Ferns families—Vinícius A. O. Dittrich and Filipe S. Souza

analyses were conducted using free access PAST v.2.17 software (Hammer et al. 2001).

Results and discussion

The number of species of vascular epiphytes recorded in the SC was 135, distributed among 62 genera and 16 families (Table 1).

The ferns comprised seven families and 43 species, including Polypodiaceae (23 spp.), Hymenophyllaceae (eight spp.), Aspleniaceae and Dryopteridaceae (four spp.

Table 2 Locations used in the floristic similarity analysis of vascular epiphytes in the Serra da Mantiqueira

Areas	Acronyms	Coordinates	Altitude	Vegetation types	*NS*	*NF*	Source
Serra do Cruz	SC	21°51′S, 43°56′W	1,300–1,700	CR, SSF, DOF	135	16	1
Serra Negra	SN	21°58′S–43°53′W	900–1,690	CR, SSF, DOF	180	17	2
P. E. Ibitipoca	PEIB	21°40′S–43°52′W	1,000–1,784	CR, SSF, DOF	180	17	3
Parna do Itatiaia	PNI	22°30′S–44°35′W	650–2,780	CA, DOF	161	16	4
P. E. Serra do Brigadeiro	PESB	20°40′S–42°26′W	1,445–1,722	CA, SSF	113	15	5
Parna do Caparaó	PNC	20°20′S–41°45′W	1,300–2,890	CA, DOF	234	16	6
Serra da Pedra Branca	SPB	21°55′S–46°22′W	1,160–1,780	CA, SSF, DOF, MOF	58	10	7

NS number of species in each area, *NF* number of families in each area. Vegetation types *CR campo rupestre*, *CA campo de altitude*, *SSF* seasonal semideciduous forest, *DOF* dense ombrophilous forest, *MOF* mixed ombrophilous forest. Source: *1* present study, *2* Menini Neto et al. (2009b), Souza et al. (2012), Salimena et al. (2013), *3* Menini Neto et al. (2009a), Forzza et al. (2013), *4* Condack (2006), *SpeciesLink*; *5* Leoni & Tinte (2004), *6* Souza (2012), Machado (2012), *SpeciesLink*, *7* Rezende et al. (2013)

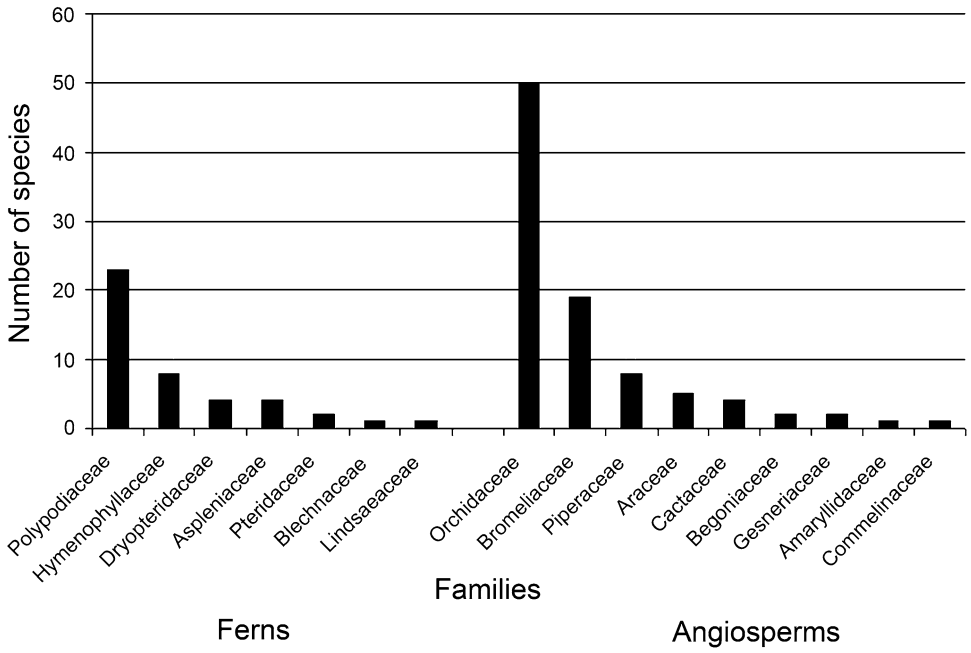

Fig. 2 Families of ferns and angiosperms recorded in Serra do Cruz

each) as the richest families (Fig. 2). The richest genus was *Hymenophyllum* J. Sm. (Hymenophyllaceae) (five spp.), followed by *Asplenium* L. (Aspleniaceae), *Campyloneurum* C. Presl. and *Pleopeltis* Humb. & Bonpl. ex Willd. (Polypodiaceae) (four spp. each), *Elaphoglossum* Schott ex J. Sm. (Dryopteridaceae), and *Serpocaulon* A.R. Sm. (Polypodiaceae) (three spp. each), representing 23 species or 51.1 % of the epiphytic ferns recorded in the area.

Angiosperms were represented by 92 species, distributed among nine families. In terms of species richness, the following families were important: Orchidaceae (50 spp.), Bromeliaceae (19 spp.), and Piperaceae (eight spp.) (Fig. 2). The richest genera were *Peperomia* Ruiz & Pav. (Piperaceae), with eight species, *Vriesea* Lindl. (Bromeliaceae) and *Epidendrum* L. (Orchidaceae) (seven spp. each), *Pleurothallis s.l.* R. Br. (Orchidaceae) (six spp.), *Oncidium s.l.* Sw., *Stelis* Sw. (Orchidaceae), and *Tillandsia* L. (Bromeliaceae) (five spp. each), representing 43 species, or about 48 % of angiosperms and approximately 31 % of the total species of vascular epiphytes in the SC.

Some specimens were observed to be sterile during the study and were, therefore, not collected nor included in the checklist. The probable taxa are as follows: *Anthurium* sp. (Araceae), *Marcgravia polyantha* (Marcgraviaceae), *Bifrenaria harrisoniae* (Hook.) Rchb. f., *Gomesa glaziovii* Cogn., *Grobya amherstiae* Lindl., *Octomeria crassifolia* Lindl. and *Oncidium* sp. (Orchidaceae), *Myrsine* cf. *umbellata* Mart. (Primulaceae), and three species of Melastomataceae (possibly accidental specimens of the genus *Miconia*), and two unidentified eudicotyledons.

The richness shown by the main families in the SC: Orchidaceae, Polypodiaceae, Bromeliaceae, Piperaceae,

and Araceae, corroborate the representativity of the richest families of vascular epiphytic species at a global level (Kress 1986; Benzing 1990) as well as in the AF (Kersten 2010); however, the relative richness abundance varied. For example, for the AF, Kersten (2010) points to Bromeliaceae and Araceae as being the second and fourth richest families, respectively, and to Polypodiaceae and Piperaceae as the third and fifth richest families, respectively. It is interesting that although these were the five richest families in several studies performed in the Atlantic domain (e.g., Borgo and Silva 2003; Giongo and Waechter 2004; Hefler and Faustioni 2004; Gaiotto and Acra 2005, Menini Neto et al. 2009a), together with Orchidaceae as the richest family, Polypodiaceae and Bromeliaceae often alternate as the second richest family, whereas Piperaceae and Araceae, often occupied the fourth and fifth richest families, in either order.

Apart from being the richest family of epiphytic species, the richness commonly found within Orchidaceae in the cited surveys, as well as in the present study, is also often the highest in the Atlantic domain, according to Barros et al. (2009). Similarly, Bromeliaceae is notable as the third richest family, in the studied area, which also reflects its representativity in this phytogeographic domain, and in the area of this study, a large number of species of *Tillandsia* and *Vriesea*, two of the richest genera of the family in the Atlantic domain, were observed (Martinelli et al. 2008).

The most frequent ecological category was characterized by characteristic holoepiphytes, with 89 species (~66 %), which supports the commonly observed pattern, although this value is lower than other studies conducted in Southern region, which are mostly in mixed ombrophilous forest (e.g., Dittrich et al. 1999; Kersten and Silva 2001; Giongo and Waechter 2004; Cervi and Borgo 2007). However, Menini Neto et al. (2009b) also found a low percentage (56.3 %) of the characteristic holoepiphytes in three areas of Minas Gerais composed by seasonal semideciduous forest or mosaic of dense ombrophilous forest and *campo rupestre*. Such proportion seems to vary in the several physiognomies of Atlantic forest, and further studies can clarify this question.

Another ecological aspect observed among the recorded species was the type of dispersion, with 110 species observed that were wind dispersed, a number which is supported by the literature concerning the epiphytic synusia, including a large number of orchids, ferns, and bromeliads (especially *Tillandsia* and *Vriesea*). Approximately, 84 % (Madison 1977) and 80 % (Benzing 1987) of vascular epiphyte species are wind dispersed, which compares well with the value of ca. 81 % found in this study.

Among the species recorded in the SC, *Peperomia subrubricaulis* (Piperaceae) is endemic to Minas Gerais State (Guimarães et al. 2013), whereas *Cryptophoranthus jordanensis* Brade and *Pleurothallis gehrtii* Hoehne & Schltr. (Orchidaceae) were recorded for the first time in Minas Gerais (Menini Neto et al. 2013), being the first previously only known in the states of Rio de Janeiro, São Paulo and the second to these two states, and also in Santa Catarina (Barros et al. 2013).

Five species that occur in the area are considered under threat of extinction in the Minas Gerais State (Biodiversitas 2007), according to the criteria of the International Union for Conservation of Natural Resources (IUCN 2001): *Epidendrum ochrochlorum*, *Hadrolaelia coccinea* and *Pleurothallis cryptophoranthoides* (Orchidaceae) are in the category Endangered (EN) and *Vriesea penduliflora* (Bromeliaceae), and *Oncidium warmingii* (Orchidaceae) as are classified as Vulnerable (VU). Additionally, species such as *Hippeastrum calyptratum* (Amaryllidaceae) and *Trichomanes anadromum* (Hymenophyllaceae) are considered as data deficient, because they are probably threatened with extinction, but current information does not allow a more accurate assessment of their conservation status. Of the above species, *H. coccinea* must be highlighted because it is relatively abundant, in contrast to observations by Menini Neto et al. (2007) in PEIB, located about 22 km from the SC. This is probably due to the difficult access of the SC, which is not frequently visited and consequently, *H. coccinea* does not suffer from collection pressure, as occurs in PEIB.

The similarity analysis resulted in a cophenetic coefficient of 0.9617, which represents a good fit between the matrix of species presence or absence and the dendrogram (Fig. 3). The dendrogram demonstrates the initial segregation of the SPB from the other areas. One reason for this might be that the SPB is the most distant area from the ocean, situated at the western extreme of Serra da Mantiqueira, presenting mixed ombrophilous forest besides other physiognomies (Rezende et al. 2013), which has a common characteristic floristic composition (Waechter 2009). The SPB is also the only area in the hydrographic

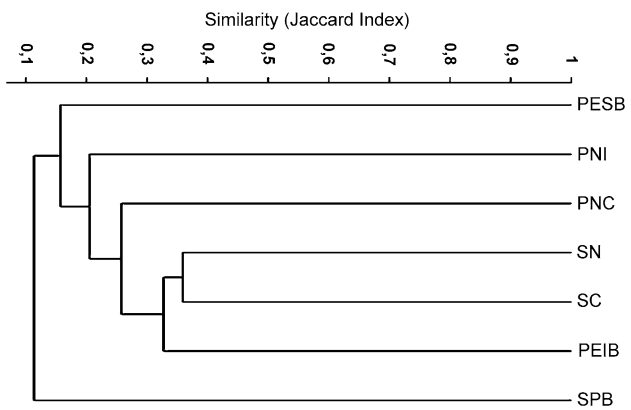

Fig. 3 Dendrogram obtained in similarity analysis using UPGMA. Acronyms presented in Table 2. Cophenetic coefficient = 0.9617

basin of the Rio Paraná, whereas the other areas lie in the Atlântico Leste Basin (http://hidroweb.ana.gov.br/). Furthermore, the SPB has a lower number of families and species compared to the other areas (Table 2).

The relationship between the areas shows the gradual divergence of the localities that possess a mosaic of forest and *campos de altitude*, (PESB, PNI, and PNC) and the formation of a group containing the three areas, PEIB, SN, and SC, where the vegetational mosaic is composed of forests and *campos rupestres*, with a maximum similarity index of 0.35.

The Mantel test showed a correlation between the geographic distance of the analyzed areas and the similarity indices ($p = 0.00272$), and the correlation coefficient ($r = 0.6232$) indicates that about 62 % of the similarity is due to the geographic distance. Although the areas are composed of a vegetation mosaic and are at high altitudes, some features may also contribute for the similarity relatively low observed in the dendrogram (Fig. 3) such as distance of the ocean, altitudinal range, and territorial extent which can influence the number and composition of species of each area used in the analysis.

Only four species occurred in all seven areas used for the similarity analysis (*Isochilus linearis*, *Peperomia tetraphylla*, *Microgramma squamulosa*, and *Pleopeltis macrocarpa*). A further 14 species occurred in at least six areas (*Billbergia nudicaulis*, *Anthurium scandens*, *Rhipsalis floccosa*, *Stelis aprica*, *Tillandsia geminiflora*, *T. stricta*, *T. tenuifolia*, *T. usneoides*, *Campyloneurum nitidum*, *Cochlidium punctatum*, *Hymenophyllum polyanthos*, *Lellingeria apiculata*, *Pleopeltis hirsutissima*, and *Polyphlebium angustatum*), whereas 23 species were found in five areas and 36 in four areas. Thus, among the 516 species used for the similarity analysis, only 77 (~15 %) were shared by the majority of the areas, reinforcing the peculiarity of the epiphytic flora in each location and explaining the low similarity values. Relatively low similarity indices were already noted by Menini Neto et al. (2009b), in a study of epiphytic angiosperms in areas of southern and southeastern regions of Brazil.

A comparison of the SC with the other two geographically close areas, which show similar vegetational physiognomies, SN (which is approximately 14 km distant) and PEIB (about 22 km distant), shows moderate similarity, as shown by the values of shared species in the Venn diagram (Fig. 4). Despite the geographic proximity between the three areas, a Mantel test using a matrix only with these locations showed no correlation between the distance and similarity index ($p = 0.4892$, $r = 0.1748$), which was low, at around 0.31 (for SC and PEIB) and 0.35 (for SC and SN). Thus, other environmental factors must be considered, such as altitude and similar vegetational types, agreeing with the results of Menini Neto et al. (2009b), who found a large influence of these environmental variables on the

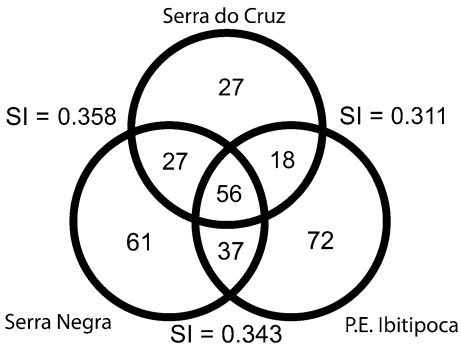

Fig. 4 Venn diagram with the superposition of vascular epiphytic species among Serra do Cruz, Serra Negra, and Parque Estadual de Ibitipoca. IS: Jaccard similarity index

relationships between the areas based on the composition of epiphytic angiosperm flora.

This relatively low similarity between the areas can be explained, for example, by the occurrence of some genera with epiphytic specimens in the SC that not were recorded in the other areas, such as *Capanemia*, *Cryptophoranthus*, and *Phymatidium* (Orchidaceae), as well as *Hippeastrum* (Amaryllidaceae), which is present in the PEIB and SN, according to Monteiro and Oliveira (2010) and Salimena et al. (2013), but without epiphytic specimens and represented by different species. The occurrence in the SC of *Dichorisandra* (Commelinaceae) and *Malaxis* (Orchidaceae) is notable, each being represented by an accidental species, since both are typically terricolous genera, present in the PEIB and SN with this habit.

The presence of the genus *Eurystyles* (Orchidaceae) in the three areas is remarkable, because it is represented by three different species, *E. cotyledon*, *E. actinosophila*, and *E. cogniauxii*, that occur in the SC, SN (Menini Neto et al. 2009a; Abreu et al. 2011), and PEIB (Menini Neto et al. 2007; 2009b), respectively.

A comparison with the other two areas of the branch (SN and PEIB) (Figs. 3, 4) shows some epiphytic species that occur exclusively in the SC: *Hippeastrum calyptratum* (Amaryllidaceae), *Philodendron cordatum* (Araceae), *Begonia fruticosa* (Begoniaceae), *Dichorisandra incurva* (Commelinaceae), *Capanemia thereziae*, *Cryptophoranthus jordanensis*, *Eurystyles cotyledon*, *Gomesa barkeri*, *Malaxis excavata*, *Phymatidium microphyllum*, *Pleurothallis gehrtii*, *P. mentiger*a (Orchidaceae), *Peperomia alata*, *P. quadrifolia*, and *P. subrubricaulis* (Piperaceae). Species such as *Aechmea aiuruocensis*, *Epidendrum secundum*, *Malaxis excavata*, *Oncidium warmingii*, and *Peperomia galioides* also occur in the other areas, but do not have epiphytic specimens.

In general, species shared by the three areas are those common in general floristic or epiphytic surveys, such as

Anthurium scandens, *Philodendron propinquum* (Araceae), *Tillandsia gardneri*, *T. geminiflora*, *T. tenuifolia*, *T. usneoides*, *Vriesea friburgensis*, *V. heterostachys* (Bromeliaceae), *Hatiora salicornioides* (Cactaceae), *Nematanthus crassifolius* (Gesneriaceae), *Encyclia patens*, *Gomesa gomezoides*, *G. recurva*, *Maxillaria notylioglossa*, *Octomeria grandiflora*, *Pleurothallis rubens*, *Prosthechea pachysepala*, *Stelis megantha* (Orchidaceae), and *Peperomia tetraphylla* (Piperaceae) (Kersten and Silva 2002; Gonçalves and Waechter 2003; Rogalski and Zanin 2003; Leoni and Tinte 2004; Gaiotto and Acra 2005; Menini Neto et al. 2009a, 2009b).

Among the species shared with the SN (Menini Neto et al. 2009b; Abreu et al. 2011; Salimena et al. 2013) are *Aechmea pineliana*, *Bilbergia distachia, Vriesea gradata* (Bromeliaceae), *Rhipsalis elliptica* (Cactaceae), *Sinningia cooperi* (Gesneriaceae), *Bifrenaria stefanae, Campylocentrum linearifolium, Epidendrum latilabre, E. parahybunense, Maxillaria bradei, Oncidium gardneri, Polysthachya estrellensis, Zygopetalum maxillare* (Orchidaceae), *Peperomia corcovadensis* and *P. diaphanoides* (Piperaceae), and *Campyloneurum acrocarpon* (Polypodiaceae).

The species shared with the PEIB (Medeiros and Guimarães 2007; Menini Neto et al. 2007; Monteiro and Forzza 2008; Forzza et al. 2013) include the following: *Anthurium minarum* (Araceae), *Aechmea nudicaulis, Vriesea guttata* (Bromeliaceae), *Rhipsalis floccosa* (Cactaceae), *Bulbophyllum regnelli, Epidendrum rigidum, Maxillaria madida, Oncidium longipes, Pleurothallis cryptophoranthoides, P. saundersiana, Prosthechea allemanoides* e *Stelis caespitosa* (Orchidaceae).

The results of this study significantly contribute to knowledge concerning vascular epiphytism in Minas Gerais, considering that studies on this topic are scarce in this state. In addition, the results reinforce the need for conservation of the greatest number of remnants possible in the Mantiqueira Complex, such as the SC, since even geographically close areas show different floristic compositions; several species recorded here only occur in one area and even some species found in other areas are not common.

Thus, the lack of Conservation Unities in the area exposes the epiphytic community as well as that of other plants, to possible predatory collection, so that the data here can aid the implementation of conservation actions in the region, as well as corroborating the importance of this region for flora, as highlighted by Drummond et al. (2005).

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