Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1679-9283
ISSN on-line: 1807-863X
Doi: 10.4025/actascibiolsci.v38i2.31320

Vascular epiphytes in seasonal semideciduous forest in the State of Espírito Santo and the similarity with other seasonal forests in Eastern Brazil

Dayvid Rodrigues Couto[1*], André Paviotti Fontana[2], Ludovic Jean Charles Kollmann[2], Vitor da Cunha Manhães[3], Talitha Mayumi Francisco[4] and Gláucio de Mello Cunha[5]

*[1]Programa de Pós-graduação em Botânica, Museu Nacional, Universidade Federal do Rio de Janeiro, Parque Quinta da Boa Vista, São Cristovão, 20940-040, Rio de Janeiro, Rio de Janeiro, Brazil. [2]Museu de Biologia Prof. Mello Leitão, Santa Teresa, Espírito Santo, Brazil. [3]Programa de Pós-graduação em Genética e Melhoramento, Universidade Federal do Espírito Santo, Alegre, Espírito Santo, Brazil. [4]Programa de Pós-Graduação em Ecologia e Recursos Naturais, Universidade do Norte Fluminense Darcy Ribeiro, Campos dos Goytacazes, Rio de Janeiro, Brazil. [5]Departamento de Biologia, Universidade Federal do Espírito Santo, Alegre, Espírito Santo, Brazil. *Author for correspondence. E-mail: dayvidcouto@hotmail.com*

ABSTRACT. In this study, we evaluated the floristic composition of vascular epiphytes in seasonal semideciduous forest fragments of the Itapemirim River basin, Southern State of Espírito Santo, in order to verify its similarity to other semideciduous forests studied in Brazil. Excursions were conducted every fortnight between June 2008 and May 2009, and epiphytes were collected and recorded (55 species, 34 genera and six families). Orchidaceae (21 species) was the richest family, whereas the genera presenting the greatest richness were *Tillandsia* (seven), *Rhipsalis* (four), *Aechmea*, *Epidendrum* and *Peperomia* (three species each). The category the most representative was characteristics holoepiphytes (84%). The riparian forests were the most important environments for the epiphytic flora. Similarity analysis and PCA supported four groups, where the study area appears disjointed from the others, supporting the hypothesis that geographical proximity, elevation and climate have a strong effect on the floristic composition, conditioning the formation of distinct floras. Detailed surveys on the floristic composition and structure of this community are important for the elaboration of studies on coherent environmental impacts, since epiphytes are typical in tropical rainforests, and they are an important floristic, structural and functional component of these ecosystems.

Keywords: Caparaó Mountains, conservation, Itapemirim river, Orchidaceae, southeastern Brazil, taxonomy.

Epífitas vasculares em floresta estacional semidecidual no estado do Espírito Santo e similaridade com outras florestas estacionais no Leste do Brasil

RESUMO. Neste estudo, avaliamos a composição florística de epífitos vasculares em remanescentes de Floresta Estacional Semidecidual na bacia hidrográfica do rio Itapemirim, sul do estado do Espírito Santo, com o intuito de analisar sua similaridade com outras florestas semideciduais estudadas no Brasil. Excursões quinzenais foram realizadas entre junho de 2008 e maio de 2009, e os epífitos foram coletados e registrados (55 espécies, 34 gêneros e seis famílias). Orchidaceae, com 21 espécies, foi a mais rica, enquanto os gêneros com a maior riqueza foram *Tillandsia* (7 spp.), *Rhipsalis* (4), *Aechmea*, *Epidendrum* e *Peperomia*, com três espécies cada. A categoria ecológica mais representativa foi holoepífita característica com 84% das espécies. O ambiente mais importante para a flora epifítica foram as matas ciliares. Análise de similaridade e PCA sustentaram quatro grupos, em que a área estudada aparece disjunta das demais, corroborando a hipótese de que a proximidade geográfica, a altitude e o clima têm forte efeito sobre a composição florística, condicionando a formação de floras distintas. Estudos detalhados sobre a composição florística e a estrutura dessa comunidade são importantes para a elaboração de estudos de impactos ambientais coerentes, porque epífitas são típicas de florestas tropicais, constituindo importante componente florístico, estrutural e funcional desses ecossistemas.

Palavras-chave: Serra do Caparaó, conservação, Rio Itapemirim, Orchidaceae, sudeste do Brasil, taxonomia.

Introduction

Vascular epiphytes are characteristic and distinctive components of tropical forests and they have attracted the attention of researchers since Schimper (1888) published the first monograph on Neotropical epiphytes. This group of plants is characteristic of tropical and subtropical rainforests, and it is an important floristic, structural and functional component of these ecosystems (Gentry & Dodson, 1987a), representing approximately 9% of the vascular flora in the world (Zotz, 2013).

Studies on vascular epiphytes in Brazilian semideciduous forests are concentrated in the Southern and Southeastern regions of the country (Borgo, Silva, & Petean, 2002; Rogalski & Zanin, 2003; Giongo & Waechter, 2004; Cervi & Borgo, 2007; Dettke, Orfrini, & Milaneze-Gutierre, 2008; Menini Neto, Forzza, & Zappi, 2009; Bataghin, Barros, & Pires, 2010); the patterns found are similar and the Orchidaceae and Bromeliaceae families prevail, although they present richness and diversity lower than that of ombrophilous forest formations (Kersten, 2010).

The seasonal semideciduous forest corresponds to one of the main forest formations in Brazil, and it occurs in almost all the phytogeographic areas of the country, such as the Atlantic Forest, the Amazon and the Pantanal (*Projeto de Conservação e Utilização Sustentável da Diversidade Biológica Brasileira* [PROBIO] 2007). This forest formation covered approximately 23% of the territory in the State of Espírito Santo (*Instituto de Pesquisas da Mata Atlântica* [IPEMA], 2005). It is more representative in the South of the State, where it has great physiognomy importance (*Instituto Brasileiro de Geografia e Estatística* [IBGE], 1983). However, the knowledge about the flora in this important forest formation in the Southern region of the State of Espírito Santo is scarce, since there are only few scientific papers on the topic (Abreu, Silva & Silva, 2013; Couto, Manhães, Campanharo & Faria, 2013).

The present study evaluated the richness of vascular epiphytic species in seasonal semideciduous forest fragments subjected to the direct influence of the small Santa Fé hydroelectric system, Itapemirim River Basin, State of Espirito Santo. We also categorized these species according to their ecological relationships and occurrence in the study sites, and evaluated the floristic similarity between other semideciduous forests in Brazil.

Material and methods

Study Area

The study was conducted in an area under the direct influence of the small Santa Fé hydroelectric system (SHS) (Figure 1), (20° 40' 12.16" S and 41° 29' 45.51" W), located in the Itapemirim River basin, in the municipality of Alegre, Caparaó Capixaba region, elevation between 128 - 480 m. The climate is Köeppen Cwa, with a mean annual temperature of 24°C, mean annual rainfall of 1.450mm, and dry seaon between June and September.

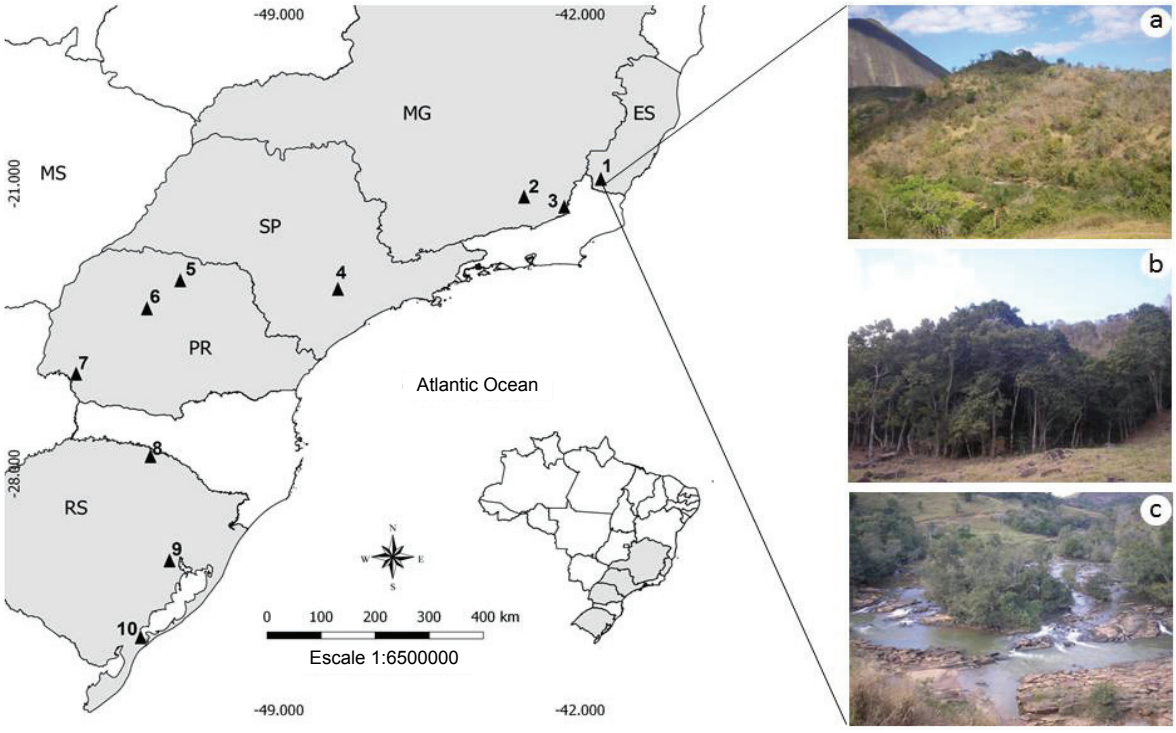

Figure 1. Location of the study area (1) with different inventory environments as hillside forests (a,b) and riparian forests and river islands (c), and of other nine sites in the semideciduous seasonal forest where the epiphytic flora was studied through cluster analysis and Principal Coordinates Analysis (PCA). (Areas: 2. Mata do Baú; 3. Represa do Grama Biological Reserve; 4. Ipanema National Forest; 5. Ingá Park; 6. Vila Rica do Espírito Santo Park; 7. Iguaçú National Park; 8. Strait of Uruguai River; 9. Central Depression of Rio Grande do Sul; 10. Triunfo Colony, Pelotas).

Source: the authors.

The area is represented by small seasonal semideciduous broadleaved forest fragments (Oliveira-Filho, 2009) in different successional stages (regenerating areas and mature forests). These native vegetation fragments are inserted in a matrix, which was anthropized by agricultural activities, primarily extensive beef cattle livestock and small coffee plantations (*Coffea canephora* Pierre ex A. Froehner). We sampled forest fragments at different conservation levels located in two different environments: hillside forests and hilltops, and areas with riparian forests (including river islands).

Floristic inventory

The floristic inventory of vascular epiphytic species was conducted from June 2008 to May 2009, when samples of fertile plant material were collected and processed according to Mori, Silva, Lisboa and Coradini (1989). All the material is deposited in the herbarium of the Mello Leitão Biology Museum (MBML), duplicates were sent to herbaria VIES and RB (see abbreviations in *Index Herbariorum*, Thiers [constantly updated]). Identification was conducted through taxonomic monographs, flowers, comparisons to the MBML herbarium collection and through consultancies with specialists.

The species circumscription in the family followed the The Angiosperm Phylogeny Group [APG] IV (2016) system for angiosperms and Smith et al. (2006) for ferns. The taxa names were updated according to The Brazil Flora Group [BFG] (2015) for angiosperms and Prado et al. (2015) for ferns, as well as taxonomic publications, using the author abbreviations suggested by Brummitt and Powell (1992) and The International Plant Names Index [IPNI] (2016).

Ecological Categories

After the field observations, the epiphytes were classified in five ecological categories according to Benzing (1990), with modifications from Kersten and Kunyioshi (2009): characteristic holoepiphytes (Epi), facultative holoepiphytes (Fac); accidental holoepiphytes (Aci), hemiepiphytes and (Hem).

Similarity

Binary matrix data were prepared (presence/absence) in order to verify the relationship between the epiphytic flora in the studied area and in other seasonal semideciduous forests in Brazil. Data consisted of 249 species compiled from nine areas in Eastern Brazilian states (Table 1, Figure 1). All the names were updated according to the website Flora do Brasil (2016). Non-identified species, as well as those considered to have dubious identification (order [aff.] or check [cf.]), were excluded. Different subspecies and varieties were considered the same species.

The selected sites were compared through cluster analysis in the Software Paleontological Statistics - PAST v. 1.89 (Hammer, Harper & Ryan, 2001), the Jaccard coefficient was incorporated as distance measurement (Mueller-Dombois & Ellenberg, 2002) and the unweighted average clustering method as the clustering algorithm. A Principal Coordinates Analysis (PCA) was also performed using the same data set and the above mentioned software to evaluate the existence of groups based on flora similarities.

Results and discussion

The survey in the semideciduous seasonal forests of the Itapemirim River presented a total of 55 species identified, representing 34 genera and 6 families (Table 2). Orchidaceae (21), Bromeliaceae (14) and Cactaceae (6) were the most representative families, contributing with 78% of the total number of species. The genera with the highest number of species were *Tillandsia* (7 spp.), *Rhipsalis* (4), and *Aechmea*, *Epidendrum* and *Peperomia*, with three species each. The other genera were represented by two or less species.

The concentration of epiphytes in six families within the study area reflects specialization of some families on epiphytism (Zotz, 2013). Such trend was observed in several studies on the epiphytic floras in the Brazilian Atlantic Forest (Freitas et al., 2016). It also meets values that usually stand out in surveys conducted in extra-Brazilian Neotropics (Küper, Kreft, Nieder, Köster, & Barthlott, 2004; Woods, Cardelús, & DeWalt, 2015). Orchidaceae, Bromeliaceae and Cactaceae (78% of the total of species) are among the richest families recorded in Brazilian Semideciduous Forests (Rogalski & Zanin, 2003; Cervi & Borgo, 2007; Dettke et al., 2008; Bataghin et al., 2010), as well as in other ecosystems in the Atlantic Domain (Buzatto, Severo, & Waechter, 2008; Kersten & Kuniyoshi, 2009; Leitman, Amorim, Menini Neto, & Forzza, 2014; Padilha et al., 2015). They also appear as the richest families in summaries on the taxonomic composition of vascular epiphytes in the world (Gentry & Dodson, 1987a; Benzing, 1990; Zotz, 2013) and in the Atlantic Domain (Freitas et al., 2016).

Orchidaceae is the richest family worldwide (Zotz, 2013) and the richest in most studies on the epiphytic flora of the Neotropics (Küper et al., 2004; Kersten & Kuniyoshi, 2009; Woods et al., 2015), including on regions of seasonal semidecidual forest in the Brazilian Atlantic rainforest (Borgo et al., 2002; Giongo & Waechter, 2004; Cervi & Borgo, 2007; Perleberg, Garcia, & Pitrez, 2013). However, other phanerogams as Bromeliaceae, Cactaceae e Araceae may occasionally rank first in richness (Dettke et al., 2008; Menini Neto et al., 2009; Bataghin et al., 2010).

Table 1. Seasonal Semideciduous Forest areas evaluated through multivariate analysis, their acronyms, locations (state), geographic coordinates, elevation, area, species richness (R), methods (Ql.= qualitative; Qt.= quantitative) and reference. (Acronyms: ITAP= Alegre, Itapemirim River basin; MBAU= Baú Woods; RBRG= Represa do Grama Biological Reserve; PEVR= Vila Rica do Espírito Santo Park; FNIP= Ipanema National Forest; PING= Ingá Park; PNIG = Iguaçú National Park; ESRU= Strait of the Uruguai River; DCRS= Central Depression of Rio Grande do Sul; PELO= Triunfo Colony, Pelotas).

Acronym	Location (State)	Coordinates	Elevation	Area	R	Methods	References
			m a.s.l.	(ha)			
ITAP	Alegre (ES)	20°40'S - 41°29'W	220 m	-	55	Ql.	This study
MBAU	Mata do Baú (MG)	21°11'S - 43°56'W	900 m	10	41	Ql.	Menini Neto et al. (2009)
RBRG	ReBio Represa do Grama (MG)	21°25'S - 42°56'W	750 m	263,8	59	Ql.	Menini Neto et al. (2009)
PEVR	Fênix (PR)	23°54'S - 51°56'W	440 m	354	32	Ql.	Borgo et al. (2002)
FNIP	Floresta Nacional Ipanema (SP)	23°21'S - 47°30'W	650 m	5.179,93	21	Qt.	Bataghin et al. (2010)
PING	Parque do Ingá (PR)	23°25'S - 51°25'W	530 m	47,3	29	Ql./ Qt.	Dettke et al. (2008)
PNIG	Parque Nacional Iguaçú (PR)	25°23'S - 53°47'W	168 m	170.000	56	Ql.	Cervi and Borgo (2007)
ESRU	Estreito de Augusto César (RS)	27°24'S - 51°27'W	650 m	-	70	Ql.	Rogalski and Zanin (2003)
DCRS	Depressão Central (RS)	30°04'S - 51°40'W	40 m	-	50	Ql.	Giongo and Waechter (2004)
PELO	Pelotas (RS)	31°22'S - 52°29'W	100 m	3	63	Ql.	Perleberg, Garcia and Pitrez (2013)

The greatest richness of Orchidaceae appears to be related to the good conditions in the forests they occur. These forests are often cited as formed by poor secondary vegetation or by richness altered by selective logging in this family (Dettke et al., 2008; Bataghin et al., 2010). These families are among the five largest families under threat in Brazil due to severe habitat losses (mature forests) (Martinelli & Moraes, 2013).

The richness recorded in the study area is a little smaller than that found in deciduous forests in the South, for instance in the studies by Rogalski and Zannin (2003), 70 species; Perleberg et al. (2013), 63 species; Cervi and Borgo (2007), 56 species; as well as in surveys in the country's Southeastern region, mainly in the Grama Dam reserve, State of Minas Gerais, conducted by Menini Neto et al. (2009), who recorded 59 species. However, the richness was greater in other studies than in the present one (Table 1); fact that highlights the importance of the seasonal deciduous forests in the Caparaó Capixaba region as a biodiversity depository. However, one must consider that there are differences between sampling sites, in addition to the methodologies employed to measure the conservation status of the sampled forests.

The seasonal semideciduous forest in the municipality of Alegre were intensively cut down due to agricultural activities; only 9% of forest remains distributed in small forest fragments, isolated in intensely anthropic landscapes, mainly occupied by extensive livestock farming (SOS *Mata Atlântica & Instituto Nacional de Pesquisas Espaciais* [INPE], 2014). The remaining fragments are located in areas with rocky outcrops and small river islands, which have no agricultural applicability. These fragments enshrine a unique flora with high species richness and taxonomic flora novelties, which is corroborated by the scientific description of new species such as the recent description of *Begonia pachypoda* L. Kollmann & Peixoto (Kollmann & Peixoto, 2013) and *Sinningia bragae* Chautems, M. Peixoto & Rossini (Chautems, Peixoto, & Rossini, 2015), both collected in the present study area.

The distribution of epiphytic species according to the ecological category relation with the phorophyte (Table 2) showed the predominance of holoepiphyte features. There were 46 species (84%) and Polypodiaceae stood out among them. All the species were in this category and in the Cactaceae and Piperaceae families. Only one species was not enclosed in this category. The facultative holoepiphytes were represented by four species (3%), two Bromeliaceae (*Aechmea lamarchei* and *A. phanerophlebia*), one Orchidaceae (*Laelia gloriosa*) and one Piperaceae (*Peperomia rubricaulis*) species. They are seen as epiphyte and rupicolous in the study area. Hemiepiphytes were observed in four species (7%), three Araceae (genera *Monstera* and *Philodendron*) and in the genus *Vanilla* sp., Orchidaceae. The accidental epiphyte was represented by *Cereus fernambucensis*, which was observed on the canopy of *Ficus* sp. (Moraceae), more than 15 m above the ground. This species is found on rocks and soils of degraded grasslands in the region.

Benzing's ecological categories are very similar to those found in other studies conducted in seasonal forests, especially due to the characteristic holoepiphytes found in other categories (Borgo et al., 2002; Cervi & Borgo, 2007; Giongo & Waechter, 2004; Gonçalves & Waechter, 2003; Rogalski & Zanin, 2003; Dettke et al., 2008). However, contradictory results were found in a semideciduous forest remnant, with occurrence of rocky boulders in the forest interior, fact that seems to facilitate the occurrence of a larger number of facultative epiphytes (Perleberg et al., 2013).

Table 2.Vascular epiphytes in the seasonal semideciduous forest of Itapemirim River basin, Alegre County, Southern State of Espírito Santo, Brazil. Cat= ecological category: Epi= characteristic holoepiphyte, Fac = facultative holoepiphyte, Aci = accidental holoepiphyte, Hem = hemiepiphyte; Environments: Ri= areas under rain influence (riparian forest and rain islands), Hf = hillside forest, Rf/Hf= areas under rain influence and hillside forest; Voucher: A.P.F.= André P. Fontana; D.R.C.= Dayvid R. Couto; L.K. = Ludovic J.C. Kollmann and V.C.M.= Vitor da C. Manhães.

Family/ Species	Cat	Environments			Voucher
		Ri	Hf	Ri/Hf	
ARACEAE (4)					
Anthurium sp.	Epi	x			Observed
Monstera adansonii var. *klotzschiana* (Schott) Madison	Hem			x	D.R.C. 715
Philodendron sp1	Hem	x			D.R.C. 1006
Philodendron sp2	Hem	x			Observed
BROMELIACEAE (14)					
Aechmea lamarchei Mez	Fac	x			V.C.M.99
Aechmea nudicaulis (L.) Griseb.	Epi	x			Observed
Aechmea phanerophlebia Baker	Fac	x			D.R.C.828
Billbergia tweedieana Baker	Epi			x	V.C.M.137
Neoregelia simulans L.B. Sm.	Epi	x			V.C.M.150
Tillandsia globosa Wawra	Epi	x			V.C.M.65
Tillandsia loliacea Mart. ex Schult. f.	Epi			x	D.R.C.800
Tillandsia polystachia (L.) L.	Epi	x			V.C.M.105
Tillandsia pruinosa Sw.	Epi	x			A.P.F. 5350
Tillandsia stricta Sol. ex Sims	Epi	x			V.C.M.136
Tillandsia recurvata (L.) L.	Epi		x		D.R.C.590
Tillandsia usneoides (L.) L.	Epi		x		V.C.M.74
Vriesea aff. *paraibica* Wawra	Epi	x			D.R.C.1043
Vriesea philippocoburgii Wawra	Epi	x			D.R.C. s.n.
CACTACEAE (8)					
Cereus fernambucensis Lem.	Aci		x		D.R.C.991
Epiphyllum phyllanthus (L.) Haw.	Epi	x			D.R.C.792
Hylocereus setaceus (Salm-Dyck) Ralf Bauer	Epi			x	Observed
Lepismium cruciforme (Vell.) Miq.	Epi			x	Observed
Rhipsalis sp 1	Epi	x			D.R.C.976
Rhipsalis sp 2	Epi		x		D.R.C.1013
Rhipsalis elliptica G. Lindb. ex K. Schum.	Epi		x		D.R.C.710
Rhipsalis lindbergiana K. Schum.	Epi			x	L.K. 11153
ORCHIDACEAE (21)					
Brasiliorchis chrysantha (Barb.Rodr.) R.B.Singer et al.	Epi	x			D.R.C.1044
Brasiliorchis sp.	Epi	x			D.R.C.1047
Brassavola tuberculata Hook.	Epi			x	D.R.C.1014
Campylocentrum robustum Cogn.	Epi	x			D.R.C. 570
Campylocentrum crassirhizum Hoehne	Epi	x			V.C.M.100
Cattleya guttata Lindl.	Epi			x	D.R.C. 711
Christensonella pumila (Hook.) Szlach. et al.	Epi	x			D.R.C. 1045
Encyclia gallopavina (Rchb. f.) Porto & Brade	Epi	x			D.R.C. 954
Epidendrum avicula Lindl.	Epi	x			D.R.C.1046
Epidendrum carpophorum Barb.Rodr.	Epi	x			D.R.C.782
Epidendrum rigidum Jacq.	Epi	x			D.R.C.568
Laelia gloriosa (Rchb.f.) L.O.Williams	Fac		x		D.R.C.602
Octomeria sp.	Epi	x			D.R.C.304
Oncidium baueri Lindl.	Epi	x			D.R.C.1000
Pabstiella crassicaulis (Barb.Rodr.) Luer	Epi	x			D.R.C.1048
Polystachya concreta (Jacq.) Garay & H.R. Sweet	Epi	x			D.R.C.628
Prosthechea fragrans (Sw.) W.E. Higgins	Epi	x			D.R.C. 571
Scaphyglottis modesta (Rchb. f.) Schltr.	Epi	x			D.R.C.569
Sophronitis cernua Lindl.	Epi	x			D.R.C.1001
Trigonidium acuminatum Bateman ex Lindl.	Epi	x			D.R.C.615
Vanilla sp.	Hem			x	D.R.C.638
PIPERACEAE (3)					
Peperomia elongata Kunth	Epi	x			D.R.C. 784
Peperomia armondii Yunck.	Epi	x			D.R.C. 992
Peperomia rubricaulis (Nees) A. Dietr.	Fac			x	D.R.C. 790
POLYPODIACEAE (5)					
Microgramma persicariifolia (Schrad.) C.Presl	Epi	x			D.R.C. 640
Microgramma vacciniifolia (Langsd. & Fisch.) Copel.	Epi			x	D.R.C. 801
Pecluma plumula (Willd.) M.G.Price	Epi	x			D.R.C. 791
Pleopeltis angusta Humb. & Bonpl. ex Willd.	Epi			x	D.R.C. 788
Pleopeltis minima (Bory) J. Prado & R.Y. Hirai	Epi			x	D.R.C. 785

Similar results were found in areas of inselbergs, where the epiphytic flora was studied and large numbers of accidental and facultative species were recorded (Couto, Dias, Pereira, Fraga, & Pezzopane, 2016). These results can be justified by the similar environmental conditions found on both the phorophytes and the rocky structures, fact that results in physiological and

morphological adaptations to resist water scarcity (Couto et al., 2016).

As for the distribution of species in the analyzed environments (Figure 2), 65% of the species were restricted to environments under the influence of riparian forests, 11% were restricted to drier environments (hillside forests), and 24% were found in both environments. The distribution of families according to the environments can be seen in Figure 2. Out of all the epiphytes found on islands, only *Cattleya guttata* was recorded in other forest fragments in the region. River islands and riparian forests were extremely important for the higher richness of the families Orchidaceae (81% of the species were restricted to these environments) and Bromeliaceae (71%) in the study area.

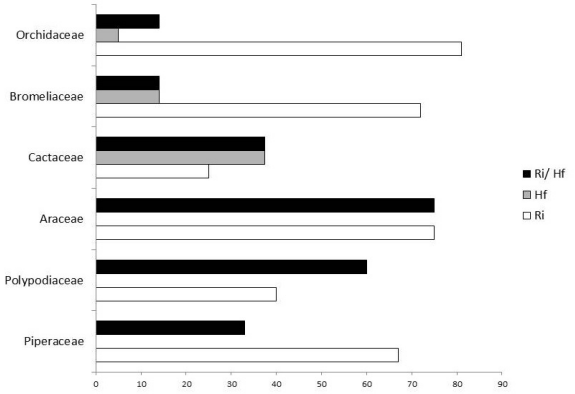

Figure 2. Families distribution (%) according to the preferential environments of occurrence, where: Ri= restricted to areas of riparian forests (including river islands), Hf = restricted to hillside forest; Ri/ Hf = species occurring in both environments.
Source: the authors.

The main remnants of seasonal semideciduous forest in good state of conservation in the study area are found in environments of riparian forests (including river islands), which are richer in epiphytic species than the secondary forest (Bataghin et al., 2010). Another important factor for most of the epiphytic richness observed in the riparian forest areas is probably the constant humidity, due to the proximity to the river, which was already confirmed by other authors (Rogalski & Zannin, 2003; Giongo & Waechter, 2004). The climatic seasonality observed in the region can be identified as an important factor for epiphyte richness, since it depends on atmospheric moisture for water and nutrients uptake (Benzing, 1990). Overall, the occurrence of good phorophytes in association with favorable climatic factors (constant humidity) is the main factor related to the high diversity of epiphytes in the tropical region (Gentry & Dodson, 1987b; Woods et. al., 2015; Ding et al., 2016).

The similarity analysis indicated the formation of four low similarity value groups (Figure 3): the epiphytic flora of the semideciduous forest in the Itapemirim River basin (Group D), which was away from other areas analyzed in the current study (Groups A, B and C). Fifty-three percent (53%) of the species in the present study were restricted and not distributed in other sites, mainly in the case of Orchidaceae. Sixty-two percent (62%) of these species were restricted to the studied region. Fifty-seven percent (57%) of the Bromeliaceae and 100% of the Piperaceae species were restricted to the studied locale. The other groups were formed in the following areas: Minas Gerais (Group A), Paraná and São Paulo (Group B), and areas in Rio Grande do Sul (Group C).

The semideciduous seasonal forests in the Itapemirim River (Group D) presented a unique flora. It consists of 29 exclusive species (53%) which were not grouped in any other of the locales analyzed in the current study. One hundred percent (100%) of the recorded Piperaceae species are exclusive to the studied locale. Orchidaceae and Bromeliaceae presented 62 and 57% exclusivity, respectively. Variance values and percentages of the first three ordination axes in the principal coordinate analysis (PCA) were: 0.68 (19.43%), 0.57 (16.29%) and 0.49 (14.13%), respectively. Such ordering revealed the formation of four distinct groups (A, B, C and D) through cluster analysis, as shown in Figure 3.

The results presented through cluster analysis and PCA showed the influence of the geographical distance on the similarities between areas, thus showing that the geographically closest areas tend to be more similar to each other, even if they do not share similar ecological conditions (Menini Neto et al., 2009). The Brazilian Atlantic Forest occurs in high latitudinal range, resulting in major environmental variation (Oliveira-Filho & Fontes, 2000), which can justify the low Jaccard index found in the current study, indicating that epiphytic floras associated with seasonal forest formations in Eastern Brazil can be considered as distinct.

The habitat heterogeneity has been suggested as one of the main factors associated with the elevated species richness and high levels of endemism recorded in the Atlantic Domain (Menini Neto et al., 2009; Caiafa & Martins, 2010; Leitman et al., 2014). However, in the Atlantic Forest, even areas very close geographically can present contrasting environmental conditions (Scarano, 2002). According to Leitman et al. (2014), the understanding of the effects of space and environment on the composition of epiphytic species is an important step towards understanding the driving factors of their biogeography.

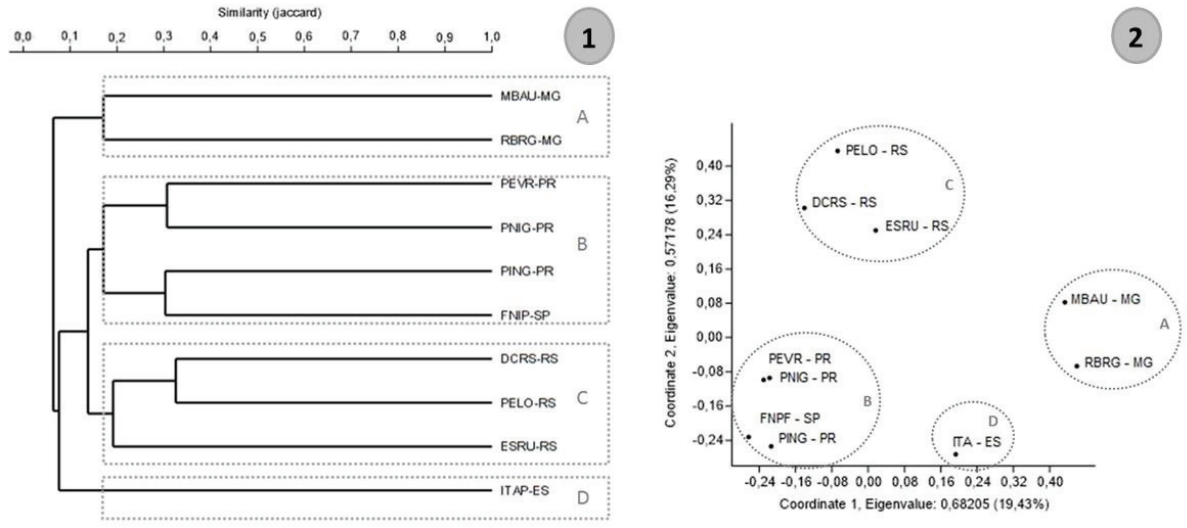

Figure 3. (1) Results of the Cluster analysis (UPGMA) applied to tropical semideciduous forest areas in Eastern Brazil, showing the formation of four groups according to the Jaccard similarity index, and (2) Principal coordinates analysis applied to the nine compared sites, highlighting the four groups formed (A, B, C and D) in the first two axes (35.72% of total variance), supporting the cluster analysis.
Source: the authors.

The clear formation of four distinct groups suggests a strong divergence in the epiphytic flora composition of secondary forests in Eastern Brazil. The analyzed forests were grouped according to geographical distance, elevation and latitude. The group formed by the locales in the State of Minas Gerais (750 to 900 m elevation), seem to have been influenced by both geographical distance and elevation, as mentioned by Menini Neto et al. (2009). Group B is formed by all the locations in the States of Paraná and São Paulo, both located at 168 to 650 m elevation. Group C (seasonal semideciduous forests in Rio Grande do Sul) have different flora from that found in other areas in Southeastern Brazil; it possibly reflects the unique characteristics of the subtropical climate found in this region of the country. Finally, the area in the State of Espírito Santo, which is different from the others, is isolated in the cladogram. It forms a unique flora, justifying the new studies in the region, which aim at ensuring greater protection to semideciduous forest areas in the Southern region of the State.

The difference between the seasonal forests found in Southeastern and Southern Brazil suggests the influence of latitude and altitude or the presence of barriers to migration of species. Elevation is an important factor for the distribution plant species, and it was corroborated by Menini Neto et al. (2009) in their study on epiphytic flora in Eastern Brazil, as well as by the tree layer presented by Oliveira-Filho and Fontes (2000) in the Semideciduous Forest in the Atlantic Domain. It should be taken into account that the low similarity between sites is possibly due to the gamma diversity of Orchidaceae.

Conclusion

According to our results, the epiphytic richness observed in the studied forests in the Itapemirim River basin may have been favored by the advanced succession stage found in areas of riparian forests, where there probably is constant humidity, due to the proximity to the river. The low forest cover in the region, mostly the well-preserved remnants, which are representative of the original vegetation, also interferes with the richness of epiphytic communities, since there is an array that may work as a diaspora source for recolonization.

Conservation actions should be taken so that the epiphytic flora can be preserved in the Itapemirim River Basin. The mountainous geography of the area favors the launching of hydroelectric projects that have strong impact on the remnants located near the waterway. These areas have the greatest epiphyte richness in regions influenced by the semideciduous forest in the Southern State of Espírito Santo. Detailed studies of the floristic composition and structure of this community is of paramount importance for the elaboration of coherent studies on environmental impacts.

Acknowledgements

The authors are thankful to FADTEC, for granting resources for the present study; to Elton

M.C. Leme, for his help in identifying bromeliads; to Claudio Nicoletti Fraga, for his assistance with Orchidaceae, and to Alexandre Salino for fern identification. The authors also thank Helio de Queiroz Boudet Fernandes, director of the Mello Leitão Biology Museum, for providing access to all herbal structure whenever needed, and Good Deal for English revision.

References

Abreu, K. M. P., Silva, G. F., & Silva, A. G. (2013). Análise fitossociológica da Floresta Nacional de Pacotuba, Cachoeiro de Itapemirim, ES, Brasil. *Cerne, 19*(1), 157-168.

Bataghin, F. A., Barros, F., & Pires, J. S. R. (2010). Distribuição da comunidade de epífitas vasculares em sítios sob diferentes graus de perturbação na Floresta Nacional de Ipanema, São Paulo, Brasil. *Revista Brasileira de Botânica, 33*(3), 501-512.

Benzing, D. H. (1990). *Vascular epiphytes*. New York: Cambridge University Press.

Borgo, M., Silva, S. M., & Petean, M. P. (2002). Epífitos vasculares em um remanescente de Floresta Estacional Semidecidual, município de Fênix, PR, Brasil. *Acta Biologica Leopoldensia, 24*(2), 121-130.

Brummitt, R. K., & Powell, C. E. (1992). *Authors of plant names: a list of authors of scientific names of plants, with recommended standard forms of their names, including abbreviations*. Kew, UK: Royal Botanic Gardens.

Buzatto, C. R., Severo, B. M. A., & Waechter, J. L. (2008). Composição florística e distribuição ecológica de epífitos vasculares na Floresta Nacional de Passo Fundo, Rio Grande do Sul. *Iheringia, série Botânica, 63*(2), 231-239.

Caiafa, A., & Martins, F. (2010). Forms of rarity of tree species in the southern Brazilian Atlantic rainforest. *Biodiversity and Conservation, 19*(9), 2597-2618.

Cervi, A. C., & Borgo, M. (2007). Epífitos vasculares no Parque Nacional do Iguaçu, Paraná (Brasil). Levantamento preliminar. *Fontqueria, 55*(51), 415-422.

Chautems, A.; Peixoto, M., & Rossini J. (2015). A new species of *Sinningia* Nees (Gesneriaceae) from Espírito Santo and Rio de Janeiro states, Brazil. *Candollea, 70*(2), 231-235.

Couto, D. R., Manhães, V. C., Campanharo, F. F., & Faria, A. P. G. (2013). Checklist of the Bromeliaceae from Pedra dos Pontões, Mimoso do Sul, Espírito Santo, Brazil, with four first records for the state. *Biota Neotropica, 13*(4), 113-120.

Couto, D. R., Dias, H. M., Pereira, M. C. A., Fraga, C. N., & Pezzopane, J. E. M. (2016). Vascular epiphytes on *Pseudobombax* (Malvaceae) in rocky outcrops (inselbergs) in Brazilian Atlantic Rainforest: basis for conservation of a threatened ecosystem. *Rodriguésia, 67(3), 583-601.*

Dettke, G. A, Orfrini, A. C., & Milaneze-Gutierre, M. A. (2008). Composição florística e distribuição de epífitas vasculares em um remanescente alterado de Floresta Estacional Semidecidual no Paraná, Brasil. *Rodriguésia, 59*(4), 859-872.

Ding, Y., Liu, G., Zang, R., Zhang, J., Lu, X., & Huang, J. (2016). Distribution of vascular epiphytes along a tropical elevational gradient: disentangling abiotic and biotic determinants. *Scientific Reports, 6*, art. n. 19706. doi:10.1038/srep19706.

Flora do Brasil 2020 (2016). Recovered from http://floradobrasil.jbrj.gov.br.

Freitas, L., Salino, A., Menini Neto, L., Almeida, T. E., Mortara, S. R., Stehmann, J. R., ... Forzza, R.C. (2016). A comprehensive checklist of vascular epiphytes of the Atlantic Forest reveals outstanding endemic rates. *PhytoKeys, 58*, 65-79. doi: 10.3897/phytokeys.58.5643.

Gentry, A. H., & Dodson, C. H. (1987a). Contribution of non trees to species richness of a tropical rain forest. *Biotropica, 19*(2), 149-156.

Gentry, A. H. &, Dodson, C. H. (1987b). Diversity and biogeography of neotropical vascular epiphytes. *Annals of the Missouri Botanical Garden, 74*(2), 205-233.

Giongo, C., & Waechter, J. L. (2004). Composição florística e estrutura comunitária de epífitos vasculares em uma floresta de galeria na Depressão Central do Rio Grande do Sul. *Revista Brasileira Botânica, 27*(3), 563-572.

Gonçalves, C. N., & Waechter, J. L. (2003). Aspectos florísticos e ecológicos de epífitos vasculares sobre figueiras isoladas no norte da planície costeira do Rio Grande do Sul. *Acta Botanica Brasilica, 17*(1), 89-100.

Hammer, O., Harper, D. A. T., & Ryan, P. D. (2001). PAST: Paleontological Statistic software package for education and data analysis. *Paleontologia Eletronica, 4*(1), 1-9.

Instituto Brasileiro de Geografia e Estatística [IBGE]. (1983). *Folhas SF.23/24 Rio de Janeiro/ Vitória: geologia, geomorfologia, pedologia, vegetação e uso potencial da terra*. Projeto Radam-Brasil. Rio de Janeiro-RJ: IBGE.

Instituto de Pesquisas da Mata Atlântica [IPEMA]. (2005). *Conservação da Mata Atlântica no Estado do Espírito Santo. Cobertura florestal e Unidades de Conservação*. Vitória-ES: Secretaria de Meio Ambiente e Recursos Hídricos.

Kersten, R. A. (2010). Epífitas vasculares: histórico, participação taxonômica e aspectos relevantes, com ênfase na Mata Atlântica. *Hoehnea, 37*(1), 9-38.

Kersten, R. A., & Kuniyoshi, Y. S. (2009). Conservação das florestas na Bacia do Alto Iguaçu, Paraná. Avaliação da comunidade de epífitos vasculares em diferentes estágios serais. *Floresta, 39*(1), 51-66.

Kollmann, L. J. C., & Peixoto, A. L. (2013). *Begonia pachypoda* L. Kollmann & Peixoto (Begoniaceae), une nouvelle espèce du Brésil actuellement connue en culture comme Begonia leathermaniae O'Reilly & Kareg. *Candollea, 68*(1), 93-97.

Küper, W., Kreft, H., Nieder, J., Köster, N., & Barthlott, W. (2004). Large-scale diversity patterns of vascular epiphytes in Neotropical montane rain forests. *Journal of Biogeography, 31*(9), 1477-1487.

Leitman, P., Amorim, A., Menini Neto, L., & Forzza, R. C. (2014). Epiphytic angiosperms in a mountain forest in southern Bahia, Brazil. *Biota Neotropica, 14*(2), 1-12.

Martinelli, G., & Moraes, M. A. (2013). *Livro vermelho da flora do Brasil*. Rio de Janeiro-RJ: Instituto de Pesquisas Jardim Botânico do Rio de Janeiro.

Menini Neto, L., Forzza, R. C., & Zappi, D. (2009). Angiosperm epiphytes as conservation indicators in forest fragments: a case study from southeastern Minas Gerais, Brazil. *Biodiversity Conservation, 18*, 3785-3807.

Mori, S. A., Silva, L. A. M., Lisboa, G. & Coradini, L. (1989). Manual de manejo do herbário fanerogâmico. Centro de Pesquisa do Cacau, Ilhéus.

Mueller-Dombois, D., & Ellenberg, H. (2002). Aims and methods of vegetation ecology. Caldwell-NJ: The Blackburn Press.

Oliveira-Filho, A. T. (2009). Classificação das fitofisionomias da América do Sul cisandina tropical e subtropical: proposta de um novo sistema – prático e flexível – ou uma injeção a mais de caos? *Rodriguésia, 60*(2), 237-258.

Oliveira-Filho, A. T., & Fontes, M. A. L. (2000). Patterns of floristic differentiation among Atlantic Forests in Southeastern Brazil and the influence of climate. *Biotropica, 32*(4b), 793-810.

Padilha, P. T., Santos Junior, R., Custódio, S. Z., Oliveira, L. C., Santos, R., & Citadini-Zanette, V. (2015). Comunidade epifítica vascular do Parque Estadual da Serra Furada, sul de Santa Catarina, Brasil. *Ciência e Natura, 37*(1), 64-78.

Perleberg, T. D., Garcia, É. N., & Pitrez, S. R. (2013). Epífitos vasculares em área com Floresta Estacional Semidecidual, Pelotas, Rio Grande do Sul, Brasil. *Ciência e Natura, 35*(2), 65-73.

Prado, J., Sylvestre, L. S., Labiak, P. H., Windish, P. G., Salino, A., Barros, I. C. L., ... Matos, F. B. (2015). Diversity of ferns and lycophytes in Brazil. *Rodriguésia, 66*(4), 1-11.

Projeto de Conservação e Utilização Sustentável da Diversidade Biológica Brasileira [PROBIO]. (2007). Subprojeto mapeamento dos biomas brasileiros. Brasília-DF: MMA e CNPq. Recovered from www.mma.gov.br/portalbio

Rogalski, J. M., & Zanin, E. M. (2003). Composição florística de epífitos vasculares no estreito de Augusto César, Floresta Estacional Decidual do Rio Uruguai, RS, Brasil. *Revista Brasileira Botânica, 26*(4), 551-556.

Scarano, F. R. (2002). Structure, function and floristic relationships of plant communities in stressful habitats marginal to the Brazilian Atlantic Rainforest. *Annals of Botany, 90*(4), 517-524.

Schimper, A. F. W. (1888). *Die epiphytische vegetation Amerikas*. Jena-DE: G. Fischer.

Smith, A. R., Pryer, K. M., Schuettpelz, E., Korall, P., Schneider, H., & Wolf, P. G. (2006). A classification for extant ferns. *Taxon, 55*(3), 705-731.

SOS Mata Atlântica, & Instituto Nacional de Pesquisas Espaciais [INPE]. (2014). *Atlas dos municípios da Mata Atlântica: período 2013*. Fundação SOS Mata Atlântica e INPE. Recovered from http://mapas.sosma.org.br/site_media/download/estatisticas/Atlas_municipios2014_anobase2013.pdf

The Angiosperm Phylogeny Group [APG]. (2016). An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. *Botanical Journal of the Linnean Society, 181*(1), 1-20.

The Brazil Flora Group [BFG]. (2015). Growing knowledge: an overview of seed plant diversity in Brazil. *Rodriguésia, 66*(4), 1-29.

The International Plant Names Index [IPNI] (2016) Recovered from http://www.ipni.org.

Woods, C. L., Cardelús, C. L., & DeWalt, S. J. (2015). Microhabitat associations of vascular epiphytes in a wet tropical forest canopy. *Journal of Ecology, 103*(2), 421-430.

Zotz, G. (2013). The systematic distribution of vascular epiphytes: a critical update. *Botanical Journal of the Linnean Society, 171*(3), 453-481.

Received on March 14, 2016.
Accepted on June 6, 2016.