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Land Flatworms (Platyhelminthes: Tricladida) in Remnants of Deciduous Forest in the Northeast Region Of Southern Brazil

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Abstract: Land flatworms show high endemism due to their restricted mobility. In southern Brazil, land flatworm communities have been found mainly in areas of ombrophilous forests. Thus, this study documents land planarian species composition in remnants of deciduous seasonal forest in the northeast region of southern Brazil. Direct, diurnal samplings reveal the occurrence of 26 species of land flatworms, of which one belongs to the subfamily Rhynchodeminae and the others to the subfamily Geoplaninae. The Rhynchodeminae genus *Rhynchodemus* Leidy 1851 and the following Geoplaninae genera occurred: *Cephaloflexa* Carbayo & Leal-Zanchet, 2003, *Choeradoplana* Graff, 1896, *Imbira* Carbayo et al., 2013, *Issoca* Froehlich, 1955, *Luteostriata* Carbayo, 2010, *Obama* Carbayo et al., 2013, *Paraba* Carbayo et al., 2013, *Pasipha* Ogren & Kawakatsu, 1990 and *Xerapoa* Froehlich, 1955, besides the collective group *Pseudogeoplana* Ogren & Kawakatsu, 1990. The genus *Obama* had the highest species richness (S=6), followed by *Paraba* (S=4) and *Pasipha* (S=3). Eighteen species were recorded exclusively in one of the two study areas, and eight species occurred in both sites. The known distribution of *Luteostriata abundans* (Graff, 1899), *Choeradoplana iheringi* Graff, 1899, *Obama ficki* (Amaral & Leal-Zanchet, 2012), *Imbira guaiana* (Leal-Zanchet & Carbayo, 2001) and *Pasipha hauseri* (Froehlich, 1959) is increased. Results emphasize the relevance of expanding taxonomic studies on land flatworms and including more study areas in southern Brazil.

Keywords: *biodiversity inventory, planarians, community composition, Neotropical Region.*

AMARAL, S.V., HACK, I.R., ITURRALDE, G.G., LEAL-ZANCHET, A.M. **Planárias Terrestres (Platyhelminthes: Tricladida) Em Remanescentes De Floresta Decidual Do Nordeste Do Rio Grande Do Sul, Brasil.** Biota Neotropica. 14(1): e20130045. http://www.biotaneotropica.org.br/v14n1/PT/abstract?inventory+bn00714012014

Resumo: Os tricladidos terrestres apresentam alto grau de endemismo, devido especialmente à sua capacidade de locomoção reduzida. No Rio Grande do Sul, dados sobre as comunidades de planárias terrestres são principalmente conhecidos de áreas de floresta ombrófila mista. O presente estudo teve como objetivo analisar a composição das espécies de planárias terrestres em remanescentes de floresta estacional decidual, situados na região nordeste do Rio Grande do Sul. Com base em coletas diurnas diretas foram registradas 26 espécies, pertencentes às subfamílias Geoplaninae e Rhynchodeminae. Foram registrados os seguintes gêneros de Geoplaninae: *Cephaloflexa* Carbayo & Leal-Zanchet, 2003, *Choeradoplana* Graff, 1896, *Imbira* Carbayo et al., 2013, *Issoca* Froehlich, 1955, *Luteostriata* Carbayo, 2010, *Obama* Carbayo et al., 2013, *Paraba* Carbayo et al., 2013, *Pasipha* Ogren & Kawakatsu, 1990 e *Xerapoa* Froehlich, 1955, além do grupo coletivo *Pseudogeoplana* Ogren & Kawakatsu, 1990 e do gênero de Rhynchodeminae *Rhynchodemus* Leidy 1851. O gênero *Obama* apresentou a maior riqueza de espécies (S=6), seguido por *Paraba* (S=4) e *Pasipha* (S=3). Dezoito espécies foram registradas exclusivamente em uma das áreas de estudo, enquanto oito espécies ocorreram em ambas localidades. Amplia-se a distribuição conhecida de *Luteostriata abundans* (Graff, 1899), *Choeradoplana iheringi* Graff, 1899, *Obama ficki* (Amaral & Leal-Zanchet, 2012), *Imbira guaiana* (Leal-Zanchet & Carbayo, 2001) e *Pasipha hauseri* (Froehlich, 1959). Além disso, os resultados enfatizam a importância de ampliação dos estudos taxonômicos de planárias terrestres, bem como das áreas de estudo no sul do Brasil.

Palavras-chave: *inventário de biodiversidade, planárias, composição de comunidades, Região Neotropical.*

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Introduction

Land flatworms are susceptible to microclimatic changes since they live in humid, non-flooded habitats (Sluys 1998, 1999). Their restricted motility leads to high endemism (Sluys 1995, Ogren et al. 1997, Winsor et al. 1998). Land triclads are carnivorous and prey on other invertebrates such as snails, insect larvae, small arthropods and other land flatworms (Du Bois-Reymond Marcus 1951, Froehlich 1955, Jones & Cumming 1998, Ogren 1995, Sluys 1999, Carbayo & Leal-Zanchet 2003, Prasniski & Leal-Zanchet 2009). Thus, flatworm diversity may reflect the diversity of other invertebrates that constitute their prey. There are records of about 170 species of land flatworms in Brazil, which has the highest species richness in the Neotropical Region (Carbayo & Froehlich 2008, 2012, Amaral et al. 2012, Leal-Zanchet et al. 2012). Recent inventories and studies on flatworm communities reveal the occurrence of at least 90 morphospecies of land flatworms, most of which are unknown to science, in forests of southern Brazil (Antunes et al. 2008, Baptista et al. 2010). Most of these studies occurred in ombrophilous forests (Leal-Zanchet & Carbayo 2000, Carbayo et al. 2002, Fick et al. 2003, 2006, Leal-Zanchet et al. 2011, Antunes et al. 2012). Two inventories have been performed in deciduous forest, one in the central region and the other in the northwest region of southern Brazil (Castro & Leal-Zanchet 2005, Baptista et al. 2010).

Deciduous forest was the greatest forest cover in southern Brazil before colonization. About 24% of the original area now remains in the southern Brazilian state Rio Grande do Sul. The northeastern region has been highly impacted by human colonization (Teixeira & Coura-Neto 1986). This study offers the first inventory of land flatworms in the northeastern deciduous forest of Rio Grande do Sul and expands our knowledge of flatworm diversity and distribution in southern Brazil.

Material and methods

The study areas are located in two cities (Salvador do Sul and São Pedro da Serra) of the northeast hillside of Rio Grande do Sul (Figure 1), between 29°26′S - 51°30′W and 29°25′S - 51°28′W, respectively. The climate is warm temperate (subtropical) and humid, without any marked dry periods (Nimer 1989). The region experiences a long cold period with a mean temperature of 15°C and a warm period with mean temperature of 20°C (Quadros & Pillar 2002). The annual rainfall is 1,200-1,750 mm year^{-1} with the heaviest rains occurring in the summer (Oliveira & Ribeiro 1986). The rough relief has a maximum altitude of 556 m a.s.l. (Leite 2002). The coverage consists of seasonal deciduous forest defined by a canopy dominated by caducifolious species and a dominance of *Pachystroma longifolium* (Nees) I.M.Johnst. and *Eugenia rostrifolia* D.Legrand (Teixeira & Coura-Neto 1986). Both study areas have suffered intense anthropogenic influence, with high level of deforestation to prepare sites for agriculture and cattle farming (Teixeira & Coura-Neto 1986), and have undergone consequent structural and physiognomic changes (A. Backes, personal communication).

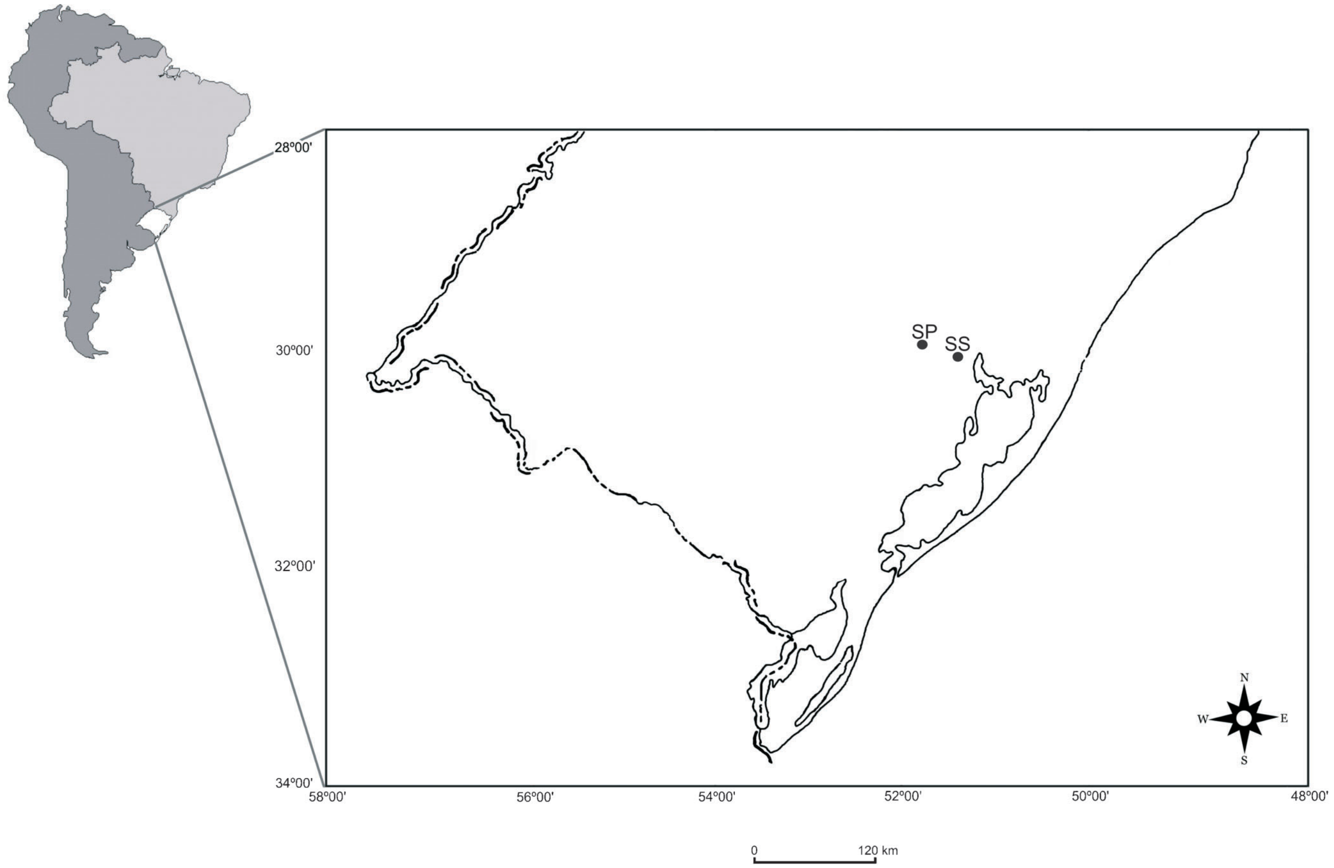

Figure 1. Study areas of the northeastern deciduous forest of Southern Brazil. SP: São Pedro da Serra, SS: Salvador do Sul.

Sixteen diurnal samplings were performed with random and non-random methods from June 1996 to March 2007. Land flatworms were directly sampled under fallen logs and branches, rocks and leaf litter, which, after inspection, were returned to their original positions in order to avoid altering soil microhabitats (Ball & Reynoldson 1981, Winsor 1997).

In the field, specimens were identified as morphospecies. Their external morphology was studied under a stereomicroscope. Body fragments of the pre-pharyngeal region, pharynx, and copulatory apparatus were histologically processed to be studied under optical microscopy according to techniques described by Baptista & Leal-Zanchet (2005). Adult specimens without all the necessary morphological characteristics required for identification at the genus level, which could be differentiated from specimens of other species occurring in the study areas, were placed in the collective group *Pseudogeoplana* Ogren & Kawakatsu, 1990.

The sampled specimens were placed in the scientific collection of the Planarian Research Institute, Universidade do Vale do Rio dos Sinos (UNISINOS).

Results

In the two study areas, we found 26 species of land flatworms (Table 1). Twenty-five of these species belong to the subfamily Geoplaninae and one to Rhynchodeminae, of which at least 13 are unknown to science. Species of the genus *Obama* Carbayo et al., 2013 represented 23% of the species found (S=6), followed by *Paraba* Carbayo et al., 2013 (S=4) (Figures 2-4) and *Pasipha* Ogren & Kawakatsu, 1990 (S=3). Another seven Geoplaninae genera were also documented: *Cephaloflexa* Carbayo & Leal-Zanchet, 2003, *Choeradoplana* Graff, 1896, *Cratera* Carbayo et al., 2013, *Luteostriata* Carbayo, 2010, *Imbira* Carbayo et al., 2013, *Issoca* Froehlich, 1955 and *Xerapoa* Froehlich, 1955. Five morphospecies were included into the collective group *Pseudogeoplana* Ogren & Kawakatsu, 1990. The genus *Rhynchodemus* Leidy, 1851 (Rhynchodeminae) was also documented.

Four species had a high number of records, with 16 or more sampled specimens (Table 1). Two of these species, *Paraba* sp.1 (Figure 2) and *Obama* sp.1, are still undescribed (Table 1). *Luteostriata abundans* (Graff, 1899) (Figure 3) and *Obama carrierei* (Graff, 1897) (Figure 4) had the third and fourth highest records, respectively. Two species, *Obama* sp.2 and *Choeradoplana iheringi* Graff, 1899, had a moderate number of occurrences at the study sites (Table 1). The other 12 species had few occurrences (less than five specimens), and five of these are formally described taxa. Eighteen species were recorded exclusively in one of the two study areas, and eight species occurred in both sites (Table 1).

Discussion

The flatworm species richness recorded in the areas of deciduous forest of this study was similar to the richness of other areas of deciduous forest in southern Brazil where land flatworms inventories have been performed (Castro & Leal-Zanchet 2005, Baptista et al. 2010). Two of these locations are

Table 1. Land planarians recorded in areas of the northeastern deciduous forest of southern Brazil.

Species	Salvador do Sul	São Pedro da Serra	Total
Paraba sp.1	21	6	27
Obama sp.1	14	4	18
Luteostriata abundans (Graff, 1899)	17	_	17
Obama carrierei (Graff, 1897)	14	2	16
Obama sp.2	7	1	8
Choeradoplana iheringi Graff, 1899	1	6	7
Obama ficki (Amaral & Leal-Zanchet, 2012)	4	_	4
Cratera sp.	4	_	4
Cephaloflexa sp.	_	4	4
Paraba gaucha (Froehlich, 1959)	3	_	3
Obama sp.3	1	2	3
Obama ladislavii (Graff, 1899)	2	_	2
Paraba sp.2	1	1	2
Paraba sp.3	_	2	2
Pasipha sp.1	2	_	2
Pasipha sp.2	1	_	1
Pasipha hauseri (Froehlich, 1959)	1	_	1
Imbira guaiana (Leal-Zanchet & Carbayo, 2001)	1	_	1
Issoca sp.	1	_	1
Xerapoa sp.	1	_	1
Pseudogeoplana sp.35	3	_	3
Pseudogeoplana sp.36	2	1	3
Pseudogeoplana sp.37	2	_	2
Pseudogeoplana sp.38	_	1	1
Pseudogeoplana sp.39	1	_	1
Rhynchodemus sp.	1	_	1
Abundance	105	30	135
Species richness	23	11	26

Figures 2-7. Land flatworms occurring in the northeastern deciduous forest of Southern Brazil. (2) *Paraba* sp.1; (3) *Luteostriata abundans*; (4) *Obama carrierei*; (5) *Obama ficki*; (6) *Paraba gaucha*; (7) *Obama ladislavii*. Scale bar: 5 mm.

Turvo State Park and Santa Maria, in northwest and central Rio Grande do Sul, respectively. The species composition, however, differs among the three areas. A single species recorded in Turvo State Park (*Geoplana* sp.2 = *Obama* sp.2) and two species in Santa Maria, *Obama* sp.2 and *O. ladislavii* (Graff, 1899), were also found in our study areas. In addition, both dominant species in the study areas, *Paraba* sp.1 and *Obama* sp.1, were not yet recorded in other sites of southern Brazil where land flatworms have been studied (Leal-Zanchet & Carbayo 2000, Carbayo et al. 2002, Fick et al. 2003, 2006, Castro & Leal-Zanchet 2005, Leal-Zanchet et al. 2012, Baptista et al. 2010).

Luteostriata abundans that is dominant in areas of semideciduous forest (Antunes et al. 2008), was recorded for the first time in a deciduous forest. The present record may be explained by the proximity between the northeastern part of the deciduous forest and semideciduous forest range. Furthermore, anthropogenic impacts in the prospected area may favour occupation by *L. abundans*, which is tolerant to such impacts (Antunes et al. 2008, Prasniski & Leal-Zanchet 2009). The distribution of this species is restricted to northeastern Rio Grande do Sul (Antunes et al. 2008, Carbayo 2010). *Obama carrierei* was previously recorded in Argentina and Bolivia (Graff 1899) and in areas of semideciduous forest (Hauser & Maurmann 1959).

Obama sp.2 has frequently been observed on the border of different types of forests and around man-made buildings (Leal-Zanchet & Carbayo 2000, Carbayo et al. 2002, Fick et al. 2003, 2006, Castro & Leal-Zanchet 2005, Antunes et al. 2008, Leal-Zanchet et al. 2012). It has been considered a generalist species regarding habitat use and tolerance (Castro & Leal-Zanchet 2005, Antunes et al. 2008). *Choeradoplana iheringi* has not yet been recorded in areas of seasonal forests from southern Brazil (Castro & Leal-Zanchet 2005, Baptista et al. 2010, Antunes et al. 2008) despite its ample distribution in Minas Gerais, Rio de Janeiro, São Paulo, Santa Catarina and Rio Grande do Sul (Graff 1899, Riester 1938, Marcus 1951, Froehlich 1956, 1959, Leal-Zanchet & Souza 2003, Baptista et al. 2006). Until now, its distribution in southern Brazil included areas of ombrophilous forest (Leal-Zanchet & Souza 2003,

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Baptista et al. 2006, Antunes et al 2012).

Obama ficki (Amaral & Leal-Zanchet, 2012) (Figure 5) has been documented in ombrophilous forest areas of Rio Grande do Sul and Santa Catarina (Leal-Zanchet & Carbayo 2000, Fick et al. 2003, 2006, Baptista et al. 2006, Amaral et al. 2012). The type-locality of *Paraba gaucha* (Froehlich, 1959) (Figure 6) is Salvador do Sul. It has also been found in areas of semideciduous forest (Froehlich 1959, Antunes et al. 2008). *Obama ladislavii* (Graff 1899) (Figure 7) was recorded in all four main types of forest formations in southern Brazil (Graff 1899, Carbayo et al. 2002, Fick et al. 2003, 2006, Castro & Leal-Zanchet 2005, Baptista et al. 2006, Leal-Zanchet & Baptista 2009, Antunes et al. 2008, 2012). Its known distribution includes locations in Rio Grande do Sul and Santa Catarina. *Imbira guaiana* (Leal-Zanchet & Carbayo, 2001) was only recorded in São Francisco de Paula, Rio Grande do Sul (type-locality), in areas of ombrophilous forest and plantations of *Araucaria angustifolia* (Carbayo et al. 2001, 2002). *Pasipha hauseri* (Froehlich, 1959) was previously recorded in the distribution range of the semideciduous forest, but also in the Amazon Forest (Froehlich & Froehlich 1972).

Deciduous forest remnants in northeastern southern Brazil suffer a greater amount of anthropogenic impacts than remnants in the northwest and central regions. Nevertheless, Geoplaninae species richness is high in this region. The occurrence of at least 13 species of land planarians that are probably new to science emphasises the importance of increasing taxonomic studies of the group, as was suggested by Antunes et al. (2008). These results, as well as differences in species composition among areas, also indicate the need to further develop studies of land planarian communities in other areas of southern Brazil.

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References

AMARAL, S.V., OLIVEIRA, S.M., & LEAL-ZANCHET, A.M. 2012. Three new species of land flatworms and comments on a complex of species in the genus *Geoplana* Stimpson Platyhelminthes: Continenticola). Zootaxa 3338:1-32.

ANTUNES, M.B., MARQUES, D.I.L. & LEAL-ZANCHET, A.M. 2008. Composição das comunidades de planárias terrestres (Platyhelminthes, Tricladida, Terricola) em duas áreas de floresta estacional decidual do sul do Brasil. Neotrop. Biol. Conserv. 31:34-38.

ANTUNES, M.B., LEAL-ZANCHET, A.M. & FONSECA, C.R. 2012. Habitat structure, soil properties, and food availability do not predict terrestrial flatworms occurrence in Araucaria Forest sites. Pedobiologia 55:25-31. doi: http://dx.doi.org/10.1016/j.pedobi.2011.09.010

BALL, I.R. & REYNOLDSON, T.B. 1981. British Planarians. Cambridge University Press, Cambridge.

BAPTISTA, V.A., & LEAL-ZANCHET, A.M. 2005. Nova espécie de *Geoplana* (Platyhelminthes, Tricladida, Terricola) do sul do Brasil. Rev. Bras. Zool. 22(4):875-882. doi: http://dx.doi.org/10.1590/S0101-81752005000400011

BAPTISTA, V.A., MATOS, L.B., FICK, I.A. & LEAL-ZANCHET, A.M. 2006. Composição de comunidades de planárias terrestres (Platyhelminthes, Tricladida, Terricola) do Parque Nacional dos Aparados da Serra, Brasil. Iheringia 96:293-297. doi: http://dx.doi.org/10.1590/S0073-47212006000300004

BAPTISTA, V.A., OLIVEIRA, S.M. & LEAL-ZANCHET, A.M 2010. Inventário de planárias terrestres (Platyhelminthes, Tricladida) em remanescente de Floresta Estacional Decidual do sul do Brasil. Biota Neotrop. 10(2): http://www.biotaneotropica.org.br/v10n2/en/abstract?inventory+bn02110022010 (last accessed on 13/09/2013). doi: http://dx.doi.org/10.1590/S1676-06032010000200027

CARBAYO, F. 2010. A new genus for seven Brazilian land planarian species, split off from *Notogynaphallia* (Platyhelminthes, Tricladida). Belg. J. Zool. 140 (Suppl.):91-101.

CARBAYO, F. & LEAL-ZANCHET, A.M. 2003. Two new genera of geoplanid land planarians (PLATYHELMINTHES: TRICLADIDA: TERRICOLA) of Brazil in the light of cephalic specialisations. Invert. Syst. 17(3):449-468. doi: http://dx.doi.org/10.1071/IT01035

CARBAYO, F. & LEAL-ZANCHET, A.M. & VIEIRA, E.M. 2001. Land planarians (PLATYHELMINTHES, TRICLADIDA, TERRICOLA) as indicators of man-induced disturbance in South Brazilian rainforest. Belg. J. Zool. 131(1):223-224.

CARBAYO, F., LEAL-ZANCHET, A.M. & VIEIRA, E.M. 2002. Flatworms (Platyhelminthes, Tricladida, Terricola) diversity versus man-induced disturbance in ombrophilous rainforest from Southern Brazil. Biodiv. Conserv. 11:1091-1104. doi: http://dx.doi.org/10.1023/A:1015865005604

CARBAYO, F. & FROEHLICH, E.M. 2008. Estado do conhecimento dos macroturbelários (Platyhelminthes) do Brasil. Biota Neotrop. 8(4): http://www.biotaneotropica.org.br/v8n4/pt/abstract?thematic-review+bn01908042008 (last accessed on 30/08/2013). doi: http://dx.doi.org/10.1590/S1676-06032008000400018

CARBAYO, F., & FROEHLICH E.M. 2012. Three new Brazilian species of the land planarian *Choeradoplana* (Platyhelminthes: Tricladida: Geoplaninae), and an emendation of the genus. J Nat. Hist. 46:1153-1177. doi: http://dx.doi.org/10.1080/00222933.2012.657699

CASTRO, R.A & LEAL-ZANCHET, A.M. 2005. Composição de comunidades de planárias terrestres (Platyhelminthes) em área de floresta estacional e de campo na região central do Rio Grande do Sul, Brasil. Acta Biol. Leopold. 27:147-150.

DU BOIS-REYMOND MARCUS, E. 1951. On south American geoplanids. Bol. Fac. Fil. Ciênc. Letr. Univ. São Paulo, série Zoologia, 16:217-255.

FICK, I.A.; LEAL-ZANCHET, A.M. & VIEIRA, E.M. 2003. Comparação da estrutura de comunidades de tricladidos terrestres (PLATYHELMINTHES: TERRICOLA) em duas formações florestais do sul do Brasil. In VI Congresso de Ecologia do Brasil. Anais de trabalhos completos. Universidade Federal do Ceará, Fortaleza, p.152-153.

FICK, I.A., LEAL-ZANCHET, A.M. & VIEIRA, E.M. 2006. Community structure of land flatworms (Platyhelminthes, Terricola): comparisons between Araucaria and Atlantic forest in Southern Brazil. Inv. Biol. 125(4):306–313. doi: http://dx.doi.org/10.1111/j.1744-7410.2006.00062.x

FROEHLICH, E.M. 1955. Sôbre espécies brasileiras do gênero *Geoplana*. Bol. Fac. Fil. Ciênc. Letr. Univ. São Paulo, série Zoologia, 19:289-369.

FROEHLICH, C.G. 1956. Tricladida Terricola das regiões de Teresópolis e Ubatuba. Pap. Av. Dep. Zool. 12(16):313-344.

FROEHLICH, C.G. 1959. On geoplanids from Brazil. Bol. Fac. Fil. Ciênc. Letr. Univ. São Paulo, série Zoologia, 22:201-265.

FROEHLICH E.M. & FROEHLICH, C.G. 1972. Land planarians from the Amazonian region. Pap. Av. Zool. 26(2):29-45.

GRAFF, L.V. 1899. Monographie der Turbellarien. Tricladida, Terricola (Landplanarien). Engelmann, Leipzig, v. 2.

HAUSER, J. & MAURMANN, E. 1959. Studien über die Bewegungen des genus *Geoplana*. Pesquisas 3:631-646.

JONES, H.D. & CUMMING, M.S. 1998. Feeding behaviour of the termite-eating planarian *Microplana termitophaga* (Platyhelminthes: Turbellaria: Tricladida: Terricola) in Zimbabwe. J. Zool. 245:53-64. doi: http://dx.doi.org/10.1111/j.1469-7998.1998.tb00071.x

LEAL-ZANCHET, A.M. & BAPTISTA, V.A. 2009. Planárias terrestres (Platyhelminthes: Tricladida) em áreas de floresta com araucária no Rio Grande do Sul. In Floresta com Araucária: Ecologia, Conservação e Desenvolvimento Sustentável (C.R.S. Fonseca, A.F. Souza, T.L. Dutra, A.M. Leal-Zanchet, A. Backes & G.M.S. Ganade, eds.), Holos, Ribeirão Preto, p.199-207.

LEAL-ZANCHET, A.M. & CARBAYO, F. 2000. Fauna de planárias terrestres da Floresta Nacional de São Francisco de Paula, Rio Grande do Sul: uma análise preliminar. Acta Biol. Leopold. 22:19-25.

LEAL-ZANCHET, A.M. & CARBAYO, F. 2001. Two new species of Geoplanidae (Platyhelminthes, Tricladida, Terricola) from South Brazil. J. Zool. 253:433-446. doi: http://dx.doi.org/10.1017/S0952836901000401

LEAL-ZANCHET, A.M., ROSSI, I., SEITENFUS, A.L.R. & ALVARENGA, J. 2012. Two new species of land flatworms and comments on the genus *Pasipha* Ogren & Kawakatsu, 1990 (Platyhelminthes: Continenticola). Zootaxa 3583:1-21.

LEAL-ZANCHET, A.M. & SOUZA, S.A. 2003. Redescrição de *Choeradoplana iheringi* Graff (Platyhelminthes, Tricladida, Terricola). Rev. Bras. Zool. 20(3):523-530. doi: http://dx.doi.org/10.1590/S0101-81752003000300026

LEAL-ZANCHET, A.M., BAPTISTA, V.A., CAMPOS, L.M., RAFFO, J.F. 2011 Spatial and temporal patterns of land flatworm assemblages in Brazilian Araucaria forests. Invert. Biol. 130:25-33. doi: http://dx.doi.org/10.1111/j.1744-7410.2010.00215.x

LEITE, P.F. 2002. Contribuição ao conhecimento fitoecológico do sul do Brasil. Ciênc. Amb. 24:51-73.

MARCUS, E. 1951. Turbellaria brasileiros. Bol. Fac. Fil. Ciênc. Letr. Univ. São Paulo, série Zoologia, 16:5-215.

NIMER, E. 1989. Climatologia do Brasil. Instituto Brasileiro de Geografia e Estatística, Rio de Janeiro.

OGREN, R.E. 1995. Predation behaviour of land planarians. Hydrobiologia 305:105-111. doi: http://dx.doi.org/10.1007/BF00036370

OGREN, R.E.; KAWAKATSU, M. & FROEHLICH, E.M. 1997. Additions and corrections of the previous lsnd planarian indices of the world (Turbellaria, Seriata, Tricladida, Terricola). Bull. Fuji Women's Coll. 35(2):55-61.

OLIVEIRA, A.A.B. & RIBEIRO, A.G. 1986. Climatologia. In Levantamento de Recursos Naturais. IBGE, Rio de Janeiro, v. 33, p. 757-791.

PRASNISKI M.E.T. & LEAL-ZANCHET, A.M. 2009. Predatory behaviour of the land flatworm *Notogynaphallia abundans* (Platyhelminthes: Tricladida). Zoologia 26(4):606-612. doi: http://dx.doi.org/10.1590/S1984-46702009005000011

QUADROS, F.L.F. & PILLAR, V.D.P. 2002. Transições floresta-campo no Rio Grande do Sul. Ciênc. Amb. 24:109-118.

RIESTER, A. 1938. Beiträge zur Geoplaniden-Fauna Brasiliens. Abh. senckenberg. naturforsch. Ges. 441:75-78.

SLUYS, R. 1995. Platyhelminthes as paleogeographical indicators. Hydrobiologia 305:49-53. doi: http://dx.doi.org/10.1007/BF00036362

SLUYS, R. 1998. Land planarians (Platyhelminthes, Tricladida, Terrícola) in biodiversity and conservation studies. Pedobiologia 42:490-494.

SLUYS, R. 1999. Global diversity of land planarians (Platyhelminthes, Tricladida, Terricola): a new indicator- taxon in biodiversity and conservation studies. Biodiv. Conserv. 8:1663-1681. doi: http://dx.doi.org/10.1023/A:1008994925673

TEIXEIRA, M.B. & COURA-NETO, A.B. 1986. Vegetação. As regiões fitoecológicas, sua natureza, seus recursos econômicos. Estudo fitogeográfico. In Levantamento de Recursos Naturais. IBGE, Rio de Janeiro, v. 33, p. 541-632.

WINSOR, L. 1997. The biodiversity of terrestrial flatworms (Tricladida: Terricola) in Queensland: a preliminary report. Mem. Mus. Vict. 56:575-579.

WINSOR, L., JOHNS, P.M. & YEATES, G.W. 1998. Introduction, and ecological and systematic background, to the Terricola (Tricladida). Pedobiologia 42:389-404.

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article

Insect galls of Itamonte (Minas Gerais, Brazil): characterization and occurrence

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Abstract: Three sites of Itamonte (Minas Gerais) were investigated for insect galls from September, 2011 to July, 2012, seasonally. One-hundred and one morphotypes of insect galls were recorded on 63 species of host plant (45 genera and 23 families). Melastomataceae was the most galled plant family, followed by Asteraceae and Myrtaceae. Galls were recorded on leaves, stems, buds, and aerial roots. Leaves were the most galled plant organ. The gall morphotypes were characterized according to their shape, color, pubescence, and number of internal chambers. Globose and fusiform galls were the most frequent. The majority was glabrous and one-chambered. The gallers comprised three insect orders: Diptera (Cecidomyiidae and Tephritidae), Hemiptera, and Lepidoptera. Cecidomyiidae were the most frequent galling taxa. Parasitoids (Hymenoptera) were obtained from six morphotypes (ca. 6% of the total). The results are compared to those of other Brazilian insect gall inventories. As there is no previous gall inventory in Itamonte, all records presented here are new.

Keywords: *Atlantic forest, galling insect, gall richness, insect-plant interaction*.

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Resumo - Três localidades de Itamonte (Minas Gerais) foram investigadas para galhas de inseto no período de setembro, 2011 a julho, 2012, sazonalmente. Cento e um morfotipos de galhas de inseto foram registrados em 63 espécies de plantas hospedeiras (45 gêneros e 23 famílias). Melastomataceae, Asteraceae e Myrtaceae foram as famílias de planta com maior riqueza de galhas. As galhas foram encontradas em folhas, caules, gemas e raízes aéreas. As folhas foram o órgão vegetal com maior incidência de galhas. Os morfotipos foram caracterizados em relação à forma, coloração, pubescência e número de câmaras internas. Galhas globosas e fusiformes foram as mais frequentes. A maioria era glabra e unilocular. Os galhadores incluíram três ordens de insetos: Diptera (Cecidomyiidae and Tephritidae), Hemiptera e Lepidoptera. Os Cecidomyiidae foram o táxon galhador mais frequente. Parasitóides (Hymenoptera) foram obtidos de seis morfotipos de galhas (cerca de 6% do total). Os resultados são comparados com outros inventários de galhas no Brasil. Como não havia inventário prévio de galhas em Itamonte, todos os registros apresentados são novos.

Palavras-chave: *Mata Atlântica, inseto galhador, riqueza de galhas, interação inseto-planta*.

Introduction

Galls are abnormal growths of plant cells, tissues or organs induced by virus, bacteria, nematodes, mites, insects, and other organisms. Among the insects, six orders comprise galling species: Diptera, Hemiptera, Coleoptera, Lepidoptera, Hymenoptera, and Thysanoptera (Felt 1940). Galling insects are considered as one of the most specialized herbivores, showing high specificity of host plant and plant organ (Carneiro et al. 2009). Each galling species induces a single gall morphotype on the host plant, so the gall is considered as a taxonomic character of the galler.

The galling insect fauna of Brazil is still little studied. Data are restricted to few localities and biomes, mainly restinga areas in the State of Rio de Janeiro (Monteiro et al. 1994, Maia 2001, Monteiro et al. 2004, Oliveira & Maia 2005, Maia & Oliveira 2010), São Paulo (Maia et al. 2008) and Espírito Santo (Bregonci et al. 2010), and in cerrado areas of the State of Minas Gerais (Fernandes et al. 1988, Fernandes et al. 1997; Urso-Guimarães et al. 2003, Maia & Fernandes 2004, Carneiro et al. 2009, Coelho et al. 2009), São Paulo (Urso-Guimarães & Scareli-Santos 2006, Saito & Urso-Guimarães 2012) and Goiás (Araújo et al. 2007). The taxonomical information of the gallers is quite incipient, as the majority of the records are at family level.

The main objective of this work is to contribute to the knowledge of the insect galls of Minas Gerais, investigating remaining areas of Atlantic forest as well high altitude fields for the first time in the Municipality of Itamonte.

Material and Methods

The survey was developed in Itamonte (Minas Gerais, Southeastern Brazil). The municipality of Itamonte has an area of about 432 km^2. The climate is highland tropical (Cwb), according to Köppen classification, with cold and dry winters (lowest temperature varying from 0°C to 10°C in the urban area with the occurrence of frosts); mild summer with higher rainfall, characterizing the rainiest period (Itamonte 2012).

Itamonte has about 35% of the area of the Parque Nacional de Itatiaia (Itatiaia National Park). This Park has about 30,000 ha and is divided into lower and upper areas. The former has remainings of the Atlantic Forest, with great richness of orchids, bromeliads and ferns. The latter presents low vegetation and predominance of high altitude fields. The Itatiaia massif comprises about 150 endemic plant species, more than 100,000 insect species and 300 bird species (Zikan & Zikan 1968, Martinelli et al. 1989, Honkala & Niiranen 2010, Itamonte 2012).

Insect galls were collected from September, 2011 to July, 2012, at the end of spring, summer, autumn, and winter, in three localities: Brejo da Lapa (22°21′31″S, 44°44′14″W; 2,100 m of altitude, low vegetation); Cachoeira do Escorrega (22°13′13,75″S, 44°49′16,05″W; 1,717 m of altitude, Atlantic Forest), and Sítio Moana (22°14′23″S, 44°47′55″W; 1320 m of altitude, Atlantic Forest).

The vegetation of each locality was investigated for insect galls for 4 hours per visit. All plant organs were examined, except for the subterraneous roots. Samples of host plants, preferably in the fertile state, were pressed in the field and later identified by Dr. Gracialda C. Ferreira and Manoel dos Reis Cordeiro (Universidade Federal Rural da Amazônia, Pará, northern Brazil). The voucher specimens were included in the Herbarium of this Institution.

All gall morphotypes were photographed in the field. Each morphotype was characterized based on shape, color, presence or absence of trichomes, and number of internal chambers. Immature insects were obtained by dissection of each kind of gall under a stereoscopic microscope. Pupal exuviae and adults were obtained by keeping samples of each gall morphotype individually in plastic pots layered at the bottom with damp cotton and covered by fine screening, at room temperature. All pots were checked daily for adult emergence.

All insects were preserved in 70% alcohol. Cecidomyidae (Diptera) were later mounted on slides for microscope, following the methodology of Gagné (1994). The gall midge genera were identified based on the keys by Gagné (1994). The specimens are deposited in the collection of Museu Nacional/ Universidade Federal do Rio de Janeiro.

Results

One hundred and one morphotypes of insect galls were found on 63 species of host plant (45 genera and 23 families) (Table 1). Melastomataceae is the most galled plant family, followed by Asteraceae and Myrtaceae, with 29, 18 and 11 gall morphotypes, respectively. The average number of galls per host species was 1.60.

Galls were recorded on leaves, stems, buds, and aerial roots (Table 2). Leaves were the most galled plant organ, with ca. 48% of the total, followed by stems and buds (29% and 21%, respectively). Otherwise, galls on tendrils, flowers, and fruits

Table 1. Number of gall morphotypes per plant family in Itamonte (MG, Brazil). Tabela 1. Número de morfotipos de galha por família de planta em Itamonte (MG, Brasil)

Host plant			
Galled families (n=23)	**Number of galled genera (n=45)**	**Number of galled species (n=63)**	**Number of gall morphotypes (n=101)**
Acanthaceae	1	1	1
Apocynaceae	1	1	1
Asteraceae	6	10	18
Bignoniaceae	3	3	3
Burseraceae	1	1	1
Campanulaceae	1	1	1
Euphorbiaceae	1	2	5
Fabaceae	2	2	2
Iracinaceae	1	1	1
Lammiaceae	1	1	1
Lauraceae	3	3	3
Loranthaceae	1	1	4
Lythraceae	1	1	1
Melastomataceae	6	15	29
Myrtaceae	4	7	11
Nyctaginaceae	1	1	1
Piperaceae	1	1	1
Proteaceae	1	1	2
Rubiaceae	4	4	4
Salicaceae	2	2	4
Sapindaceae	1	1	1
Solanaceae	1	2	3
Vochysiaceae	1	1	1

Table 2. Number of gall morphotypes per plant organ in Itamonte (MG, Brazil). Tabela 2. Número de morfotipo de galhas por órgão vegetal em Itamonte (MG, Brasil).

Galled plant organ	Number of gall morphotypes
Leaf	52 (48.1%)
Stem	31 (28.7%)
Bud	23 (21.3%)
Aerial root	2 (1.85%)
Tendril	0
Inflorescence	0
Fruit	0

were not found. All morphotypes occurred in a single plant organ, except seven morphotypes which occurred simultaneously on stem and leaf (n=3), stem and bud (n=2), and bud and leaf (n=2).

The gall morphotypes were classified according to their shape in globose, fusiform, circular, marginal roll, ovoid, leaf roll, leaf fold, and rosette. The globose and fusiform shapes were the most frequent ones (about 38% each), followed by marginal roll (about 8%), circular and conical (each about 7%), ovoid (about 2%), and others (each at about 1%) (Table 3). The majority was glabrous (81 morphotypes, ca. 80%), the remainders being (20 morphotypes, ca. 20) hairy. About 97% (98 morphotypes) are one-chambered, with 3% (four morphotypes) multichambered.

The gallers of 65 morphotypes were determined. They belong to three insect orders: Diptera (Cecidomyiidae and Tephritidae), Hemiptera, and Lepidoptera. The former was the most frequent galling taxa, being responsible for 51 morphotypes (78% of the determined gallers) (Table 4), followed by Hemiptera (ca. 12%), and Lepidoptera (ca. 9%). Coleopterous, Hymenopterous and Thysanopterous galls were not found. The gallers of 36 morphotypes cannot be determined, because the gall samples were collected without dwellers, or less frequently, occupied by parasitoids (in this case, fragments of the host were found). Parasitoids (Hymenoptera) were obtained from six morphotypes (ca. 6% of the total). Predators and inquilines were not found. As successors, ants were found in a single gall morphotype.

Table 3. Number of gall morphotypes of different shapes in Itamonte (MG, Brazil). Tabela 3. Número de morfotipos de galha de diferentes formas em Itamonte (MG, Brasil).

Gall shape	Number of gall morphotypes
Fusiform	38 (37.62%)
Globose	38 (37.62%)
Marginal roll	8 (7.92%)
Circular	7 (6.93%)
Conical	7 (6.93%)
Ovoid	2 (1.98%)
Rosette	1 (0.99%)
Leaf fold	1 (0.99%)
Leaf roll	1 (0.99%)

Table 4. Number of gall morphotypes per galling insect order in Itamonte (MG, Brazil). Tabela 4. Número de morfotipos de galha por ordem de inseto galhador em Itamonte (MG, Brazil).

Galler	Number of gall morphotypes
Diptera	51 (78.5%)
Hemiptera	(12.3%)
Lepidoptera	(9.2%)
Not determined	(35.6%)

As there is no previous gall inventory in Itamonte, all records presented here are new. The geographic distribution of *Lopesia similis* Maia, 2004, and *Neolasioptera eugeniae* Maia, 1993 (Diptera, Cecidomyiidae) is widened to the municipality of Itamonte.

Data on insect galls are presented here under host plant families, genera and species in alphabetical order. They include gall morphological characterization, associated fauna and previous records in Brazil.

Acanthaceae

Not determined

Vein or petiole swelling, fusiform, green, glabrous, one-chambered (Figures 1 and 2). Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: March. Previous records: Galls on *Justicia* sp. and *Avicennia shaeuriana* Stapf & Leechm. ex Moldenke (Acanthaceae) were recorded in Rio Grande do Sul and São Paulo, respectively by Tavares (1909) and Maia et al. (2008).

Apocynaceae

Aspidosperma sp.

Circular leaf gall, green, glabrous, one-chambered (Figure 3). Galler: Psyliidae (Hemiptera). Locality: Cachoeira do Escorrega. Occurrence: June.

Previous records: leaf galls on *Aspidosperma* spp. were recorded in the States of Goiás, Mato Grosso do Sul, Minas Gerais, and Rio de Janeiro (Fernandes et al. 1988, Monteiro et al. 1994, Maia 2001a, Julião et al. 2002, Oliveira & Maia 2005, Araujo et al. 2007, Coelho et al. 2009, Maia & Oliveira 2010).

Asteraceae

Baccharis sp. 1

Vein swelling, fusiform, green, glabrous, one-chambered. Galler: Cecidomyiidae (Diptera). Associated fauna: parasitoid - Hymenoptera. Locality: Brejo da Lapa. Occurrence: December.

Baccharis sp.2

Leaf gall, fusiform, green, glabrous, one-chambered (Figure 4). Galler: Cecidomyiidae (Diptera). Locality: Brejo da Lapa. Occurrence: September.

Previous records: Several galls on *Baccharis* spp. have been recorded by in cerrado and rupestrian fields of Minas Gerais by Fernandes et al. (1996), Maia & Fernandes (2004), Coelho et al. (2009), Carneiro et al. (2009), Malves & Frieiro-Costa (2012), and in restingas of São Paulo by Maia et al. (2008).

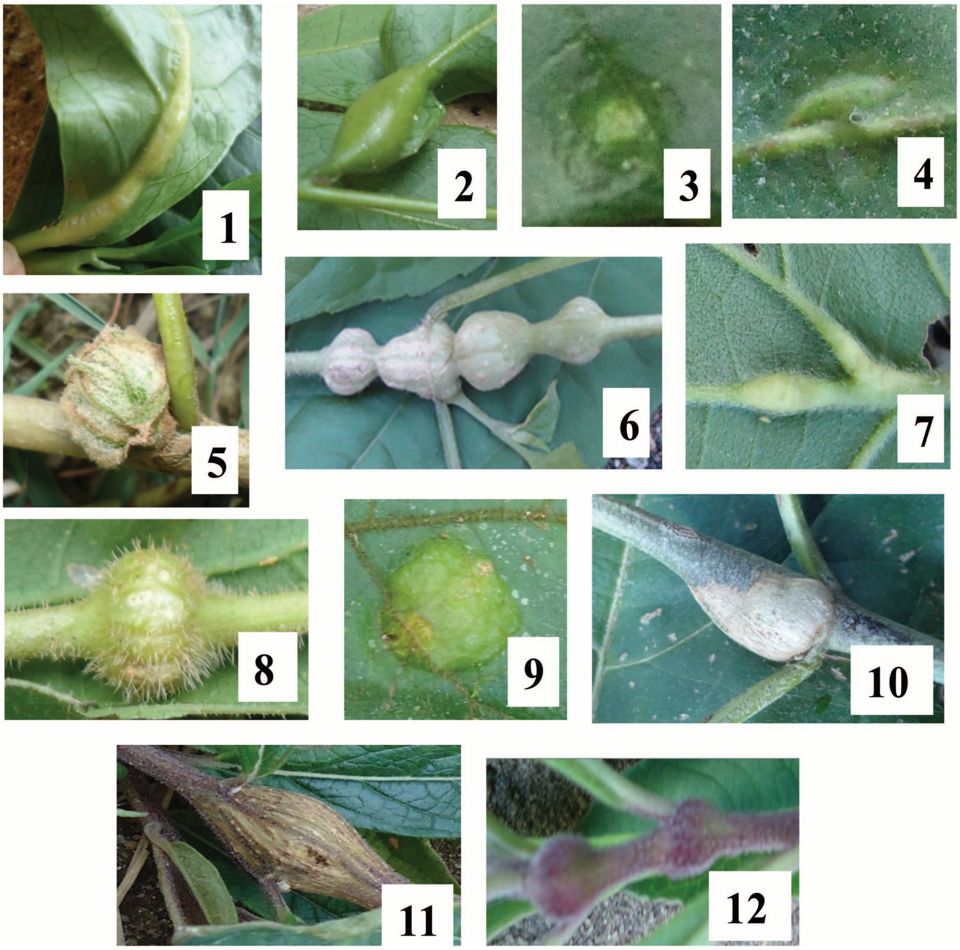
Eupatorium sp.

Bud gall, globose, brownish, micropubescent, one-chambered (Figure 5). Galler: Cecidomyiidae (Diptera). Associated fauna: parasitoid – Hymenoptera. Locality: Brejo da Lapa. Occurrence: September.

Previous records: Galls on *Eupatorium* spp. were recorded by Tavares (1917b) in Rio de Janeiro.

Mikania sp.1

Stem swelling, globose, brownish, glabrous, one-chambered (Figure 6). Galler: Cecidomyiidae (Diptera). Locality: Brejo da Lapa. Occurrence: June.



Figures 1-12. Insect galls of Itamonte (MG, Brazil): 1. Vein gall on Acanthaceae; 2. Petiole gall on Acanthaceae not determined; 3. Leaf gall on *Aspidosperma* sp. (Apocynaceae); 4. Leaf gall on *Baccharis* sp.2 (Asteraceae); 5. Bud gall on *Eupatorium* sp. (Asteraceae); 6. Stem gall on *Mikania* sp.1 (Asteraceae); 7. Vein gall on *Mikania* sp.1 (Asteraceae); 8. Stem gall on *Mikania* sp.2 (Asteraceae); 9. Leaf gall on *Mikania* sp.3 (Asteraceae); 10. Stem gall on *Vernonia* sp.1 (Asteraceae); 11. Stem gall on *Vernonia* sp.2 (Asteraceae); 12. Stem gall on *Vernonia* sp.2 (Asteraceae).Figuras 1-12. Galhas de insetos de Itamonte (MG, Brasil): 1. Galha na nervura em Acanthaceae; 2. Galha no pecíolo em Acanthaceae não determinada; 3. Galha foliar em *Aspidosperma* sp. (Apocynaceae); 4. Galha foliar em *Baccharis* sp.2 (Asteraceae); 5. Galha da gema em *Eupatorium* sp. (Asteraceae); 6. Galha caulinar em *Mikania* sp.1 (Asteraceae); 7. Galha na nervura em *Mikania* sp.1 (Asteraceae); 8. Galha caulinar em *Mikania* sp.2 (Asteraceae); 9. Galha foliar em *Mikania* sp.3 (Asteraceae); 10. Galha caulinar em *Vernonia* sp.1 (Asteraceae); 11. Galha caulinar em *Vernonia* sp.2 (Asteraceae);12. Galha caulinar em *Vernonia* sp.2 (Asteraceae).

Vein swelling, fusiform, green, glabrous, one-chambered (Figure 7). Galler: Cecidomyiidae (Diptera). Associated fauna: parasitoid – Hymenoptera. Locality: Brejo da Lapa. Occurrence: September, December

Mikania sp.2

Stem or petiole swelling, globose, green, hairy, one-chambered (Figure 8). Galler: not determined. Locality: Brejo da Lapa. Occurrence: September.

Mikania sp.3

Leaf gall, circular, green, glabrous, one-chambered (Figure 9). Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: March.

Previous records: several galls on *Mikania* spp. were recorded in Amazonas, Minas Gerais, Rio de Janeiro, and Rio Grande do Sul (Rübsaamen 1907, 1908, 1916a, Tavares 1909, Monteiro et al. 1994, Maia 2001a, Maia & Fernandes 2004, Oliveira & Maia, 2005, Maia et al. 2008, Carneiro et al. 2009, Maia & Oliveira 2010, Malves & Frieiro-Costa 2012).

Vernonia sp. 1

Stem or bud swelling, fusiform, greenish, glabrous, one-chambered (Figure 10). Galler: Cecidomyiidae (Diptera). Locality: Brejo da Lapa. Occurrence: September.

Vernonia sp. 2

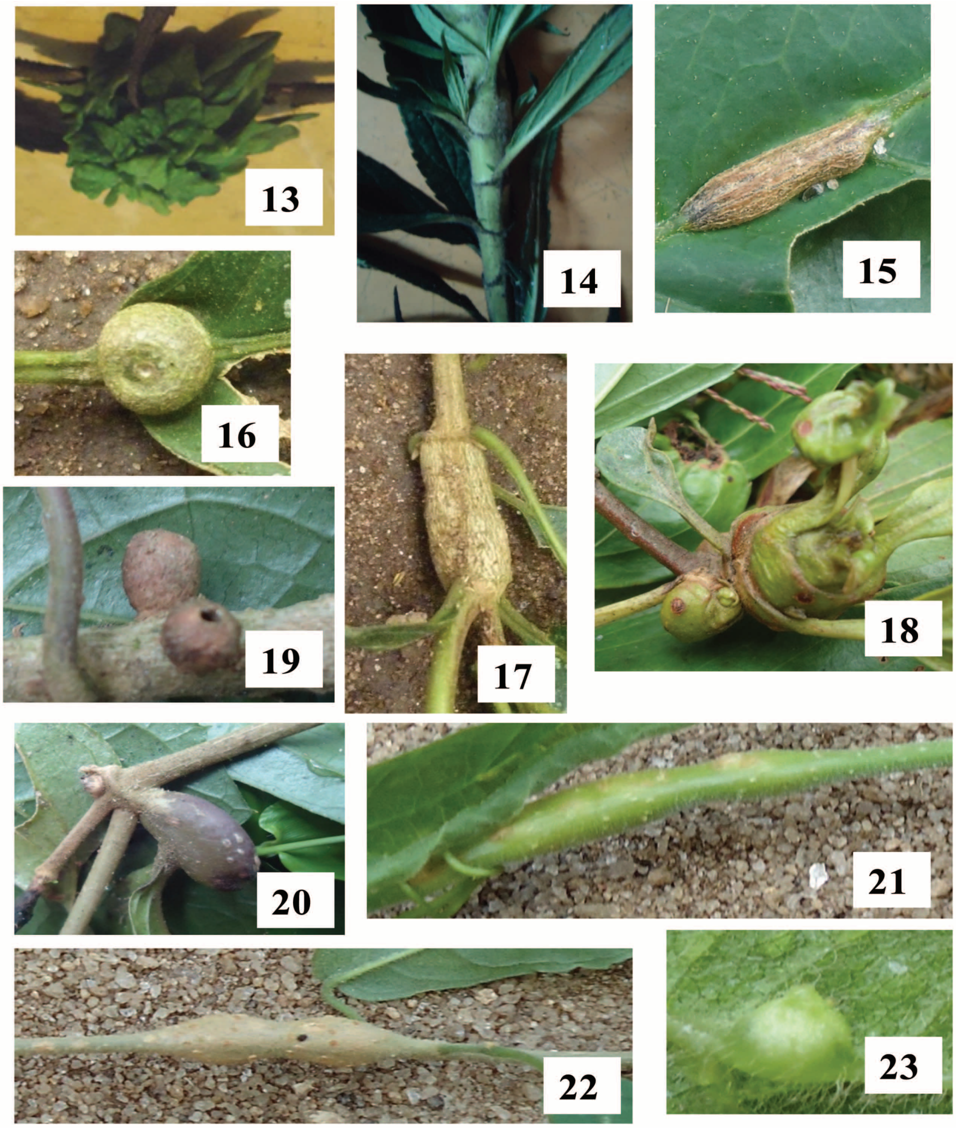
Stem swelling, fusiform, brown, glabrous, one-chambered (Figure 11). Galler: Tephritidae (Diptera). Localities: Sitio Moana, Cachoeira do Escorrega. Occurrence: September, March, June.

Stem swelling, globose, reddish, glabrous, one-chambered (Figure 12). Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: December, March.

Previous records: galls on *Vernonia* spp. were recorded in Mato Grosso do Sul, Minas Gerais, Rio de Janeiro, and São Paulo (Gagné 1994, Julião et al. 2002, Urso-Guimarães et al. 2003, Maia 2001a, Monteiro et al. 2004, Maia & Fernandes 2004, Maia et al. 2008).

Asteraceae not determined (sp.1)

Rosette bud gall, green, glabrous (Figure 13). Galler: not



Figures 13-23. Insect galls of Itamonte (MG, Brazil): 13. Bud gall on Asteraceae sp.1; 14. Stem gall on Asteraceae sp.1; 15. Vein gall on Asteraceae sp.2; 16. Petiole gall on Asteraceae sp.2; 17. Stem gall on Asteraceae sp.2; 18. Apical bud gall on Asteraceae sp.2; 19. Lateral bud on Asteraceae sp.2; 20. Lateral bud on Asteraceae sp.2; 21. Stem gall on *Cuspidaria* sp. (Bignoniaceae); 22. Stem gall on *Stizophyllum riparum* (Bignoniaceae); 23. Leaf gall on Bignoniaceae.Figuras 13-23. Galhas de insetos de Itamonte (MG, Brasil): 13. Galha da gema em Asteraceae sp.1; 14. Galha caulinar em Asteraceae sp.1; 15. Galha na nervura em Asteraceae sp.2; 16. Galha no pecíolo em Asteraceae sp.2; 17. Galha caulinar em Asteraceae sp.2; 18. Galha da gema apical em Asteraceae sp.2; 19. Galha da gema lateral em Asteraceae sp.2; 20. Galha da gema lateral em Asteraceae sp.2; 21. Galha caulinar em *Cuspidaria* sp. (Bignoniaceae); 22. Galha caulinar em *Stizophyllum riparum* (Bignoniaceae); 23. Galha foliar em Bignoniaceae.

determined. Locality: Brejo da Lapa. Occurrence: December

Stem swelling, elongate-fusiform, green, glabrous, one-chambered (Figure 14). Galler: Lepidoptera. Locality: Brejo da Lapa. Occurrence: December, June.

Asteraceae not determined (sp. 2)

Vein swelling, linear, brown, glabrous, one-chambered (Figure 15). Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: June.

Petiole swelling, globose, green, glabrous, one-chambered (Figure 16). Galler: not determined. Locality: Cachoeira do Escorrega. Occurrence: March.

Stem swelling, fusiform, brown, glabrous, one-chambered (Figure 17). Galler: not determined. Localities: Brejo da Lapa, Cachoeira do Escorrega. Occurrence: December, March, June.

Apical bud gall, globose, green, glabrous, one-chambered (Figure 18). Galler: Cecidomyiidae (Diptera). Associated fauna: parasitoid – Hymenoptera. Localities: Brejo da Lapa, Cachoeira do Escorrega. Occurrence: December, March.

Lateral bud gall, globose, brown, glabrous, one-chambered (Figure 19). Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: December.

Lateral bud gall, ovoid, reddish, glabrous, one-chambered (Figure 20). Galler: not determined. Locality: Cachoeira do Escorrega. Occurrence: December.

Bignoniaceae

Cuspidaria sp.

Stem swelling, elongate-fusiform, green, glabrous, one-chambered (Figure 21). Galler: not determined. Locality: Cachoeira do Escorrega. Occurrence: March.

Stizophyllum riparum (Kunth) Sandwith

Stem swelling, fusiform, brown, glabrous, one-chambered (Figure 22). Galler: not determined. Locality: Cachoeira do Escorrega. Occurrence: March.

Bignoniaceae not determined

Leaf gall, globose, green, hairy, one-chambered (Figure 23). Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: December, June.

Burseraceae

Protium heptaphyllum March

Marginal leaf roll, green, glabrous, one-chambered (Figure 24). Galler: *Lopesia similis* Maia, 2004 (Cecidomyiidae, Diptera). Locality: Cachoeira do Escorrega. Occurrence: December, June.

Previous records: the same gall was recorded in Bahia, Minas Gerais, and Rio de Janeiro (Tavares 1922, Maia 2001, Monteiro et al. 2004, Maia & Fernandes 2004).

Campanulaceae

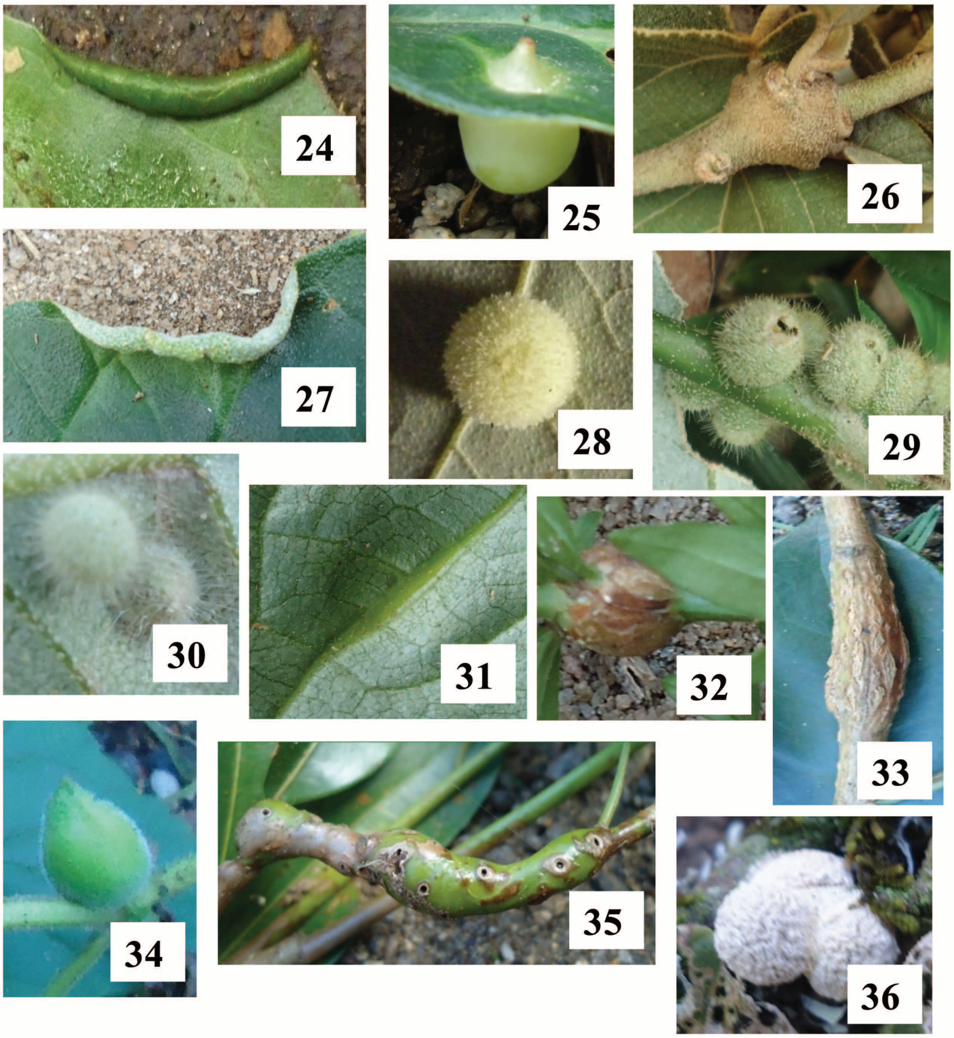
Centropogon sp.

Leaf gall, globose abaxially, conical adaxially, green, glabrous, one-chambered (Figure 25). Galler: Hemiptera. Locality: Brejo da Lapa. Occurrence: March.

Euphorbiaceae

Croton sp.1

Stem swelling, fusiform, green, glabrous, one-chambered (Figure 26). Galler: not determined. Locality: Brejo da Lapa. Occurrence: September.



Figures 24-36. Insect galls of Itamonte (MG, Brazil):24. Marginal leaf roll on *Protium heptaphyllum* (Burseraceae); 25. Leaf gall on *Centropogon* sp. (Campanulaceae); 26. Stem gall on *Croton* sp.1 (Euphorbiaceae); 27. Marginal leaf roll on *Croton* sp.2 (Euphorbiaceae); 28. Leaf gall on *Croton* sp.2 (Euphorbiaceae); 29. Bud gall on *Croton* sp.2 (Euphorbiaceae); 30. Leaf gall on *Croton* sp.2 (Euphorbiaceae); 31. Vein gall on *Inga* sp. (Fabaceae); 32. Stem gall on *Stylosanthes graciles* (Fabaceae); 33. Stem gall on *Humiriantheca* sp. (Iracinaceae); 34. Bud gall on *Hyptis* sp. (Lammiaceae); 35. Stem gall on *Licania* sp. (Lauraceae); 36. Leaf gall on *Nectandra* sp. (Lauraceae).Figuras 24-36. Galhas de insetos de Itamonte (MG, Brasil): 24. Enrolamento da margem foliar em *Protium heptaphyllum* (Burseraceae); 25. Galha foliar em *Centropogon* sp. (Campanulaceae); 26. Galha caulinar em *Croton* sp.1 (Euphorbiaceae); 27. Enrolamento da margem foliar em *Croton* sp.2 (Euphorbiaceae); 28. Galha foliar em *Croton* sp.2 (Euphorbiaceae); 29. Galha da gema em *Croton* sp.2 (Euphorbiaceae); 30. Galha foliar em *Croton* sp.2 (Euphorbiaceae); 31. Galha na nervura em *Inga* sp. (Fabaceae); 32. Galha caulinar em *Stylosanthes graciles* (Fabaceae); 33. Galha caulinar em *Humiriantheca* sp. (Iracinaceae); 34. Galha da gema em *Hyptis* sp. (Lammiaceae); 35. Galha caulinar em *Licania* sp. (Lauraceae); 36. Galha foliar em *Nectandra* sp. (Lauraceae).

Croton sp. 2

Marginal leaf roll, green, glabrous, one-chambered (Figure 27). Galler: not determined. Locality: Cachoeira do Escorrega. Occurrence: December, June.

Leaf gall, globose, yellow, hairy, one-chambered (Figure 28). Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: June.

Bud gall, globoid, yellow, hairy, gregarious, one-chambered (Figure 29). Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: December

Leaf, petiole or stem gall, globose, yellow, hairy, one-chambered (Figure 30) Galler: Cecidomyiidae (Diptera). Localities: Sitio Moana, Cachoeira do Escorrega. Occurrence: September, December, June.

Previous records: several galls on *Croton* spp. were recorded in Ceará, Pernambuco, Minas Gerais, and Rio de Janeiro (Rübsaamen 1905, Tavares 1922, 1925 Urso-Guimarães et al. 2003, Maia & Fernandes 2004, Carneiro et al. 2009, Santos et al. 2011, Malves & Frieiro-Costa 2012).

Fabaceae

Inga sp.

Vein swelling, fusiform, green, glabrous one-chambered (Figure 31). Galler: *Neolasioptera* sp. (Cecidomyiidae, Diptera). Locality: Cachoeira do Escorrega. Occurrence: December. Previous records: several galls on *Inga* sp. were recorded in Amazonas, Pará, Goiás, Mato Grosso do Sul, Minas Gerais, Rio de Janeiro, São Paulo, and Santa Catarina (Rübsaamen 1907, Tavares 1920b, Fernandes et al. 1988, Maia 2001, Julião et al. 2002, Urso-Guimarães et al. 2003, Maia & Fernandes 2004, Oliveira & Maia 2005, Maia et al. 2008, Maia & Oliveira 2010, Santos et al. 2010, Maia 2011).

Stylosanthes graciles Kunth

Stem swelling, globose, green, glabrous, one-chambered (Figure 32). Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: March.

Previous records: a stem gall on *Stylosanthes* sp. was recorded in Minas Gerais by Coelho et al. (2009).

Iracinaceae

Humiriantheca sp.

Stem swelling, fusiform, green, glabrous, one-chambered (Figure 33). Galler: Cecidomyiidae (Diptera). Locality: Brejo da Lapa. Occurrence: June.

Lammiaceae

Hyptis sp.

Bud gall, conical, green or yellowish, hairy, one-chambered (Figure 34). Galler: Cecidomyiidae (Diptera). Locality: Brejo da Lapa. Occurrence: December, March, June.

Previous records: galls on *Hyptis* spp. were recorded in Pernambuco, Minas Gerais, and São Paulo (Maia & Fernandes 2004, Maia et al. 2008, Carneiro et al. 2009, Coelho et al. 2009, Santos et al. 2011).

Lauraceae

Licania sp.

Stem swelling, fusiform, green, glabrous, one-chambered (Figure 35). Galler: Cecidomyiidae (Diptera). Locality: Brejo da Lapa. Occurrence: June.

Previous records: galls on *Licania* spp. were recorded in Pará, Goiás, Minas Gerais, and São Paulo (Maia & Fernandes 2004, Maia et al. 2008, Santos et al. 2010, Maia 2011).

Nectandra sp.

Leaf gall, brown, globose, glabrous, one-chambered (Figure 36). Galler: Hemiptera. Locality: Brejo da Lapa. Occurrence: March, June.

Previous records: several galls were recorded on *Nectandra* spp. in Goiás, São Paulo, Santa Catarina, and Rio Grande do Sul (Rübsaamen 1908, Tavares 1909, 1921, Maia et al. 2008, Santos et al. 2010).

Ocotea cernua (Nees) Mez

Aerial root swelling, globose, brown, glabrous, one-chambered (Figure 37). Galler: not determined. Locality: Sitio Moana. Occurrence: September

Previous records: Rübsaamen (1908), Monteiro et al. (1994), Maia (2001), Julião et al. (2002), Monteiro et al. (2004), Maia & Fernandes (2004), Maia et al. (2008), and Carneiro et al. (2009) recorded galls on *Ocotea* spp. in Mato Grosso do Sul, Minas Gerais and Rio de Janeiro.

Loranthaceae

Phthirusa sp.

Leaf gall, globose, glabrous, green or red, one-chambered (Figure 38). Galler: Cecidomyiidae (Diptera) (1 larva on 11.XII.2011). Locality: Brejo da Lapa. Occurrence: September, December.

Leaf gall, circular, yellow, glabrous, one-chambered (Figure 39). Galler: not determined. Locality: Brejo da Lapa. Occurrence: September.

Aerial root swelling, fusiform, brown, glabrous, one-chambered (Figure 40). Galler: Cecidomyiidae (Diptera). Locality: Brejo da Lapa. Occurrence: September.

Stem swelling, fusiform, glabrous, brown, one-chambered. Galler: Lepidoptera. Locality: Brejo da Lapa. Occurrence: September, December.

Lythraceae

Cuphea sp.

Stem swelling, fusiform, brown, glabrous, one-chambered (Figure 41). Galler: Cecidomyiidae (Diptera). Locality: Sítio Moana. Occurrence: September.

Previous record: Gagné (1994) and Carneiro et al. (2009) recorded galls on *Cuphea* spp. in Minas Gerais.

Melastomataceae

Aciotis cf. *indecora* (Bonpl) Triana

Vein swelling, fusiform, woody, brown, glabrous, one-chambered (Figure 42). Galler: not determined. Locality: Cachoeira do Escorrega. Occurrence: June.

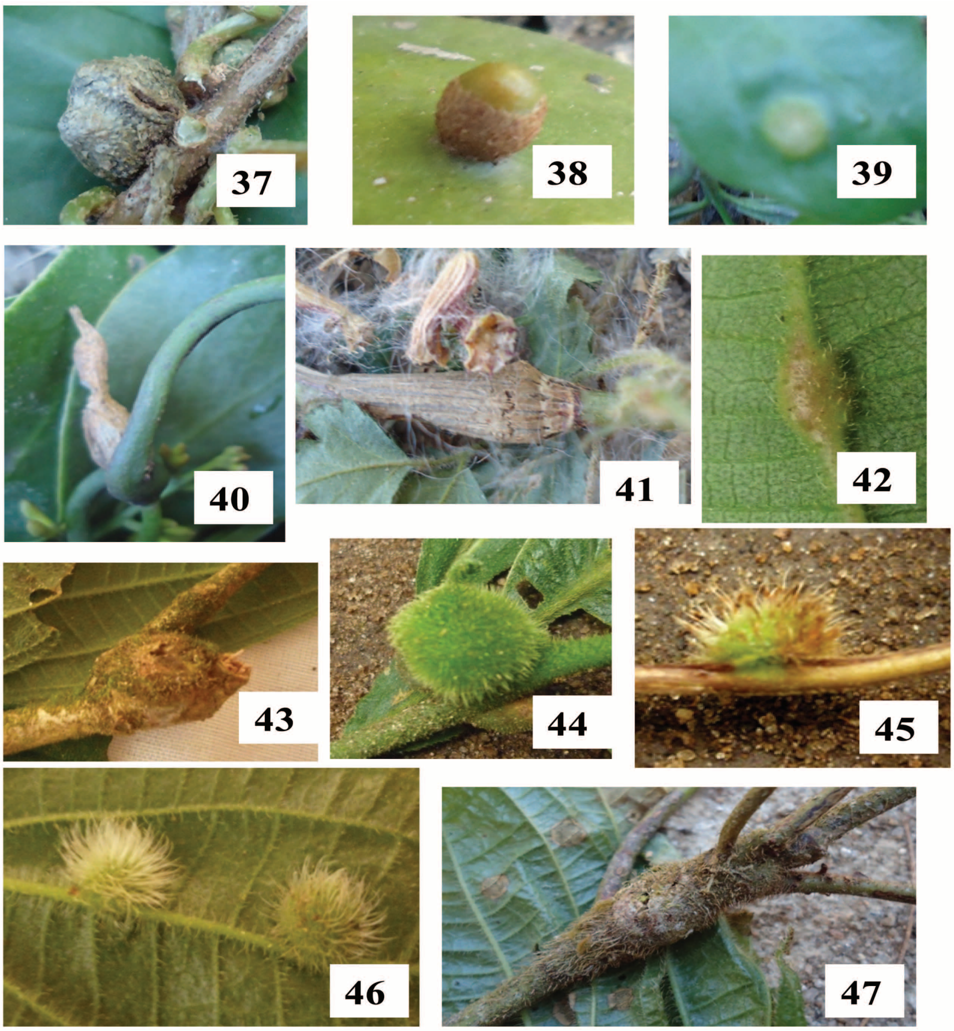
Stem swelling, brown, fusiform, glabrous, one-chambered (Figure 43). Galler: not determined. Locality: Cachoeira do Escorrega. Occurrence: June.

Bud gall, globose, green, micropubescent, one-chambered (Figure 44). Galler: not determined. Locality: Cachoeira do Escorrega. Occurrence: June.

Bud gall, globose, green, macropubescent (reddish trichomes), one-chambered (Figure 45). Galler: not determined. Locality: Cachoeira do Escorrega. Occurrence: June.

Clidemia capitellata (Bonpl) D.Don

Leaf gall, globose, green, hairy, one-chambered (Figure 46). Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: June.



Figures 37-47. Insect galls of Itamonte (MG, Brazil): 37. Aerial root gall on *Ocotea cernua* (Lauraceae); 38. Leaf gall on *Phthirusa* sp. (Loranthaceae); 39. Leaf gall on *Phthirusa* sp. (Loranthaceae); 40. Aerial root gall on *Phthirusa* sp. (Loranthaceae); 40. Stem gall on *Phthirusa* sp. (Loranthaceae); 41. Stem swelling on *Cuphea* sp. (Lythraceae); 42. Vein gall on *Aciotis* cf. *indecora* (Melastomataceae); 43. Stem gall on *Aciotis* cf. *indecora* (Melastomataceae); 44. Bud gall on *Aciotis* cf. *indecora* (Melastomataceae); 45. Bud gall on *Aciotis* cf. *indecora* (Melastomataceae); 46. Leaf gall on *Clidemia capitellata* (Melastomataceae); 47. Stem swelling on *Clidemia* sp.1 (Melastomataceae).Figuras 37-47. Galhas de insetos de Itamonte (MG, Brasil): 37. Galha em raízes aéreas em *Ocotea cernua* (Lauraceae); 38. Galha foliar em *Phthirusa* sp. (Loranthaceae); 39. Galha foliar em *Phthirusa* sp. (Loranthaceae); 40. Galha em raízes aéreas em *Phthirusa* sp. (Loranthaceae); 40. Galha caulinar em *Phthirusa* sp. (Loranthaceae); 41. Galha caulinar em *Cuphea* sp. (Lythraceae); 42. Galha na nervura em *Aciotis* cf. *indecora* (Melastomataceae); 43. Galha caulinar em *Aciotis* cf. *indecora* (Melastomataceae); 44. Galha da gema em *Aciotis* cf. *indecora* (Melastomataceae); 45. Galha da gema em *Aciotis* cf. *indecora* (Melastomataceae); 46. Galha foliar em *Clidemia capitellata* (Melastomataceae); 47. Galha caulinar em *Clidemia* sp.1 (Melastomataceae).

Clidemia sp. 1

Stem swelling, fusiform, brown, hairy, one-chambered (Figure 47). Galler: not determined. Locality: Sítio Moana. Occurrence: September.

Lateral bud or leaf gall, globose, yellow, hairy (reddish trichomes), one-chambered. Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: March, June.

Clidemia sp. 2

Stem swelling, fusiform, gregarious, glabrous, brown, multichambered (Figure 48). Galler: Cecidomyiidae (Diptera). Associated fauna: parasitoid – Hymenoptera. Locality: Brejo da Lapa. Occurrence: December, March.

Leaf gall, globose, green, hairy (whitish trichomes), one-chambered (Figure 49). Galler: Cecidomyiidae (Diptera). Locality: Brejo da Lapa. Occurrence: March.

Previous records: Tavares (1917a) and Maia et al. (2008) recorded galls on *Clidemia* spp.

Miconia cf. *cinnamomifolia* (DC.) Naudin

Leaf gall, globose, hairy, one-chambered (Figure 50). Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: December, March.

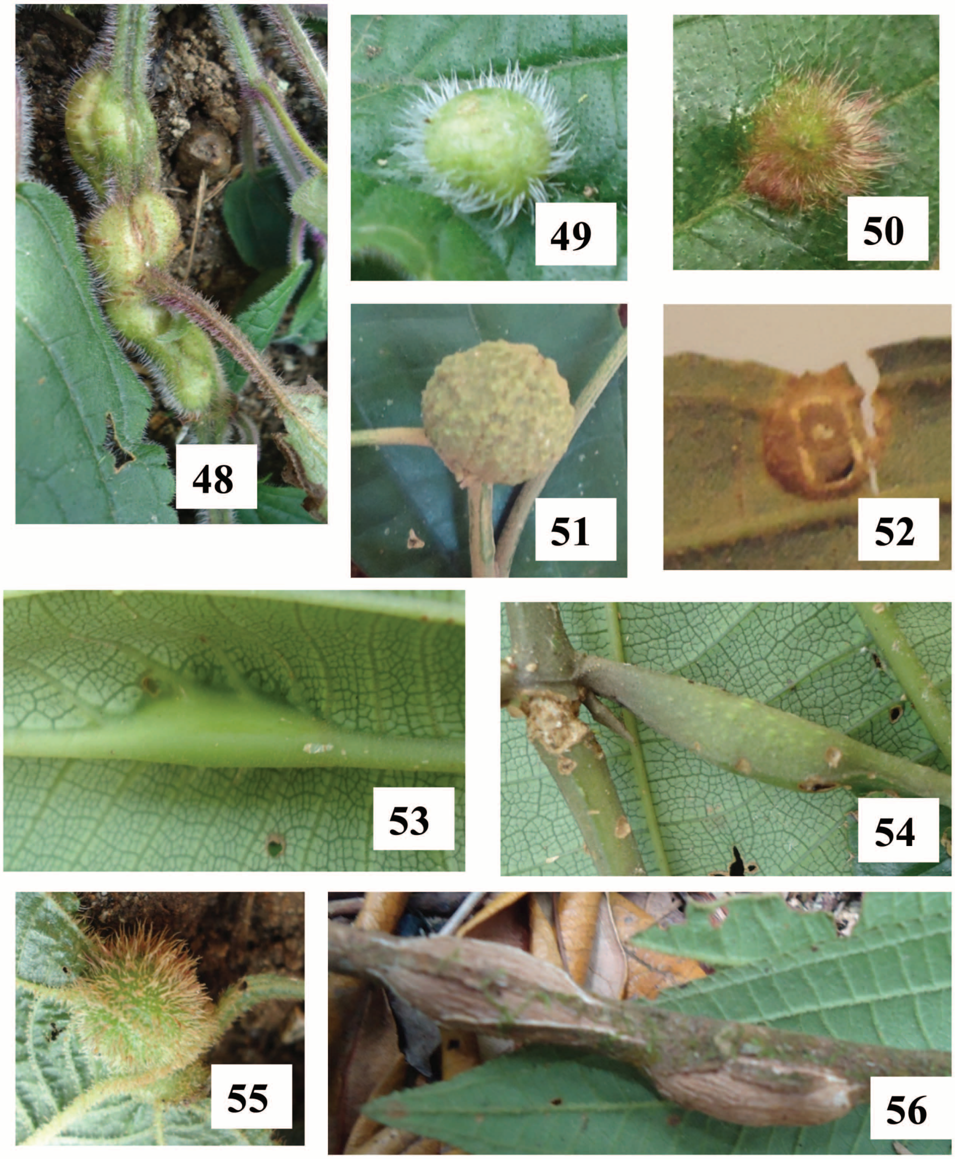
Miconia cf. *latecrenata* (DC.) Naudin

Bud gall, pedunculate, globose, rough, glabrous, one-chambered (Figure 51). Galler: not determined. Locality: Sítio Moana. Occurrence: September.

Leaf gall, circular, yellowish, glabrous, one-chambered (Figure 52). Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: December, March.

Miconia sp.1

Midvein or petiole swelling, fusiform, green, glabrous, one-chambered (Figures 53 and 54). Galler: not determined. Locality: Brejo da Lapa. Occurrence: March.



Figures 48-56. Insect galls of Itamonte (MG, Brazil): 48. Stem gall on *Clidemia* sp. 2 (Melastomataceae); 49. Leaf gall on *Clidemia* sp. 2 (Melastomataceae); 50. Leaf gall on *Miconia* cf. *cinnamomifolia* (Melastomataceae); 51. Bud gall on *Miconia* cf. *latecrenata* (Melastomataceae); 52. Leaf gall on *Miconia* cf. *latecrenata* (Melastomataceae); 53. Midvein gall on *Miconia* sp.1 (Melastomataceae); 54. Petiole gall on *Miconia* sp.1 (Melastomataceae); 55. Leaf gall on *Miconia* sp.2 (Melastomataceae); 56. Stem gall on *Miconia* sp.3 (Melastomataceae).Figuras 48-56. Galhas de insetos de Itamonte (MG, Brasil): 48. Galha caulinar em *Clidemia* sp. 2 (Melastomataceae); 49. Galha foliar em *Clidemia* sp. 2 (Melastomataceae); 50. Galha foliar em *Miconia* cf. *cinnamomifolia* (Melastomataceae); 51. Galha da gema em *Miconia* cf. *latecrenata* (Melastomataceae); 52. Galha foliar em *Miconia* cf. *latecrenata* (Melastomataceae); 53. Galha da nervura central em *Miconia* sp.1 (Melastomataceae); 54. Galha peciolar em *Miconia* sp.1 (Melastomataceae); 55. Galha foliar em *Miconia* sp.2 (Melastomataceae); 56. Galha caulinar em *Miconia* sp.3 (Melastomataceae).

Miconia sp. 2

Leaf or bud gall, globose, green with reddish trichomes, one-chambered (Figure 55). Galler: Cecidomyiidae (Diptera). Locality: Brejo da Lapa. Occurrence: September, December, March.

Miconia sp.3

Stem swelling, fusiform, brown, glabrous, one-chambered (Figure 56). Galler: not determined. Locality: Cachoeira do Escorrega. Occurrence: December.

Bud gall, globose, reddish, hairy, one-chambered. Galler: Lepidoptera. Locality: Cachoeira do Escorrega. Occurrence: December.

Miconia sp. 4

Stem swelling, fusiform, brown, glabrous, one-chambered (Figure 57). Galler: not determined. Locality: Cachoeira do Escorrega. Occurrence: December.

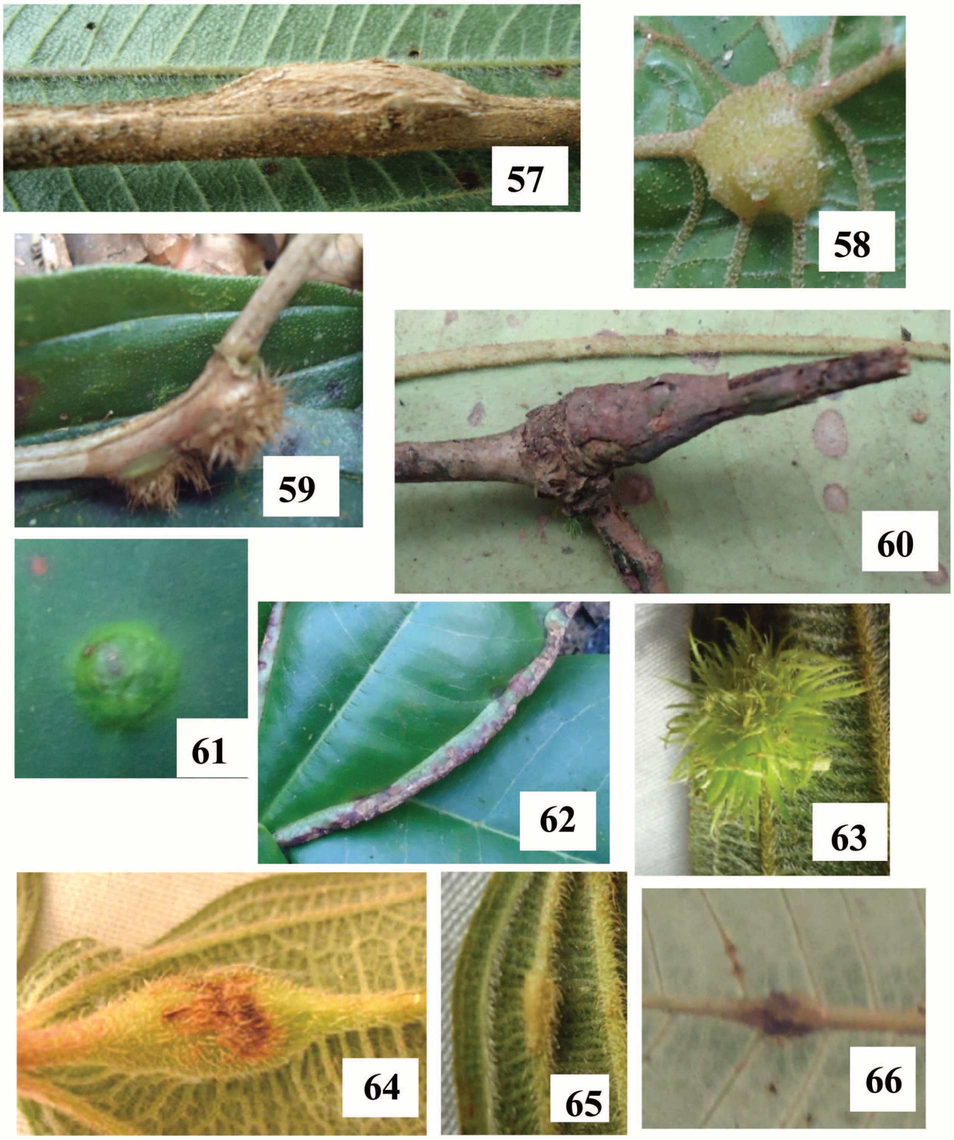
Leaf gall, globose, red, hairy, gregarious, one-chambered. Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: December.

Miconia sp.5

Leaf gall, globose, brownish, glabrous, one-chambered (Figure 58). Galler: not determined. Locality: Cachoeira do Escorrega. Occurrence: December.

Miconia sp.6

Bud gall, globose, yellowish or reddish, hairy, one-chambered (Figure 59). Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: December, March.



Figures 57-66. Insect galls of Itamonte (MG, Brazil): 57. Stem gall on *Miconia* sp.4 (Melastomataceae); 58. Leaf gall on *Miconia* sp.5 (Melastomataceae); 59. Bud gall on *Miconia* sp.6 (Melastomataceae); 60. Stem gall on *Mouriri* sp. (Melastomataceae); 61. Leaf gall on *Mouriri* sp. (Melastomataceae); 62. Marginal leaf roll on *Mouriri* sp. (Melastomataceae); 63. Leaf gall on *Tibouchina* cf. *stenocarpa* (Melastomataceae); 64. Vein gall on *Tibouchina* cf. *stenocarpa* (Melastomataceae); 65. Vein gall on *Tibouchina* cf. *stenocarpa* (Melastomataceae); 66. Midvein gall on Melastomataceae not determined.Figuras 57-66. Galhas de insetos de Itamonte (MG, Brasil): 57. Galha caulinar em *Miconia* sp.4 (Melastomataceae); 58. Galha foliar em *Miconia* sp.5 (Melastomataceae); 59. Galha da gema em *Miconia* sp.6 (Melastomataceae); 60. Galha caulinar em *Mouriri* sp. (Melastomataceae); 61. Galha foliar em *Mouriri* sp. (Melastomataceae); 62. Enrolamento da margem foliar em foliar *Mouriri* sp. (Melastomataceae); 63. Galha foliar em *Tibouchina* cf. *stenocarpa* (Melastomataceae); 64. Galha da nervura em *Tibouchina* cf. *stenocarpa* (Melastomataceae); 65. Galha da nervura em *Tibouchina* cf. *stenocarpa* (Melastomataceae); 66. Galha da nervura central em Melastomataceae não determinada.

Previous records: several different kinds of gall were recorded in Amazonas, Pará, Minas Gerais, São Paulo and Rio de Janeiro (Rübsaamen 1907, Tavares 1917a, Maia 2001a, Monteiro et al. 2004, Maia & Fernandes 2004,Urso-Guimarães & Scareli-Santos 2006, Maia et al. 2008; Carneiro et al. 2009, Maia 2011, Malves & Frieiro-Costa 2012).

Mouriri sp.

Stem swelling, fusiform, brown, glabrous, one-chambered (Figure 60). Galler: not determined. Locality: Cachoeira do Escorrega. Occurrence: December.

Leaf gall, circular, yellow, glabrous, one-chambered (Figure 61). Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: December, March, June.

Marginal leaf roll, reddish, glabrous, one-chambered (Figure 62). Galler: Cecidomyiidae (Diptera). Locality: Brejo da Lapa. Occurrence: June.

Previous records: Rübsaamen 1908 described a flower gall, probably induced by *Asphondylia* sp. (Cecidomyiidae) on *Mouriri ulei* from Amazonas state (Brazil).

Tibouchina cf. *stenocarpa* (DC.) Cogn.

Leaf gall, globose, green, hairy, one-chambered (Figure 63). Galler: Lepidoptera. Locality: Cachoeira do Escorrega. Occurrence: March, June.

Vein swelling, fusiform, conspicuous, green, glabrous, one-chambered (Figure 64). Galler: Lepidoptera. Locality: Cachoeira do Escorrega. Occurrence: March, June.

Vein swelling, linear, barely evident, green, glabrous, one-chambered (Figure 65). Galler: not determined. Locality: Cachoeira do Escorrega. Occurrence: June.

Stem swelling, fusiform, brown, glabrous, one-chambered. Galler. Not determined. Locality: Cachoeira do Escorrega. Occurrence: March.

Previous records: galls on other *Tibouchina* spp. were recorded in Minas Gerais, São Paulo, and Rio de Janeiro (Rübsaamen, 1908; Tavares, 1917a, Maia & Fernandes, 2004; Maia et al. 2008).

Melastomataceae not determined

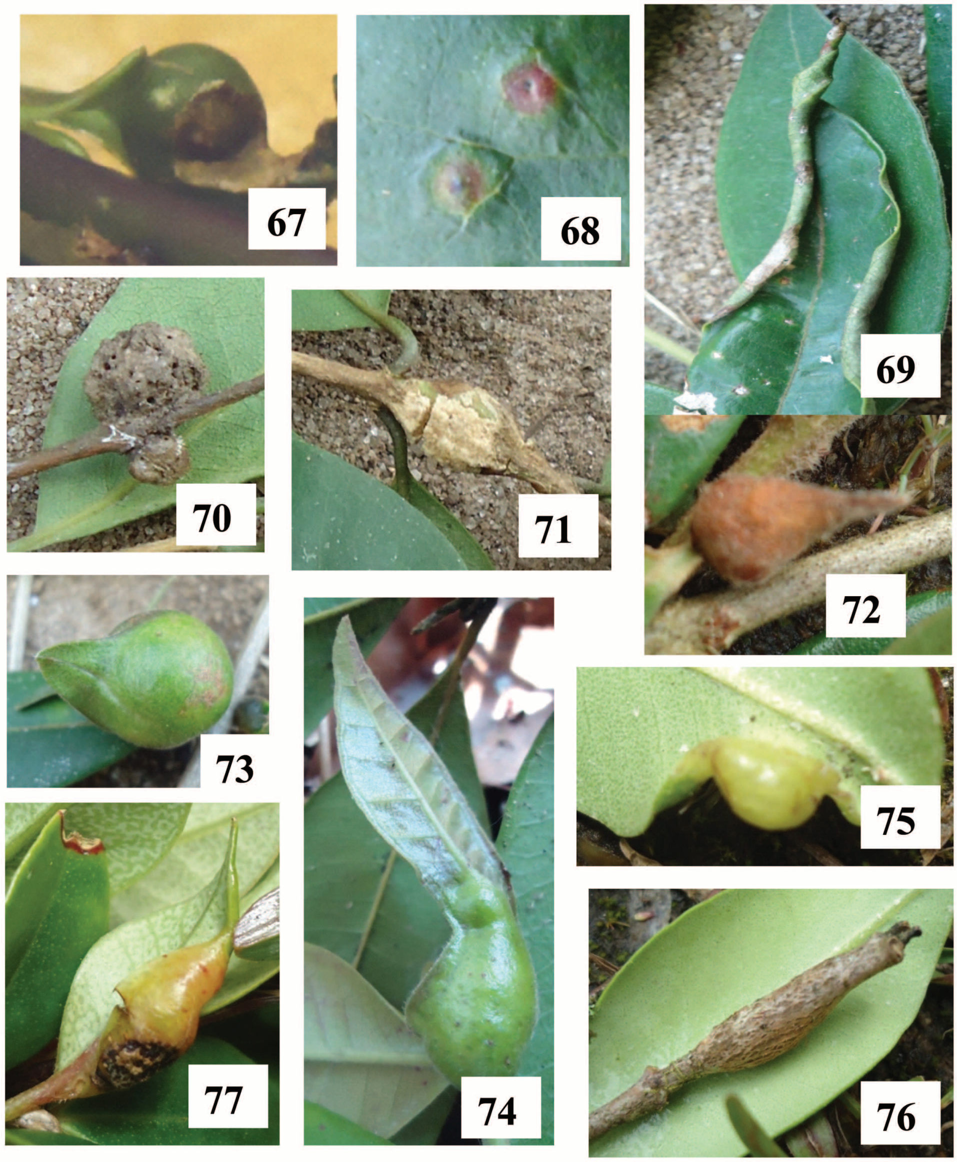
Midvein swelling, fusiform, brown, glabrous, one-chambered (Figure 66). Galler: not determined. Locality: Brejo da Lapa. Occurrence: December.

Leaf gall, globose, green, glabrous, one-chambered (Figure 67). Galler: not determined. Locality: Cachoeira do Escorrega. Occurrence: June.

Myrtaceae

Eugenia uniflora L.

Leaf gall, circular, green or yellow, glabrous, one-chambered (Figure 68). Galler: *Neolasioptera eugeniae* Maia, 1993



Figures 67-77. Insect galls of Itamonte (MG, Brazil): 67. Leaf gall on Melastomataceae not determined; 68. Leaf gall on *Eugenia uniflora* (Myrtaceae); 69. Marginal leaf gall on *Marlierea* sp. (Myrtaceae); 70. Lateral bud gall on *Marlierea* sp. (Myrtaceae); 71. Stem gall on *Marlierea* sp. (Myrtaceae); 72. Apical bud gall on *Marlierea* sp. (Myrtaceae); 73. Lateral bud gall on *Marlierea* sp. (Myrtaceae); 74. Leaf gall on *Myrcia fallax* (Myrtaceae); 75. Marginal leaf gall on *Myrcia* sp. (Myrtaceae); 76. Apical bud gall on *Myrcia* sp. (Myrtaceae); 77. Marginal leaf gall on *Myrciaria* sp. (Myrtaceae).Figuras 67-77. Galhas de insetos de Itamonte (MG, Brasil): 67.Galha foliar em Melastomataceae não determinada; 68. Galha foliar em *Eugenia uniflora* (Myrtaceae); 69. Enrolamento da margem foliar em *Marlierea* sp. (Myrtaceae); 70. Galha da gema lateral em *Marlierea* sp. (Myrtaceae); 71. Galha caulinar em *Marlierea* sp. (Myrtaceae); 72. Galha da gema apical em *Marlierea* sp. (Myrtaceae); 73. Galha da gema lateral em *Marlierea* sp. (Myrtaceae); 74. Galha foliar em *Myrcia fallax* (Myrtaceae); 75. Enrolamento da margem foliar em *Myrcia* sp. (Myrtaceae); 76. Galha da gema apical em *Myrcia* sp. (Myrtaceae); 77. Enrolamento da margem foliar em *Myrciaria* sp. (Myrtaceae).

(Cecidomyiidae, Diptera). Cachoeira do Escorrega. Occurrence: December.

Previous records: the same gall was recorded in the several localities of the State of Rio de Janeiro (Monteiro et al. 1994, Maia 2001a, Monteiro et al. 2004, Oliveira & Maia 2005, Maia & Oliveira 2010).

Marlierea sp.

Marginal leaf gall, green, glabrous, one-chambered (Figure 69). Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: December

Lateral bud gall, globose, brown, glabrous, multichambered (Figure 70). Galler: not determined. Locality: Brejo da Lapa, Cachoeira do Escorrega. Occurrence: December, March, June.

Stem swelling, fusiform, brown, glabrous, one-chambered (Figure 71). Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: December, March, June.

Apical bud gall, conical, brownish or reddish, glabrous, one-chambered (Figure 72). Galler: not determined. Locality: Cachoeira do Escorrega. Occurrence: December

Lateral and apical bud gall, conical, green, glabrous, one-chambered (Figure 73). Galler: not determined. Associated fauna: successors – ants (adults) (Hymenoptera). Locality: Cachoeira do Escorrega. Occurrence: December, March.

Myrcia fallax (Rich) DC.

Leaf gall, globose, green, glabrous, one-chambered (Figure 74). Galler: Cecidomyiidae (Diptera). Locality: Sítio Moana. Occurrence: September. Previous records: Maia et al. (2008) recorded seven different galls on this host plant in São Paulo.

Myrcia pubipetala Miq.

Marginal leaf roll, green, glabrous, one-chambered. Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: June.

Myrcia sp.

Marginal leaf gall, green, glabrous, one-chambered (Figure 75). Galler: Hemiptera. Locality: Brejo da Lapa. Occurrence: March.

Apical bud gall, fusiform, brown, glabrous, one-chambered (Figure 76). Galler: Lepidoptera. Locality: Brejo da Lapa. Occurrence: March.

Previous records: galls on *Myrcia* spp. were recorded in Goiás, Minas Gerais, Rio de Janeiro, and São Paulo (Maia 2001a, Maia et al. 2002, Maia & Fernandes 2004, Monteiro et al. 2004, Araujo et al. 2007, Maia et al. 2008, Carneiro et al. 2009, Coelho et al. 2009, Santos et al. 2010, Malves & Frieiro-Costa 2012).

Myrciaria sp.

Marginal leaf gall, green, glabrous, one-chambered (Figure 77). Galler: Hemiptera. Locality: Brejo da Lapa. Occurrence: March. Previous records: Galls on *Myrciaria* spp. were recorded in Minas Gerais, Espírito Santo, and Rio de Janeiro (Gagné 1994, Monteiro et al. 1994, Maia 2001a, Maia & Fernandes 2004, Monteiro et al. 2004, Bregonci et al. 2010, Maia & Oliveira 2010).

Nyctaginaceae

Neea sp.

Leaf gall, circular, green, glabrous, one-chambered (Figure 78). Galler: *Bruggmannia* sp. (Cecidomyiidae, Diptera). Locality: Cachoeira do Escorrega. Occurrence: December, March. Previous records: galls on *Neea* sp. were recorded in Amazonas, Mato Grosso do Sul, Rio de Janeiro, and Santa Catarina (Rübsaamen 1908, Julião et al. 2002).

Piperaceae

Piper sp.

Stem swelling, globose or fusiform, green, glabrous, multichambered (Figure 79). Galler:.not determined. Locality: Sítio Moana. Occurrence: September.

Leaf gall, globose, green, glabrous, one-chambered (Figure 80). Galler: Cecidomyiidae (Diptera) Locality: Sítio Moana. Occurrence: September.

Bud gall, globose, brown, glabrous, one-chambered (Figure 81). Galler: not determined. Associated fauna: parasitoid – Hymenoptera. Locality: Cachoeira do Escorrega. Occurrence: December.

Previous records: different galls on *Piper* spp. were recorded in Goiás, Minas Gerais, São Paulo, and Rio de Janeiro (Rübsaamen 1908, Tavares 1909, 1925, Maia 2001, Maia & Fernandes 2004, Oliveira & Maia 2005, Araujo et al. 2007, Maia et al. 2008, Santos et al. 2010).

Proteaceae

Roupala montana var. *brasiliensis* (Klotzsch) K. S. Edwards

Leaf fold, green, glabrous, one-chambered (Figure 82). Galler: not determined. Locality: Brejo da Lapa. Occurrence: June.

Roupala montana var. *dentata* (R. BR.) Sleumer

Leaf gall, conical, glabrous, green, one-chambered (Figure 83). Galler: not determined. Locality: Cachoeira do Escorrega. Occurrence: June.

Previous records: a hemipterous gall on *Roupala montana* was recorded in Goiás by Araujo et al. (2007).

Rubiaceae

Pagamea sp.

Stem swelling, fusiform, whittish, glabrous, one-chambered (Figure 84). Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: December, March, June.

Palicourea sp.

Leaf gall, conical, green, glabrous, one-chambered (Figure 85). Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: December, March, June. Previous record: Carneiro et al. (2009) recorded a globose leaf gall on *Palicourea rigida* Kunth in Minas Gerais.

Psychotria sp.

Leaf gall, green, globose, glabrous, succulent, one-chambered (Figure 86). Galler: not determined. Localities: Brejo da Lapa, Cachoeira do Escorrega. Occurrence: December, March.

Previous records: several galls were recorded in Mato Grosso do Sul, Minas Gerais, Rio de Janeiro, São Paulo and Rio Grande do Sul (Rübsaamen 1908, Julião et al. 2002, Carneiro et al. 2009, Tavares 1909, 1922, Maia 2008).

Rubiaceae not determined

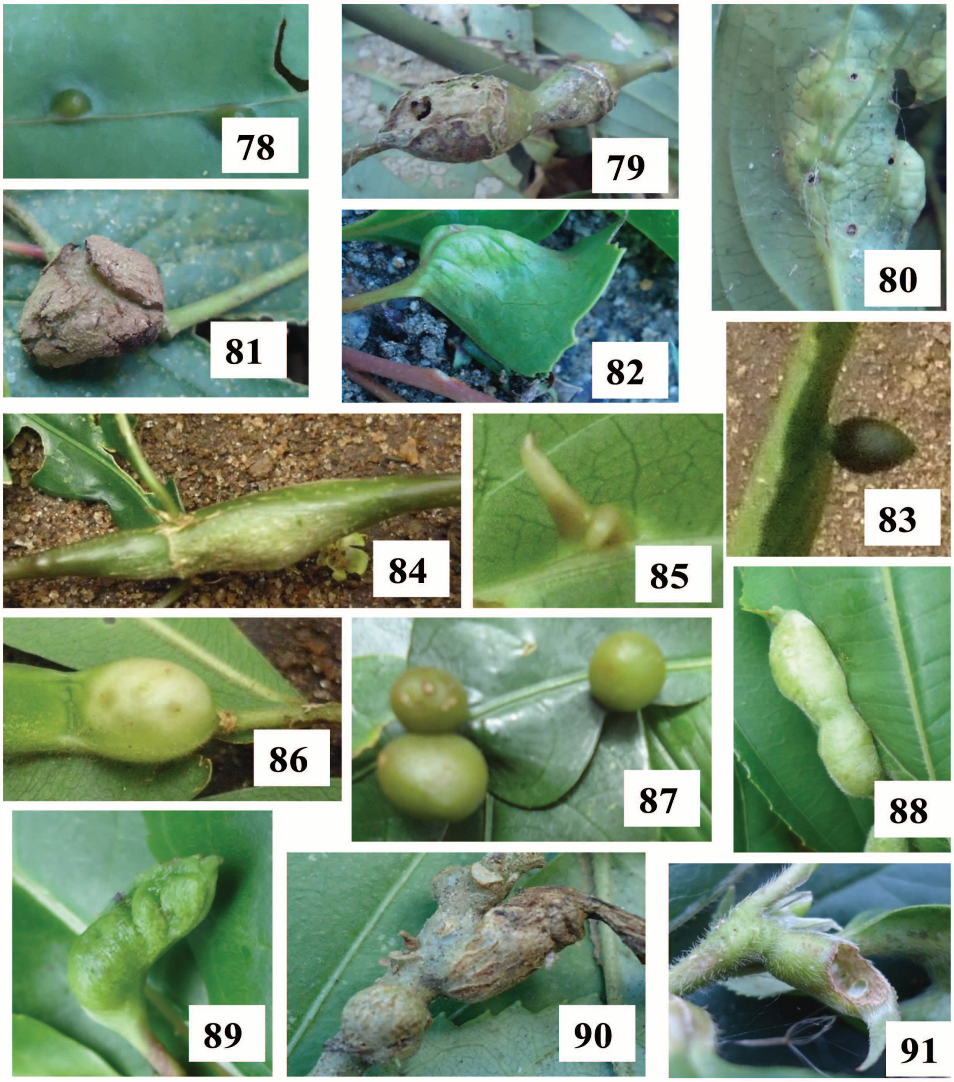
Leaf gall, globose, green, glabrous, one-chambered (Figure 87). Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: December.

Salicaceae

Homalium sp.

Marginal leaf roll, green, glabrous, one-chambered (Figure 88). Galler: Hemiptera. Locality: Cachoeira do Escorrega. Occurrence: December.

Young leaf roll, green, glabrous, one-chambered (Figure 89). Galler: Hemiptera. Locality: Brejo da Lapa. Occurrence: March, June.



Figures 78-91. Insect galls of Itamonte (MG, Brazil): 78. Leaf gall on *Neea* sp. (Nyctaginaceae); 79. Stem gall on *Piper* sp. (Piperaceae); 80. Leaf gall on *Piper* sp. (Piperaceae); 81. Bud gall on *Piper* sp. (Piperaceae); 82. Leaf fold on *Roupala montana* var. *brasiliensis* (Proteaceae); 83. Leaf gall on *Roupala montana* var. *dentata* (Proteaceae); 84. Stem gall on *Pagamea* sp. (Rubiaceae); 85. Leaf gall on *Palicourea* sp. (Rubiaceae); 86. Leaf gall on *Psychotria* sp. (Rubiaceae); 87. Leaf gall on Rubiaceae not determined; 88. Marginal leaf roll on *Homalium* sp. (Salicaceae); 89. Young leaf roll on *Homalium* sp. (Salicaceae); 90. Stem gall on *Xylosma* sp. (Salicaceae); 91. Bud gall on *Xylosma* sp. (Salicaceae).Figuras 78-91. Galhas de insetos de Itamonte (MG, Brasil): 78. Galha foliar em *Neea* sp. (Nyctaginaceae); 79. Galha caulinar em *Piper* sp. (Piperaceae); 80. Galha foliar em *Piper* sp. (Piperaceae); 81. Galha da gema em *Piper* sp. (Piperaceae); 82. Dobramento da folha em *Roupala montana* var. *brasiliensis* (Proteaceae); 83. Galha foliar em *Roupala montana* var. *dentata* (Proteaceae); 84. Galha caulinar em *Pagamea* sp. (Rubiaceae); 85. Galha foliar em *Palicourea* sp. (Rubiaceae); 86. Galha foliar em *Psychotria* sp. (Rubiaceae); 87. Galha foliar em Rubiaceae não determinada; 88. Enrolamento da margem foliar em *Homalium* sp. (Salicaceae); 89. Enrolamento da folha jovem em *Homalium* sp. (Salicaceae); 90. Galha caulinar em *Xylosma* sp. (Salicaceae); 91. Galha da gema em *Xylosma* sp. (Salicaceae).

Xylosma sp.

Stem, midvein or petiole swelling, fusiform, green, glabrous, one-chambered (Figure 90). Galler: Cecidomyiidae (Diptera). Locality: Brejo da Lapa. Occurrence: June.

Bud gall, conical, green, glabrous, one-chambered (Figure 91). Galler: Hemiptera. Locality: Brejo da Lapa. Occurrence: June.

Previous record: Julião et al. (2002) recorded a leaf gall on *Xylosma venosum*.

Sapindaceae

Serjania sp.

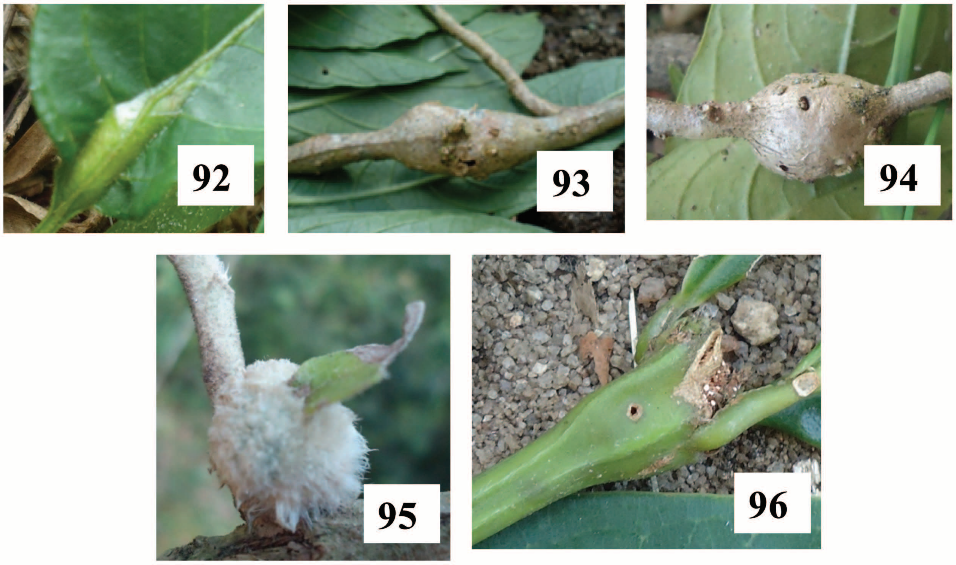
Midvein swelling, fusiform, green, glabrous, one-chambered (Figure 92). Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: December.

Previous records: different galls were recorded on *Serjania* spp. in Amazonas, Goiás, Mato Grosso do Sul, Pernambuco, Minas Gerais, and São Paulo (Rübsaamen 1908, 1916a, Julião et al. 2002, Maia et al. 2008, Coelho et al. 2009, Santos et al. 2011).

Solanaceae

Solanum sp.1

Stem swelling fusiform , brown, glabrous, one-chambered (Figure 93). Galler: not determined. Locality: Brejo da Lapa. Occurrence: March.



Figures 92-96. Insect galls of Itamonte (MG, Brazil): 92. Midvein gall on *Serjania* sp. (Sapindaceae); 93. Stem gall on *Solanum* sp.1 (Solanaceae); 94. Stem gall on *Solanum* sp.1 (Solanaceae); 95. Bud gall on *Solanum* sp.2 (Solanaceae); 96. Bud gall on *Vochysia* sp. (Vochysiaceae).Figuras 92-96. Galhas de insetos de Itamonte (MG, Brasil): 92. Galha da nervura central em *Serjania* sp. (Sapindaceae); 93. Galha caulinar em *Solanum* sp.1 (Solanaceae); 94. Galha caulinar em *Solanum* sp.1 (Solanaceae); 95. Galha da gema em *Solanum* sp.2 (Solanaceae); 96. Galha da gema em *Vochysia* sp. (Vochysiaceae).

Stem swelling, globose, brown, glabrous, one-chambered (Figure 94). Galler: Cecidomyiidae (Diptera). Locality: Brejo da Lapa. Occurrence: September.

Solanum sp.2

Bud gall, globose, whittish, hairy, one-chambered (Figure 95). Galler: Cecidomyiidae (Diptera). Locality: Cachoeira do Escorrega. Occurrence: December.

Previous records: other galls on *Solanum* spp. were recorded in Pernambuco, Bahia, São Paulo and Rio de Janeiro by Rübsaamen (1908), Tavares (1918a), Monteiro et al. (1994), Maia (2001a), Monteiro et al. (2004), Oliveira & Maia (2005), Maia et al. (2008), Santos et al. (2011), Malves & Frieiro-Costa (2012).

Vochysiaceae

Vochysia sp.

Bud or stem gall, fusiform, green, glabrous, one-chambered (Figure 96). Galler: not determined. Locality: Cachoeira do Escorrega. Occurrence: March. Previous records: Carneiro et al. (2009) recorded galls on *Vochysia* spp. in Minas Gerais.

Discussion

Although several sampling methods and different collecting efforts have been employed in galls inventory in Brazil, Itamonte can be considered as an area of high richness of insect galls,overtaking several other areas in Brazilian states, such as Goiás (Parque Estadual da Serra dos Pireneus in Pirenópolis, and Campus Samambaia, Universidade Federal de Goiás, Goiânia) (Araújo et al. 2007, Santos et al. 2010), Minas Gerais (Serra do Cipó, Delfinópolis, Aimorés, and Jequitinhonha Valley) (Coelho et al. 2009, Urso-Guimarães et al. 2003, Fernandes & Negreiros 2006, Fernandes et al. 1997), São Paulo (Pé-de-Gigante Cerrado Reserve in Santa Rita do Passa-Quatro, and Ecological Station of Jataí in Luiz Antônio) (Urso-Guimarães & Scarelli-Santos 2006, Saito & Urso-Guimarães 2012), Espírito Santo (Parque Estadual Paulo César Vinha in Guarapari (Bregonci et al. 2010), and Rio de Janeiro (Reserva Biológica da Praia do Sul in Ilha Grande - Angra dos Reis, Maricá, Carapebus, Grumari - Rio de Janeiro, and Arraial do Cabo) (Maia & Oliveira 2010, Maia 2001, Oliveira & Maia 2005, Monteiro et al. 1994).

The above cited areas comprise cerrado and restinga vegetation, and are considered as xeric environments with hygrotermical stress. One of the hypothesis on the adaptive nature of the insect galls (microenvironment hypothesis) predicts that xeric environments have higher gall diversity than mesic ones (Price et al. 1986). The surveyed areas of Itamonte are not xeric, and they are richer in gall morphotypes than those areas. Inventories in Amazonian forest (Julião 2007 and Oda 2006) showed an unexpected high diversity of galls, overtaking all other Brazilian biomes. So, the microenvironment hypothesis does not explain the pattern found in South America. The plant diversity hypothesis (Fernandes, 1992), which predicts a positive relation between plant diversity and gall diversity appears to be the most adequate.

In Itamonte, Melastomataceae, Asteraceae and Myrtaceae are the most galled plant families. A similar result was found in Bertioga (restinga vegetation, São Paulo state) and Serra de São José (rupestrian fields, Minas Gerais). Melastomataceae and Asteraceae are also one of the most galled families in Espinhaço Range (cerrado, Minas Gerais), and Myrtaceae in Santa Rita do Passa-Quatro (cerrado, Minas Gerais) and in several restinga areas of the State of Rio de Janeiro. As these botanical families are well represented in the surveyed areas, the plant diversity hypothesis can explain this pattern.

Leaves were the most galled plant organ. This pattern has been observed in almost all Brazilian inventories, as well as in a majority of cases elsewhere in the world, probably because leaves represent an abundant and frequently renewable resource, with undifferentiated meristematic cells which are essential to gall growth (Maia 2011). Espinhaço Range represents an exception, as well as savanna areas in South

Africa, where stem galls are the most frequent as indicated by Carneiro et al. (2009) and Veldtman & McGeoch (2003), respectively. According to these authors, stems are safer than leaves as oviposition sites as they do not suffer mechanical injuries caused by winds or other herbivores. Furthermore, they can provide tissues with better food quality, due to their placement in relation to the vascular system. The high specificity of host plant organ is confirmed as almost all morphotypes occurred in a single plant organ.

Globose galls were the most frequent. The same shape predominance was observed in several localities and biomes: Espinhaço Range, MG (cerrado, Carneiro et al. 2009), Pernambuco (caatinga, Santos et al. 2001), Espírito Santo (restinga, Bregonci et al. 2010), and Goiás (cerrado, Araújo et al. 2007), suggesting that this is the most common gall shape in Brazil. The majority of the galls was glabrous and one-chambered as in all other Brazilian galls inventories, excepting by Delfinópolis, where hairy galls are more frequent than glabrous (54% and 46%, respectively) (Urso-Guimarães et al. 2003).

The galling guild of Itamonte comprises only three insect orders: Diptera, Hemiptera, and Lepidoptera. In other Brazilian inventories, galls of Coleoptera, Hymenoptera and Thysanoptera have been recorded in Barra de Maricá and Arraial do Cabo (RJ) (Monteiro et al. 1994), and Espinhaço Range (MG) (Carneiro et al. 2009); Coleoptera and Hymenoptera in Grumari (RJ) (Oliveira & Maia 2005); Coleoptera in Boqueirão (MG) (Malves & Frieiro-Costa 2012) and Pernambuco (Santos et al. 2011); Hymenoptera in Santa Rita do Passa Quatro (SP) (Urso-Guimarães & Scareli-Santos 2006); and Thysanoptera in Luiz Antônio (SP) (Saito & Urso-Guimarães 2012). Hymenoptera and Thysanoptera are the less frequent galling insects in Brazil (Maia 2006 and Maia, in press.). Thysanopterous galls are rare throughout the world (Felt 1940), but Hymenopterous galls, especially those induced by Cynipidae are common, specially in the Holarctic region. There are more than 1,300 described galling species of Cynipidae (Ronquist & Liljeblad 2001). The scarcity of galls induced by Hymenoptera and Thysanoptera appears to be a peculiar pattern of Brazil.

Cecidomyiidae (Diptera) was the most frequent galling insect, followed by Hemiptera and Lepidoptera. Cecidomyiidae are the most speciose and frequent galling insects in all zoogeographic regions (Gagné 2010). Hemiptera and Lepidoptera are also important gallers. In the Neotropical region, they are the second and third most frequent galling insects (Maia 2006). Coleoptera is the fourth (Maia 2012), but they are not found in the surveyed areas of Itamonte.

The associated fauna can be very rich, as pointed by Maia (2001), Maia & Fernandes (2004) and Maia & Azevedo (2009), but it showed a very low frequency and diversity in Itamonte: parasitoids were obtained from 6% of the gall morphotypes, successors from a single morphotype, predators and inquilines were not found. This is a surprising result as the frequency of parasitoids is higher than this value in all Brazilian inventories: 23% in Luiz Antônio, SP (Saito & Urso-Guimarães 2012); 31% in Guarapari, ES (Bregonci et al. 2010); 35% in Tiradentes, MG (Maia & Fernandes, 2004); 48% in Bertioga, SP (Maia et al. 2008); 60% in restingas of Rio de Janeiro (Maia & Azevedo 2009), 71% in Pirenópolis, GO (Araujo et al. 2007), excepting by Porto de Trombetas, where the frequency of parasitoids is about 3% (Maia 2011). According to Fernandes & Price (1992), parasitism is higher in mesic habitats because of longer maturation and hardening of the gall; however, this was not observed in the present study.

Conclusion

The results of the present study add evidences to support several known patterns or hypothesis, such as the plant diversity hypothesis, the predominance of leaf galls, the high specificity of host plant organ, the predominance of globoid, glabrous and one-chambered galls in Brazil, and the highest frequency of galling species of Cecidomyiidae (Diptera), Hemiptera and Lepidoptera in the Neotropical region. On the other hand, no evidence to the microenvironment hypothesis and to the prediction that parasitism is higher in mesic than in xeric habitats was provided.

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References

ARAÚJO, W.S., GOMES-KLEIN, V.L. & SANTOS, B.B. 2007. Galhas Entomógenas Associadas à Vegetação do Parque Estadual da Serra dos Pireneus, Pirenópolis, Goiás, Brasil. R. Bras. Bioci. 5(supl. 1):45-47.

BREGONCI, J.M., POLYCARPO, P.V. & MAIA, V.C. 2010. Insect galls of the Parque Estadual Paulo César Vinha (Guarapari, ES, Brazil). Biota Neotrop. 10(1):265-274. http://www.biotaneotropica.org.br/v10n1/en/abstract?inventory+bn01410012010. http://dx.doi.org/10.1590/S1676-06032010000100023

CARNEIRO, M.A.A., BORGES, R.A..X., ARAÚJO, A.P.A. & FERNANDES, G.W. 2009. Insetos indutores de galhas da porção sul da Cadeia do Espinhaço, MG, Brasil. Rev. Bras. entomol . 53:570–592. http://dx.doi.org/10.1590/S0085-56262009000400007

COELHO, M.S, ALMADA, E., FERNANDES, G.W., CARNEIRO, M.A.A. SANTOS, R.M., QUINTINO, A.V. & SANCHEZ-AZOFEIFA, A. 2009. Gall inducing arthropods from a seasonally dry tropical forest in Serra do Cipó, Brazil. Rev. Bras. entomol. 53:404–414. http://dx.doi.org/10.1590/S0085-56262009000300015

FELT, E.P. 1940. Plant Galls and Gall Makers. Comstock Publishing Co., Ithaca, N. Y., viii + 364p.

FERNANDES, G.W. 1992. Plant family size and age effects on insular gallforming species richness. Glob Ecol Biogeogr Let. 2:71–74. http://dx.doi.org/10.2307/2997508

FERNANDES, G.W. & NEGREIROS, D. 2006. A comunidade de insetos galhadores da RPPN Fazenda Bulcão, Aimorés, Minas Gerais, Brasil. Lundiana 7(2):111-120.

FERNANDES G.W. & PRICE P. 1992. The adaptive significance of the insect gall distribution: survivorship of species in xeric and mesic habitats. Oecologia 90:14-20. http://dx.doi.org/10.1007/BF00317803

FERNANDES, G.W., TAMEIRÃO-NETO E. & MARTINS, R.P. 1988. Ocorrência e caracterização de galhas entomógenas na vegetação do Campus Pampulha da Universidade Federal de Minas Gerais. Rev. Bras. Zool. 5(1):11-29. http://dx.doi.org/10.1590/S0101-81751988000100002

FERNANDES, G.W., CARNEIRO, M.A.A.,LARA, A.C.F., ALLAIN, L.R., JULIÃO, G.R., ANDRADE, G.I., REIS, T. R., & SILVA, I.M. 1996. Galling insects on neotropical species of *Baccharis* (Asteraceae). Trop. Zool. 9:315–332. http://dx.doi.org/10.1080/03946975.1996.10539315

FERNANDES, G.W., ARAÚJO, R.C., ARAÚJO, S.C., LOMBARDI, J.A., PAULA, A.S., LOYOLA-JÚNIOR, R. & CORNELISSEN, T.G. 1997. Insect galls from savanna and rocky fields of the Jequitinhonha Valley, Minas Gerais, Brazil. Naturalia 22:221–244.

GAGNÉ, R.J. 1994. The gall midges of the Neotropical region. Ithaca: Cornell University Press. 352p.

GAGNÉ, R.J. 2010. A Catalog of the Cecidomyiidae (Diptera) of the world. http://www.ars.usda.gov/SP2UserFiles/Place/12754100/Gagne_2010_World_Catalog_Cecidomyiidae.pdf. Captured on January

HONKALA, J. & NIIRANEN, S. 2010. A birdwatching Guide to South-East Brazil. Portal do Bosque Association, 416p.

ITAMONTE. 2012. http://turismo.itamonte.mg.gov.br/meioambiente.asp. (05/xii/2012).

JULIÃO, G.R. 2007. Riqueza e abundância de insetos galhadores associados ao dossel de florestas de terra firme, várzea e igapó da Amazônia Central. Tese de Doutorado, Universidade Federal do Amazonas, Manaus, 144p.

JULIÃO G.R., AMARAL, M.E.C. & FERNANDES, G W. 2002. Galhas de insetos e suas plantas hospedeiras do Pantanal sul-mato-grossense. Naturalia 27:47–74.

MAIA, V.C. 2001. The gall midges (Diptera, Cecidomyiidae) from three restingas of Rio de Janeiro State, Brazil. Rev. Bras. Zool. 18(2):583-629. http://dx.doi.org/10.1590/S0101-81752001000200028

MAIA, V.C. 2006. Galls of Hemiptera, Lepidoptera and Thysanoptera from Central and South America. Pub. Avul. Mus. Nac. 110:3-22.

MAIA, V.C. 2011. Characterization of insect galls, gall makers, and associated fauna of Platô Bacaba (Porto de Trombetas, Pará, Brazil). Biota Neotrop. 11(4):37-53. http://www.biotaneotropica.org.br/v11n4/en/abstract?article+bn00511042011. http://dx.doi.org/10.1590/S1676-06032011000400003

MAIA, V.C. 2012. Coleopterous galls from the Neotropical region. Pap. Avulsos de Zool. 52(15):175-184.

MAIA, V.C. in press. Hymenopterous galls from South America. Pap. Avulsos de Zool..

MAIA, V.C. & AZEVEDO, M.A.P. 2009. Micro-Hymenoptera associated with Cecidomyiidae (Diptera) galls at Restingas of the Rio de Janeiro State. Biota Neotrop. 9(2):151-164. http://www.biotaneotropica.org.br/v9n2/en/abstract?article+bn02809022009. http://dx.doi.org/10.1590/S1676-06032009000200015

MAIA, V.C. & FERNANDES, G.W. 2004. Insect galls from Serra de São José (Tiradentes, MG, Brazil). Braz. J. Biol. 64(3):423-445. http://dx.doi.org/10.1590/S1519-69842004000300007

MAIA, V.C. & OLIVEIRA, J.C. 2010. Insect galls of the Reserva Biológica Estadual da Praia do Sul (Ilha Grande, Angra dos Reis, RJ). Biota Neotrop. 10(4):227-237. http://www.biotaneotropica.org.br/v10n4/en/abstract?inventory+bn04110042010. http://dx.doi.org/10.1590/S1676-06032010000400028

MAIA, V.C., AZEVEDO, M.A.P. & COURI, M.S. 2002. New contribution to the knowledge of the gall midges (Diptera, Cecidomyiidae) from the restinga of Barra de Maricá (Rio de Janeiro, Brazil). Studia Dipt. 9:447–452.

MAIA, V.C., MAGENTA, M.A.G. & MARTINS, S.E. 2008. Ocorrência e caracterização de galhas de insetos em áreas de restinga de Bertioga (São Paulo, Brasil). Biota Neotrop. 8(1):167-197. http://www.biotaneotropica.org.br/v8n1/en/abstract?inventory+bn02408012008. Captured on January 2013. http://dx.doi.org/10.1590/S1676-06032008000100020

MALVES, K. & FRIEIRO-COSTA, F.A. 2012. List of plants with galls induced by insects from the UNILAVRAS/Boqueirão Biological Reserve, Ingaí, State of Minas Gerais, Brazil. Check List 8(3):426-431.

MARTINELLI, G., BANDEIRA, J. & BRAGANÇA, J O. 1989. Campos de Altitude. Index, Rio de Janeiro.

MONTEIRO, R.F., FERRAZ, F.F., MAIA, V.C. & AZEVEDO, M.A.P. 1993. Galhas entomógenas em restinga: uma abordagem preliminar. In Anais do III Simpósio de Ecossistemas da Costa Brasileira, p. 210-220.

MONTEIRO, R.F., ODA, R.A.M., NARAHARA, K.L. & CONSTANTINO, P.A.L. 2004. Galhas: diversidade, especificidade e distribuição. In C. F. D. Rocha, F. A. Esteves and F. R. Scarano (orgs). Pesquisas de longa duração na Restinga de Jurubatiba: ecologia, história natural e conservação. Rima, São Carlos, p. 127-141.

ODA, R.A.M. 2006. Distribuição espacial de insetos fitófagos, com ênfase em galhadores, em três diferentes regiões do Brasil. Tese de Doutorado, Universidade Federal do Rio de Janeiro, Rio de Janeiro, 105p.

OLIVEIRA, J.C. & MAIA, V.C. 2005. Ocorrência e caracterização de galhas de insetos na restinga de Grumari (Rio de Janeiro, RJ, Brasil). Arq. Mus. Nac. 63(4):669-676.

PRICE, P.W., WARING, G.L. & FERNANDES, G.W. 1986. Hypotheses on the adaptive nature of galls. P. Entomol. Soc. Wash. 88:361–363.

RONQUIST, F. & LILJEBLAD, J. 2001. Evolution of the gall wasp-host plant association. Evolution 55(12):2503–2522.

RÜBSAAMEN, E.H. 1905. Beiträge zur Kenntnis aussereuropäischer Zoocecidien. II. Beitrag: Gallen aus Brasilien und Peru. Marcellia 4:65-85; 115-138.

RÜBSAAMEN, E.H. 1907. Beiträge zur Kenntnis aussereuropäischer Zoocecidien. III. Beitrag: Gallen aus Brasilien und Peru. Marcellia 6:110-173.

RÜBSAAMEN, E.H. 1908. Beiträge zur Kenntnis aussereuropäischer Zoocecidien. III. Beitrag: Gallen aus Brasilien und Peru. Marcellia 7:15-79.

RÜBSAAMEN, E.H. 1916. Beiträge zur Kenntnis aussereuropäischer Gallmücken. Sitzber. Ges. Natur. Freunde Berlin 1915:431-481.

SAITO, V.S. & URSO-GUIMARÃES, M.V. 2012. Characterization of galls, insect galls and associated fauna of Ecological Station of Jataí (Luiz Antônio, SP). Biota Neotrop. 12(3):99-107. http://www.biotaneotropica.org.br/v12n3/en/abstract?article+bn02312032012. http://dx.doi.org/10.1590/S1676-06032012000300011

SANTOS, B.B., FERREIRA, H.D. & ARAÚJO, W.S. 2010. Ocorrência e caracterização de galhas entomógenas em uma área de floresta estacional semidecídua em Goiânia, Goiás, Brasil. Acta Bot. Bras. 24(1):243-249. http://dx.doi.org/10.1590/S0102-33062010000100026

SANTOS, J.C; ALMEIDA-CORTEZ, J.S. & FERNANDES, G.W. 2011. Richness of gall-inducing insects in the tropical dry forest (caatinga) of Pernambuco. Rev. Bras. entomol. 55(1):45–54. http://dx.doi.org/10.1590/S0085-56262011000100009

TAVARES, J.S. 1909. Contributio prima ad cognitionem cecidologiae Braziliae. Brotéria (Zool.) 5:5-28.

TAVARES, J.S. 1917a. As cecídias do Brazil que se criam nas plantas da família das Melastomataceae. Brotéria (Zool.) 15:18-59.

TAVARES, J.S. 1917b. Cecídias brazileiras que se criam em plantas das famílias das Compositae, Rubiaceae, Lythraceae e Artocarpaceae. Brotéria (Zool.) 15:113-181.

TAVARES, J.S. 1918. Cecidologia brazileira. Cecídias que se criam nas plantas das famílias das Verbenaceae, Euphorbiaceae, Malvaceae, Anacardiaceae, Labiatae, Rosaceae, Anonaceae, Ampelidaceae, Bignoniaceae, Aristolochiaceae e Solanaceae. Brotéria (Zool.) 16:21-68.

TAVARES, J.S. 1920. Cecidologia brazileira. Cecídias que se criam em plantas das famílias das Leguminosae, Sapotaceae, Lauraceae, Myrtaceae, Punicaceae, Aurantiaceae, Malpighiaceae, Sapindaceae, Umbelliferae, Loranthaceae, Apocynaceae, Urticaceae, Salicaceae e Graminae. Brotéria (Zool.) 18:82-125.

TAVARES, J.S. 1921. Cecidologia brazileira. Cecidias que se criam em plantas das famílias das Leguminosae, Sapotaceae, Lauraceae, Myrtaceae, Punicaceae, Aurantiaceae,Malpighiaceae, Sapindaceae, Umbelliferae, Loranthaceae, Apocynaceae, Urticaceae, Salicaceae e Graminae. Brotéria (Série Zool.) 19:76-112, pl. I.

TAVARES, J.S. 1922. Cecidologia Brazileira. As restantes famílias.

Brotéria (Zool.) 20:5-48.

TAVARES, J.S. 1925. Nova contribuição para o conhecimento da Cecidologia Brazileira. Brotéria (Zool.) 22:5-55.

URSO-GUIMARÃES, M.V. & SCARELLI-SANTOS, C. 2006. Galls and gall makers in plants from the Pé-de-Gigante Cerrado Reserve, Santa Rita do Passa Quatro, SP, Brazil. Braz. J. Biol. 66:357–369.

URSO-GUIMARÃES, M.V., SCARELLI-SANTOS, C. & BONIFÁCIO-SILVA, A.C. 2003. Occurrence and characterization of entomogen galls in plants from natural vegetation areas in Delfinópolis, MG, Brazil. Braz. J. Biol. 63(4):705-715.

ZIKAN, J F. & ZIKAN, W. 1968. Inseto-fauna do Itatiaia e da Mantiqueira. III. Lepidoptera. Pesq. Agropec. Bras. 3:45-104.

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Range extension of the mud crab *Eurypanopeus depressus* (Smith, 1869) (Decapoda, Panopeidae): A new record for the coastal south of Brazil

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RODRIGUES, M.A., VIEIRA, R.R.R., D'INCAO, F. **Range extension of the mud crab *Eurypanopeus depressus* (Smith, 1869) (Decapoda, Panopeidae): A new record for the coastal south of Brazil.** Biota Neotropica. 14(1): e20130063. http://www.biotaneotropica.org.br/v14n1/en/abstract?short-communication+bn00814012014

Abstract: The discovery of *Eurypanopeus depressus* (Decapoda: Panopeidae; Smith, 1869) on the coast of Rio Grande do Sul, Brazil suggests that the species was recently introduced, possibly due to different sources of introduction, such as the ballast water of ships. *E. depressus* were collected using otter-trawl net in the Patos Lagoon Estuary. Discussion focuses on the fact that the primary South American distribution derives from Uruguayan shores, and later expanded to nearby places (Brazil and Argentina). This work extends the Southern Hemisphere distribution for the species, as it was previously reported only from Argentina to Uruguay.

Keywords: *range distribution, bioinvasion, ecology, systematics.*

RODRIGUES, M.A., VIEIRA, R.R.R., D'INCAO, F. **Expansão da distribuição do caranguejo *Eurypanopeus depressus* (Smith, 1869) (Decapoda, Panopeidae). Um novo registro para a costa do sul do Brasil.** Biota Neotropica. 14(1): e20130063. www.biotaneotropica.org.br/v14n1/pt/abstract?short-communication+bn00814012014

Resumo: O registro de *Eurypanopeus depressus* (Smith, 1869) na costa do Rio Grande do Sul, Brasil (Decapoda:Xanthidae) levanta a hipótese de que a espécie pode ser invasora, devido a diferentes fontes de introdução como água de lastro. *E. depressus* foi coletada com rede de portas no estuário da Lagoa dos Patos. A discussão foca no fato de que a distribuição primária da espécie na América do Sul pode ter sido na costa uruguaia, tendo esta posteriormente se irradiado para locais próximos (Brasil e Argentina). Este trabalho estende a distribuição da espécie no hemisfério sul, já que previamente era citada somente para a Argentina e Uruguai.

Palavras-chave: *intervalo de distribuição, bioinvasão, ecologia, sistemática.*

Introduction

Eurypanopeus depressus, also known as the flat mud crab, or depressed mud crab, is common along the East and Gulf coasts of North America from Massachusetts to Florida and Texas. It lives in subtidal or intertidal oyster beds, and has been reported from depths ranging from 1 to 27 meters (Grant & McDonald 1979, Sulkin et al. 1983, Williams 1984). The species is also found in the Dutch West Indies and Bermuda and, in South America, *Eurypanopeus depressus* has been recorded in Uruguay and Argentina, with the latter record from Mar Chiquita, a warm-temperate coastal lagoon south of Rio de la Plata, Its occurrence in South America is probably due to introduction (Williams 1984, Spivak & Luppi 2005, Tavares 2011).

This study presents information about the presence of *E. depressus* in the Patos Lagoon Estuary (Brazil), one of the biggest lagoons in the world, and discusses the role of ballast water in transporting species, and other ways of introduction.

Material and methods

Specimens presented in this article were collected during several projects of the "Laboratório de Crustáceos Decápodos", from 1980 through 2012, and the general sampling method consisted of a 5-minute tow using an otter-trawl net, with 13 mm distance between opposite knots, towed at an average speed of 2.0 knots. Sampling locations included the "Saco da Mangueira" inlet, on the Patos Lagoon Estuary (Rio Grande do Sul, Brazil), the "Ilha dos Marinheiros" island and the breakwater that marks the entrance to the estuary. Specimens were identified using the descriptions published by Rathbun (1930), and reviewed by Williams (1984). Ryan (1965) describes an alcohol persistent red spot in the inner surface of the ischium of the third maxillipeds of both sexes as a recognition character, but it is also present on *Panopeus herbstii* H.Milne Edwards 1834 (Williams 1984). The analyzed material is currently deposited in the scientific collection of the "Laboratório de Crustáceos Decápodes" laboratory, at the

http://dx.doi.org/10.1590/S1676-06032014006313

Oceanographic Institute of the University of Rio Grande (FURG).

Results

Systematics
Section Eubrachyura Saint Laurent, 1980
Subsection Heterotremata Guinot, 1977
Infraorder Brachyura Linnaeus, 1758
Family Panopeidae Ortmann, 1893
Subfamily Panopeinae Ortmann, 1893
Eurypanopeus depressus (Smith, 1869) (Fig. 1)

Sinonym: Williams 1984, Nizinski 2003, Spivak & Luppi 2005;

Distribution: Massachusetts Bay through Florida, to southern Texas; "Dutch West Indies" (now Netherlands Antilles), Bermuda, Uruguay, Mar Chiquita on Argentina and Patos Lagoon estuary, Brazil (Juanicó 1978, Williams 1984, Spivak & Luppi 2005, present study).

Material Examined: BRAZIL, Rio Grande do Sul, Lagoa dos Patos. "Molhe Oeste": 5 males (CW 6.34, 7.44, 6.94, 7.83 and 6.92), 8 females (CW 8.67, 8.24, 5.47, 8.09, 7.30, 7.24, 5.91 and 7.29), 13/III/1985, coll. Capitoli, P.R. (FURG - **2990**). Rio Grande do Sul, Lagoa dos Patos. "Molhe Leste": 2 males (CW 7.72 and 5.38), 1 female (CW 7.30), 12/V/1985, coll. Capitoli, P.R. (FURG - **3143**). Rio Grande do Sul, Lagoa dos Patos. "Saco da Mangueira" inlet: 1 male (CW 14.88), 11/V/1999 (FURG - **2792**). Rio Grande do Sul, Lagoa dos Patos. "Saco da Mangueira" inlet: 1 female (CW 6.01), 12/V/1999 (FURG-**2782**). Rio Grande do Sul, Lagoa dos Patos. "Saco da Mangueira" inlet: 1 male (CW 12.21), 15/VII/1999 (FURG-**2973**). Rio Grande do Sul, Lagoa dos Patos. "Saco da Mangueira" inlet: 1 female (CW 8.08), 15/VII/1999 (FURG-**3035**). Rio Grande do Sul, Lagoa dos Patos. "Ilha dos Marinheiros" island: 2 males (CW 11.3, 3.9), 13 females (CW 4.1, 4.2, 4.5, 3.5, 4.5, 5.3, 5.4, 3.4, 6.1, 5.1, 5.5, 3.4, 2.6) 04/VI/2012, coll. Rodrigues, M.A. (FURG-**3289**).

Description (Williams 1984): Carapace transversely oval, approximately 3/4 as long as wide, flattened posteriorly, slightly convex in anterior half; aerolations well defined, finely granulate, with several pairs of transverse rows of granulations. Anterolateral teeth 4, outer margins curved granulate; first 2 teeth coalesced to form broad lobe with slightly sinuate margin; third tooth blunt or spine tipped; fourth and fifth spine tipped, pointing obliquely upward and forward. Front nearly straight, median notch small or absent. Chelipeds dissimilar and quite unequal. Smaller one more rugose than larger and with margin of fingers nearly straight and completely closing for considerable distance distally, opposed margins of tips thin edged and hollowed out - "spoon shaped". Larger chelipeds with nearly smooth articles, hand heavy and inflated; dactyl strongly curved, obscurely toothed at base and meeting fixed finger only at tip; internal tooth of carpus tipped with small spinule; in unworn condition both fingers show indication of possible flattening.

Discussion

The primary citation for *E. depressus* in the southern hemisphere is the work of Juanicó (1978), where the author indicates that although surprising, there is no doubt on the identification of the species, reported on the northern shores of the Rio de la Plata, from Montevideo to Piriápolis, Uruguay. More than an expansion of distribution, this can be interpreted as a record of a new geographic locality. The occurrence in the Patos Lagoon indicates that the La Plata River, which has been considered as a significant biogeographical barrier on the southwest Atlantic coast, might have allowed the expansion of the range of the species, possibly through larval transport due to advances from the river plume northward (Pimenta et al. 2008).

Although the species has been reported for Mar Chiquita in 2005 (Spivak & Luppi 2005), the specimens examined for this study were sampled from 1985 through 2012. From its primary distribution in Uruguay, it is possible that *E. depressus* had

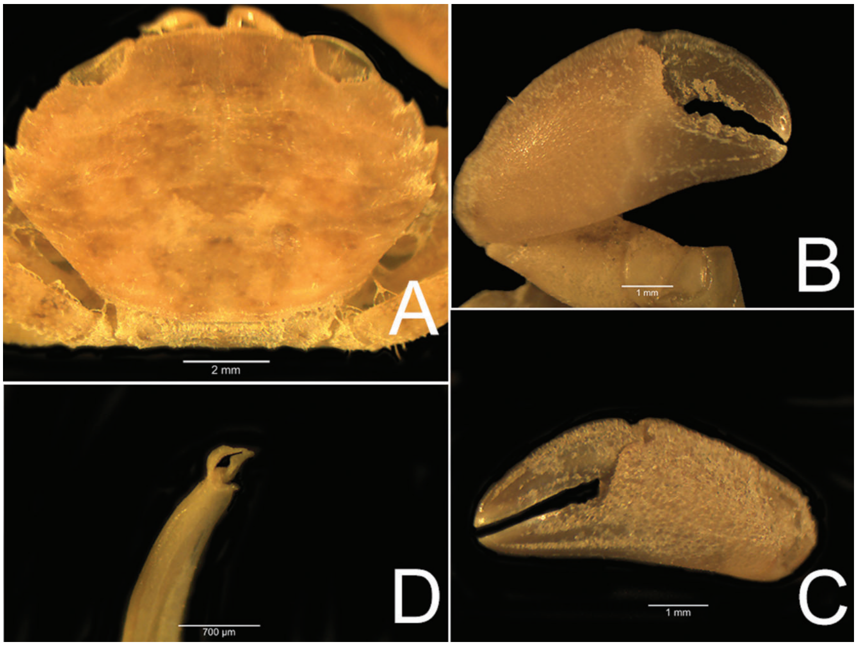

Figure 1. *Eurypanopeus depressus* (Smith, 1869). Male LCD n° 3289 A: dorsal view; B: right pereopod (ventral view); C: left pereopod (ventral view); D: right gonopod. Scales are indicated.

been collected later in Argentina than in the Patos Lagoon Estuary due to sampling efforts. Individuals collected by Juanicó (1978) are from 1954, prior to the sampling of the present article, and also from individuals collected on Argentina (Luppi et al. 2003).

The Patos Lagoon estuary can act as a barrier to the distribution of *E. depressus* to the north because of its conformation, with a high volume of freshwater discharged through the estuary mouth. Considered a ''strangled'' lagoon, the Patos Lagoon covers an area of 10.360 km^2, with an average depth of 15 m and width of 800 m forming a huge body of water with only one opening to the sea, (32°04′17″S - 052°07′52″W) (Kjerfve 1986). Intense seaport movement from cargo shipping raises the problem of ballast water transport (Seeliger & Costa 1997).

The species had been reported to the coast of Bahia in the 1980's (Gouvêa & Leite 1980, Gouvêa 1986), but the identification is considered invalid, until consistent evidence is provided, as reported by Almeida & Coelho (2008), which adds to this the fact that the individuals listed for the location are not available for reanalysis. The authors herein consider this citation as the first for the Brazilian coast.

New occurrences of species around the world have been well documented, and new territories are often reached by ''doors'' that are opened on determined biogeographic barriers, or by ship's ballast water transport. Most often this transport includes larvae, resistance eggs or juveniles, with the latter being the main source of species distribution changes on present days (Carlton & Geller 1993, D'Incao & Martins 1998).

Tavares (2011) suggests that the presence of *E. depressus* may be anthropogenic, because of the disjunct occurrence both in Argentina and in Uruguay. The species is commonly associated with oyster farms and artificial reefs (Williams 1984), but this does not explain the occurrence reported here, because there is no oyster culture on the Patos Lagoon estuary, as in the aforementioned countries. One of the possible explanations is introduction via ships ballast water. High-volume of industrial sea-faring ship traffic has been responsible for the range expansion of several species of Brachyura, including *Rhithropanopeus harrisii* (Gould, 1865) *Carcinus maenas* (L.) and *Charybdis hellerii* (Milne Edwards, 1867) (D'Incao & Martins 1998, Ferreira et al. 2001, Tavares 2011, Briski et al. 2012).

The definitive cause for the distribution of this species still remains unknown, but it can be speculated that water transport by ships may play a role on in its presence, since it is an effective dispersal method for aquatic organisms, and may have influenced the current geographic distribution of this species.

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References

ALMEIDA, A.O. & COELHO, P.A. 2008. Estuarine and marine brachyuran crabs (Crustacea: Decapoda) from Bahia, Brazil: checklist and zoogeographical considerations. Lat. Am. J. Aquat Res. 36(2):183-222. doi: http://dx.doi.org/10.3856/vol36-issue2-fulltext-4

BRISKI, E., GHABOOLI, S, BAILEY, S.A. & MACISAAC, H.J. 2012. Invasion risk posed by macroinvertebrates transported in ships' ballast tanks. Biol. Inv. 14:1843-1850. doi: http://dx.doi.org/10.1007/s10530-012-0194-0

CARLTON, J.T. & GELLER, J. 1993. Ecological roulette: the global transport and invasion of nonindigenous marine organisms. Science 261:78-82. doi: http://dx.doi.org/10.1126/science.261.5117.78

D'INCAO, F. & MARTINS, S.T.S. 1998. Occurrence of *Rhithropanopeus harrisii* (Gould, 1841) in the Southern Coast of Brazil (Decapoda, Xanthidae). Nauplius 6:191-194.

FERREIRA, A.C., SANKARANKUTY, C., CUNHA, I.M.C., & DUARTE. F.T. 2001. Yet another record of *Charybdis hellerii* (Milne Edwards, 1867) (Crustacea, Decapoda) from the Northeast of Brazil. Rev. Bras. Zool. 18(1):357-358. doi: http://dx.doi.org/10.1590/S0101-81752001000500034

GOUVÊA, E.P. & LEITE Y.M. 1980. A Carcinofauna do Fital da *Halimeda opuntia* (Linnaeus) Lamoroux e a variação sazonal de sua densidade. Cienc. Cult. 32(5):596-600.

GOUVÊA, E.P. 1986. A Carcinofauna do Litoral Rochoso de Salvador, BA, e Alguns Aspectos Ecológicos. Cienc. Cult. 38(2):346-355.

GRANT J. & MCDONALD. J. 1979. Dessication tolerance of *Eurypanopeus depressus* (Smith) (Decapoda: Xanthidae) and the exploitation of microhabitat. Estuaries 2:172-177. doi: http://dx.doi.org/10.2307/1351731

JUANICÓ, M. 1978. Ampliación de la distribución geográfica de tres especies de Brachyura. Iheringia Ser. Zool. 51:45-46.

KJERFVE, B. 1986. Comparative Oceanography of Coastal Lagoons. In Estuarine variablity (D.A.Wolfe, ed.) Academic Press, New York, p.63-81.

LUPPI, T.A., BAS, C C. & SPIVAK, D. 2003. The effect of temperature and salinity on larval development of *Armases rubripes* Rathbun, 1897 (Brachyura, Grapsoidea, Sesarmidae) and the southern limit of its geographical distribution. Estuar. Coast. Shelf Sci. 58:575-585. doi: http://dx.doi.org/10.1016/S0272-7714(03)00136-7

NIZINSKI, M. S. 2003. Annotated checklist of decapod crustaceans of Atlantic coastal and continental shelf waters of the United States. Proc. Biol. Soc. Wash. 116(1):96-157.

PIMENTA, F., GARVINE, R.W. & MÜNCHOW, A. 2008. Observations of coastal upwelling off Uruguay downshelf of the Plata estuary, South America. J. Mar. Res. 66:835-872. doi: http://dx.doi.org/10.1357/002224008788064577

RATHBUN, M. J. (1930). ''The cancroid crabs of America.'' Bull. United States Nat. Mus. 152:1-608. doi: http://dx.doi.org/10.5479/si.00963801.78-2851.1

RYAN, E.P. 1956. Observations on the life histories and the distribution of the Xanthidae (mud crabs) of Chesapeake Bay. Am. Midl. Nat. 56:138-162. doi: http://dx.doi.org/10.2307/2422450

SEELIGER, U. & COSTA, C.S.B. 1997. Natural and Human Impact. In Subtropical Convergence Environments: The Coast and Sea in the Southwestern Atlantic (U. Seeliger, C. Odebrecht & J.P. Castello, eds.). Springer, p.197-204.

SPIVAK, E. D. & LUPPI. T.A. 2005. Southern range extension of two western Atlantic intertidal mud crabs: *Panopeus meridionalis* Williams, 1984 and *Eurypanopeus depressus* Smith, 1869 (Crustacea: Brachyura: Panopeidae) in Argentinian waters. Proc. Biol. Soc. Wash. 118(3):551-557. doi: http://dx.doi.org/10.2988/0006-324X(2005)118[551:SREOTW]2.0.CO;2

SULKIN SD, VAN HEUKELEM W.F. & KELLY, P. 1983. Behavioral basis of depth regulation in hatching and post-larval stages of the mud crab *Eurypanopeus depressus*. Mar. Ecol. Prog. Ser. 11:157-164. doi: http://dx.doi.org/10.3354/meps011157

TAVARES M. 2011. Alien decapod crustaceans in the Southwestern Atlantic Ocean. In In the wrong place - alien marine crustaceans: distribution, biology and impacts (B.S. Galil, P.F. Clark & J.T. Carlton eds.) Invading Nature - Springer Series in Invasion Ecology 6:251-268.

WILLIAMS, A.B. 1984. Shrimps, Lobsters and Crabs of the Atlantic Coast of the Eastern United States, Maine to Florida. Smithsonian Institution, Washington.

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Zooplankton (Copepoda, Rotifera, Cladocera and Protozoa: Amoeba Testacea) from natural lakes of the middle Rio Doce basin, Minas Gerais, Brazil

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BARBOSA, P.M.M., MENENDEZ, R.M., PUJONI, D.G.F., AOKI, A., BARBOSA, A.R. **Zooplankton (Copepoda, Rotifera, Cladocera and Protozoa: Amoeba Testacea) from natural lakes of the middle Rio Doce basin, Minas Gerais, Brazil.** Biota Neotropica. 14(1): e20134040. http://www.biotaneotropica.org.br/v14n1/en/abstract?inventory+bn00414012014

Abstract*:* A list of zooplankton species identified during ten years of studies in the lake system of the middle Rio Doce basin is presented. This lake system integrates the Atlantic Forest biome, a biodiversity hotspot. Three types of studies were achieved by the Brazilian Long Term Ecological Research Program (Brasil-LTER/PELD-UFMG site 4): i) a temporal study (study 1) which sampled four lakes monthly and three lakes twice a year during ten years; ii) a comparative study of limnetic and littoral species composition (study 2) and iii) a spatial study (study 3) that evaluated the species composition of eighteen lakes (eight lakes inside the Rio Doce State Park (RDSP) and ten lakes in its surrounding area) during one year with quarterly sampling. A total of 354 taxa were identified out of which 175 belong to the Rotifera, 95 to the Protozoa (Amoeba Testacea), 55 to Cladocera and 25 to Copepoda. Although many identified species where common in tropical environments, we present new records for the Middle Rio Doce basin. The group of lakes outside the RDSP showed higher exclusive species compared to lakes inside the RDSP. This pattern may be due to higher disturbance intensity and frequency to which the lakes outside RDSP are subjected, being an important factor affecting community structure. These aquatic ecosystems presents more than half of the zooplankton species registered for the Minas Gerais State and is, undoubtedly, one of the Brazil's priorities for conservation, sustaining high diversity in a very small, limited and threatened region.

Keywords: Species list, Atlantic Forest, Freshwater.

BARBOSA, P.M.M., MENENDEZ, R.M., PUJONI, D.G.F., AOKI, A., BARBOSA, A.R. **Zooplâncton (Copepoda, Rotifera, Cladocera and Protozoa: Amoeba Testacea) de lagos naturais do trecho médio da bacia do Rio Doce, Minas Gerais, Brasil.** Biota Neotropica. 14(1): e20134040. http://www.biotaneotropica.org.br/v14n1/pt/abstract?inventory+bn00414012014

Resumo: Uma lista das espécies de zooplâncton identificadas durante dez anos de estudos no sistema de lagos do médio Rio Doce é apresentada. Este sistema de lagos faz parte do bioma da Mata Atlântica, um hotspot de biodiversidade. Três tipos de estudos foram conduzidos pelo Programa de Pesquisas Ecológicas de Longa Duração (PELD-UFMG site4): i) um estudo temporal, que amostrou quatro lagoas mensalmente e três lagoas semestralmente durante dez anos; ii) um estudo comparativo entre a composição de espécies da região limnética e litorânea e iii) um estudo espacial que avaliou a composição de espécies de dezoito lagoas (oito dentro dos limites do Parque Estadual do Rio Doce (PERD) e dez na sua região do entorno) durante um ano com amostragens trimestrais. Um total de 354 taxa foram identificados sendo 175 pertencentes a Rotifera, 95 a Protozoa (Amoeba Testacea), 55 a Cladocera e 25 a Copepoda. Embora muitas espécies identificadas sejam comuns a ambientes tropicais, são apresentados novos registros para a bacia do Médio Rio Doce. O grupo de lagos fora do PERD apresentou uma maior riqueza exclusiva comparado ao grupo de lagoas dentro do PERD. Este padrão pode ser devido a maiores frequência e intensidade de distúrbios aos quais as lagoas fora do PERD estão sujeitas, já que este é um fator importante que afeta a estruturação de comunidades. Este ecossistema aquático apresenta mais da metade das espécies de zooplâncton já registradas para o Estado de Minas Gerais e é, sem dúvida, uma das prioridades do Brasil para a conservação, sustentando uma alta diversidade em uma região muito pequena, limitada e ameaçada.

Palavras-chave: Lista de espécies, Mata Altântica, Água Doce.

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Introduction

Brazil is known as the most mega diverse country (Myers et al. 2000). The Atlantic Forest is classified as a biodiversity hotspot, as it is one of the most deforested and threatened amongst the Brazilian biomes that still maintains a high species diversity (Fonseca 1985, Mittermeier et al. 1998). Furthermore, inland waters have become critical ecosystems for conservation, since they bear a high biodiversity in confined spaces, threatened by humanity's need for water (Dudgeon et al. 2006). The middle Rio Doce lake system is a lacustrine complex formed by c. 300 natural water bodies amidst the Atlantic Forest biome. Considering its regional importance, in 1944, a state decree created the Rio Doce State Park (RDSP) which is the largest continuous Atlantic Forest fragment in Minas Gerais state, recently incorporated to the Ramsar sites for preservation of wetlands (RAMSAR 2010).

Despite having its integrity protected by law, Gontijo & Britto (1997) identified 26 types of human impacts occurring both internally and externally to the Park's boundaries. Among the impacts within the park the illegal hunting and fishing, introduction of exotic species (mollusks, fishes and even a primate) and tourism on the shore grounds of Lake Dom Helvécio deserve special attention. Concerning the latter, some modifications in the species abundance and functioning were related to anthropic interferences (Maia-Barbosa et al. 2010). Some examples of impacts in the vicinity of the Park, which have been cited by the authors, are the extensive Eucalyptus spp. monocrops - mainly used as charcoal in the steel plants - the extensive farming and abandoned pasture lands, and a fast growing urbanization that produces sewage and garbage which, not rarely, reaches the Park limits.

Since the 1970's, the plankton diversity of this lake system has been cataloged (e.g. Barbosa & Tundisi 1980). After the implementation of the LTER program in November 1999 (LTER/PELD-UFMG site 4), samplings became systematic until late 2010. The Brazilian site 4 ILTER project aims to evaluate the impacts of anthropogenic activity on local and regional biodiversity assuming that the RDSP has been threatened mainly by two factors: forest fragmentation and introduction of exotic species.

With the objective to catalog the existing zooplankton biodiversity of the middle Rio Doce lake system, we present in this study the limnologic features and the species list of the zooplankton community of eighteen lakes (eight inside the RDSP and ten in its surrounding). The objective was assessed with three interrelated studies conducted in site 4 by the ILTER/PELD program:

Study 1: Long term (1999-2009) monitoring of limnological variables and plankton community in the limnetic region of seven lakes;

Study 2: Plankton studies conducted in the littoral zone of two lakes with samplings during rainy and dry periods;

Study 3: Large spatial scale monitoring of limnological variables and plankton community in the limnetic region of eighteen lakes with quarterly samplings during one year.

Material and Methods

1. *Study site*

The naturally barred lake system is located in the middle part of the Rio Doce basin (19°29'24" S - 19°48'18" S, 42°28'18" W - 42°38'30" W) and was formed by tectonic and sedimentary mechanisms during late Pleistocene (Mello et al. 1999) (Figure 1). The region has a marked seasonality exhibiting two distinct periods: the dry period (May-August), with low temperature and precipitation and the rainy period (September to April), with high values of temperature and precipitation, allowing to classify the region as tropical semi-humid with mesothermal characteristics (Tundisi 1997). The lakes within the RDSP are currently protected from recent human impacts, despite still suffering with past impacts such as the introduction of exotic fish species (Latini & Petrere 2004). Most lakes outside the park had their surrounding natural forests replaced by Eucalyptus spp. plantations and some lakes are used for recreation, fishing clubs and local projects for net cage fish cultures (e.g. Jacaré and Verde lakes).

2. *Data Collection and Analysis*

The zooplankton community was sampled at a fixed point in the pelagic zone filtering 200 liters of lake water through a 68 µm plankton net using a hydraulic pump at depths defined by the Secchi disk assumed as corresponding to 10% of incident light (Cole, 1983). In shallow lakes (depth < 3m) samples were collected at the sub-surface, at the Secchi depth and at 0.5 m from the bottom. For the study in the littoral region of Patos lake ten liters of water were filtered through a 45 µm plankton net with a bucket. Different macrophyte banks were evaluated and six samples were collected two meters distant from each other along a transect parallel to the lake's margin (Table 1). The littoral region of Dom Helvécio lake was also sampled and the results presented by Maia-Barbosa et al. (2008). All collected samples were immediately transferred into plastic bottles, stained with rose bengal and preserved with 4% neutral formaldehyde solution. The identification of the species was made under a light microscope at 200x to 1000x magnification, referring to the relevant taxonomic literature (e.g. Koste 1978, Koste & Robertson 1983, Reid 1985, Matsumura-Tundisi 1986, Dussart 1987, Segers 1995, Segers & Dumont 1995, Smirnov 1996, Elmoor-Loureiro 1997, Rocha 1998, Gomes-Souza 2008, checked for synonyms and redescriptions).

Water temperature, dissolved oxygen and pH were measured each time with a multiprobe Horiba U-22 sensor. Water samples were also collected for total phosphorus quantification, according to Mackereth et al. (1978). The samplings were authorized by the Minas Gerais State Forest Institute (IEF-MG, license number 005/07).

Using data from study 3, where the sample effort was the same for all 18 lakes (4 months and 3 depths = 12 samples), we calculated the 95% percentile confidence interval for the medians of total phosphorus by nonparametric bootstrap with 10000 replications (Efron

& Tibshirani 1993). Sample-Based Rarefaction Curves were also constructed with biological data from study 3 using the exact calculations of the average and standard deviation of species richness for combinations of samples (Gotelli & Cowell 2001)

The zooplankton samples are stored in the Laboratório de Limnologia, Ecotoxicologia e Ecologia Aquática of the Instituto de Ciências Biológicas of the Universidade Federal de Minas Gerais, Brazil.

Results and discussion

The sampled lakes in this study are listed in Table 2 with geographic coordinates and some lake characteristics. The identified species list is presented in Table 3. Concerning the data from study 3 and according to trophic index limits based on total phosphorus concentration proposed by Lamparelli (2004), the majority of the lakes were classified as mesotrophic although some exhibit tendency to eutrophy such as lakes Pimenta, Santa Helena, Barra,

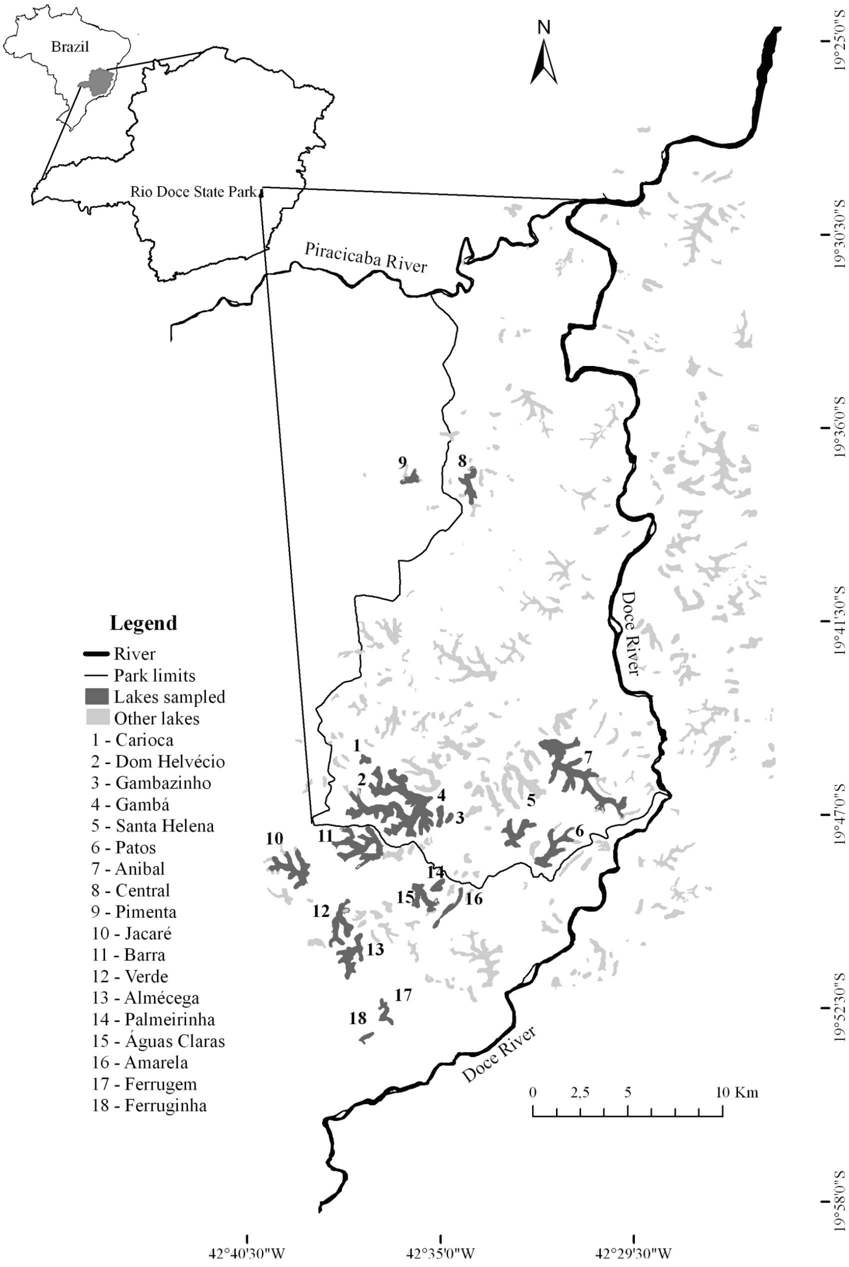

Figure 1: The lake system of the middle Rio Doce basin. The sampled lakes are shaded.

Table1: Methodologies used in the three types of studies conducted in lakes of the RDSP and surroundings.

Study	Sampled lakes	Lake Compartment	Month/Year	Sampling frequency	Methodology	Evaluated groups
Temporal Sampling (Study 1)	Carioca (CA) and Dom Helvécio (DH)	Limnetic	From January 2001 to December 2010	Monthly	200 liters filtered with a 68 µm plankton net	Copepoda, Rotifera and Cladocera
	Gambazinho (GN) and Jacaré (JA)		From January 2002 to December 2010			
	Águas Claras (AC) and Palmeirinha (PA)		From January 2002 to December 2010	Bimonthly		Copepoda, Rotifera, Cladocera and Amoeba Testacea
	Amarela (AM)					
Littoral and Limnetic comparison (Study 2)	Patos (PT)	Littoral and Limnetic	August 2008 and January 2009	Seasonal	12 sampling points in the littoral, 10 liters filtered with a 45 µm plankton net. One sampling point in the limnetic region, vertical tow with a 45 µm plankton net.	Copepoda, Rotifera, Cladocera and Amoeba Testacea
Spatial Sampling (Study 3)	Lakes within DRSP: Aníbal (AN), Carioca (CA), Central (CE), Dom Helvécio (DH), Gambá (GA), Gambazinho (GN), Patos (PT) and Santa Helena (SH). Lakes outside DRSP: Águas Claras (AC), Almécega (AL), Barra (BA), Ferrugem (FE), Ferruginha (FN), Jacaré (JA), Palmeirinha (PA), Pimenta (PI) and Verde (VE)	Limnetic	August and November 2007 and February and May 2008	Quaterly	200 liters filtered with a 68 µm plankton net	Copepoda, Rotifera and Cladocera

Table 2: Lakes' initials, names, geographic coordinates of sampling points, altitude, lakes' area, margin development index (DL), mean depth at the sampling point in the four periods sampled in study 3 (August and November 2007 and February and May 2008) and lake location in relation to Rio Doce State Park boundaries.

Lake initials	Lake name	Sampling point coordinates	Sampling point altitude (m)	Lake area (Km^2)	DL	Mean depth at the sampling point (m)	Location according to RDSP limits
AC	Águas Claras	S 19º 49´06,9´´ W 042º 35´42,5´´	254	0.62	2.24	9.1	Outside
AL	Almécega	S 19º 51´25,4´´ W 042º 37´31,9´´	268	0.92	2.44	6.4	Outside
AM	Amarela	S 19º 49´23,1´´ W 042º 34´28,7´´	250	0.20	1.82	1.9	Outside
AN	Aníbal	S 19º 46´47,1´´ W 042º 29´54,5´´	237	2.75	4.29	5.1	Inside
BA	Barra	S 19º 48´11,1´´ W 042º 37´43,6´´	249	1.12	3.45	6.4	Outside
CA	Carioca	S 19º 45´26,0´´ W 042º 37´06,2´´	270	0.12	1.28	9.4	Inside
CE	Central	S 19º 37´39,0´´ W 042º 34´12,5´´	264	0.51	2.03	4.5	Inside
DH	Dom Helvécio	S 19º 46´55,7´´ W 042º 35´28,9´´	257	3.81	4.93	27.5	Inside
FE	Ferrugem	S 19º 52´39,0´´ W 042º 36´34,3´´	270	0.34	2.01	3.3	Outside
FN	Ferruginha	S 19º 53´17,5´´ W 042º 36´59,4´´	273	0.13	1.61	3.9	Outside
GA	Gambá	S 19º 47´15,1´´ W 042º 35´01,0´´	209	0.23	1.40	11.0	Inside
GN	Gambazinho	S 19º 47´07,7´´ W 042º 34´45,5´´	260	0.09	1.13	9.3	Inside
JA	Jacaré	S 19º 48´37,8´´ W 042º 38´57,0´´	269	1.05	2.90	7.6	Outside
PA	Palmeirinha	S 19º 49´41,8´´ W 042º 36´25,4´´	271	0.20	1.28	5.6	Outside
PI	Pimenta	S 19º 37´27,4´´ W 042º 35´44,3´´	263	0.22	1.63	3.1	Outside
PT	Patos	S 19º 48´19,9´´ W 042º 32´12,7´´	257	0.86	2.83	7.3	Within
SH	Santa Helena	S 19º 47´48,8´´ W 042º 33´04,7´´	262	0.68	2.42	9.0	Inside
VE	Verde	S 19º 49´55,2´´ W 042º 37´54,1´´	274	0.75	2.29	11.3	Outside

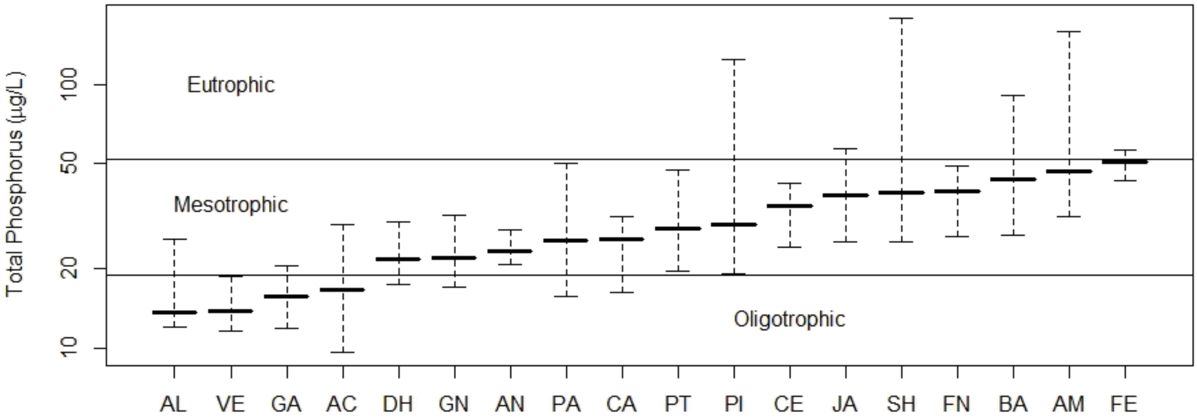

Figure 2: Median and 95% percentilic interval (whiskers) of the total phosphorus concentration median in the 18 lakes.

Amarela and Ferrugem (Figure 2). Only lake Verde was considered strictly oligotrophic. Water temperature has an amplitude of 10°C between dry and rainy periods (from 22°C to 32°C, respectively), dissolved oxygen concentrations showed a mean of 5.8 mg/L, varying from 9.4 mg/L in the sub-surface to complete anoxia at some depths greater than five meters and pH varied between 8.6 and 5. The lakes' area varied from 0.09 to 3.81Km^2 with a mean of 0.81Km^2 (Table 2).

In a large sample effort Tundisi & Saijo (1997) evaluated the zooplankton biodiversity of 13 lakes of this system in November 1985 and July 1987. The authors reported 16 species of Rotifera, 9 of Cladocera and 7 of Copepoda. Moreto (2001) evaluated the limnetic and littoral region of 5 lakes of this system and identified 39 species of Rotifera, 13 of Cladocera and 4 of Copepoda. Considering the three studies described in our study, a total of 354 zooplankton species were identified out of which 175 belonging to Rotifera, 55 to Cladocera, 25 to Copepoda and 95 to Protozooa (Amoeba Testacea) (Table 3). The species Itura aurita (Ehrenberg, 1830), Ploesoma truncatum (Levander, 1894), Biapertura affinis (Alona ossiani Sinev, 1998) and Brachionus caudatus Barrois & Daday, 1894 were reported only by Moreto (2001). Argyrodiaptomus furcatus (Sars, 1901) and Scolodiaptomus corderoi Wright, 1936 were recorded in lake Dom Helvécio in the 80's by Tundisi & Saijo (1997), but these species have never been reported since that time, being considered locally extinct, probably due to non-native fish species introduction (Pinto-Coelho et al. 2008). The other species cited only by Tundisi & Saijo (1997) and Moreto (2001) are considered synonyms, redescriptions or misidentifications as described hereafter. Mesocyclops brasilianus Kiefer, 1933 may be M. meridianus (Silva & Matsumura-Tundisi 2011) as both species are restricted to the southern hemisphere, despite the latter having a wider distribution (Silva 2008), Conochiloides caenobasis Skorikov, 1914 was redescribed as C. (Conochiloides) coenobasis (Skorikov, 1914), Monostyla bulla Gosse, 1851 as Lecane bulla (Gosse, 1851) and Brachionus patulus Müller, 1786 as Plationus patulus (Müller, 1786). Disparalona sp. may be Disparalona dadayi redescribed as Alonella dadayi Birge, 1910, Macrothrix laticornis (Jurine, 1820) may be Macrothrix squamosa Sars, 1901, a Neotropical species and Keratella quadrata may be K. tropica as both are cosmopolitan species although the former is restricted to cold climates (Segers & Smet 2008). The species Synchaeta stylata was cited by Moreto (2001) but in our study the individual was identified only until genus level. Lecane gillardi armata Koste, 1978 is a synonym for Lecane armata and Proales giganthea (Glascott, 1893) is probably a misidentification because this specie is not recorded in Neotropical regions. Alona quadrata is not a valid species so its report is considered as uncertain.

The checklist presented by the Project BIOTA/FAPESP in São Paulo state reported 277 Rotifera species from 90 water bodies, 12 Copepoda Calanoida species from 250 water bodies, 39 species of Copepoda Cyclopoida from 207 water bodies and 96 Cladocera species from 300 water bodies (Matsumura-Tundisi & Tundisi 2011, Silva & Matsumura-Tundisi 2011, Rocha et al 2011, Soares et al. 2011). In the upper Paraná River flood plain 541 species were reported from 36 aquatic environments from 2000 to 2007 (Lansac-Tôha,et al. 2009). Comparing the richness here reported we can see that the middle Rio Doce sustains high zooplankton diversity in a very small and limited region.

The dominance of rotifer species is a common pattern in most of the cited environments and can be explained by its typical opportunistic life history with parthenogenetic reproduction and short life cycles combined with the ability to produce eggs that survive desiccation, resulting in great resistance and resilience to disturbances (Allan 1976). Within the rotifers, four families contributed significantly to the species richness: Lecanidae, with 43 species of the genus Lecane, Brachionidae, with 22 species (8 species of Brachionus), Lepadellidae, with 21 species (14 Lepadella species) and Trichocercidae, with 17 Trichocerca species. Moreto (2001) also reported

Lecanidae and Brachionidae as the families with the largest number of species, although there was great contribution of other species. The following species were widespread, occurring in at least 15 of the 18 sampled lakes: Anuraeopsis spp. Brachionus angularis Gosse, 1851, B. falcatus Zacharias, 1898, B. mirus Daday, 1905, Keratella americana Carlin, 1943, Lecane bulla (Gosse, 1851), L. lunaris (Ehrenberg, 1832), Trichocerca pusilla (Jennings, 1903), Hexarthra intermedia (Wiszniewski, 1929), Conochilus spp., Ptygura libera Myers, 1934 and bdelloid rotifers. Most of these species are known to be cosmopolitan, and the association of Lecane, Brachionus, Keratella and Trichocerca is regarded as typical in tropical regions as well as the dominance of Brachionidae and Lecanidae families reported by other authors (Paggi & José de Paggi 1990, Bozelli 1992, Sendacz 1993, Bonecker et al. 1994, Lansac-Toha et al. 1997).

Bosmina tubicen Brehm, 1953 and Diaphanosoma birgei Korineck, 1981 were the most common cladoceran species found in fifteen and fourteen lakes respectively. Among the copepods, Thermocyclops minutus (Lowndes, 1934) was present in all eighteen lakes and Notodiaptomus isabelae (Wright S., 1936) wasn't recorded only in three lakes (Amarela, Pimenta and Santa Helena). The occurrence of two exotic species should also be noted: Kellicottia bostoniensis (Rousselet, 1908) (Rotifera) and Mesocyclops ogunnus Onabamiro, 1957 (Copepoda), but these species were recorded only once and may not have established themselves.

The protozoan group was represented by 95 Testacea species and 4 ciliates species, although no specific sampling procedure was employed. The recorded species were collected in littoral zones of two lakes (Dom Helvécio and Patos) and in Amarela lake. Difflugidae, with 39 species (26 Difflugia species) and Arcellidae, with 22 species (15 Arcela species) were the families with the highest richness. Compared with the checklist provided by Regali-Seleghim et al. (2011), where 84 taxa of Testacea were reported from 75 aquatic environments in São Paulo state, the richness reported in our work is very expressive and it might be underestimated because only three lakes were evaluated. Lake Amarela alone had a richness of 74 species, with predominance of Difflugia (21 species), Arcella (15 species) and Centropyxis (13 species). The families of these three genera are described as dominant in littoral environments.

Considering the results from study 3, where the 18 lakes were sampled with the same effort, from a total of 95 identified taxa, 29 taxa were recorded only in lakes outside the park limits and 7 taxa were recorded only in lakes inside the park limits. This greater richness of the group of lakes outside the park can be clearly visualized with Sample-Based Rarefaction Curves plot (Figure 3). Most of the exclusive richness found in lakes outside the park is due to Amarela lake, which is small and shallow (area < 30ha and depth < 3m) with a well-developed macrophyte community. But even if we remove Amarela lake from the outside group of lakes we can see that this group still has a higher richness compared to lakes inside the park (Figure 4). This pattern is probably due to higher disturbance intensity and frequency to which the lakes outside the park limits are subjected, thus preventing lakes to reach a stable state where competitive exclusion may take place.

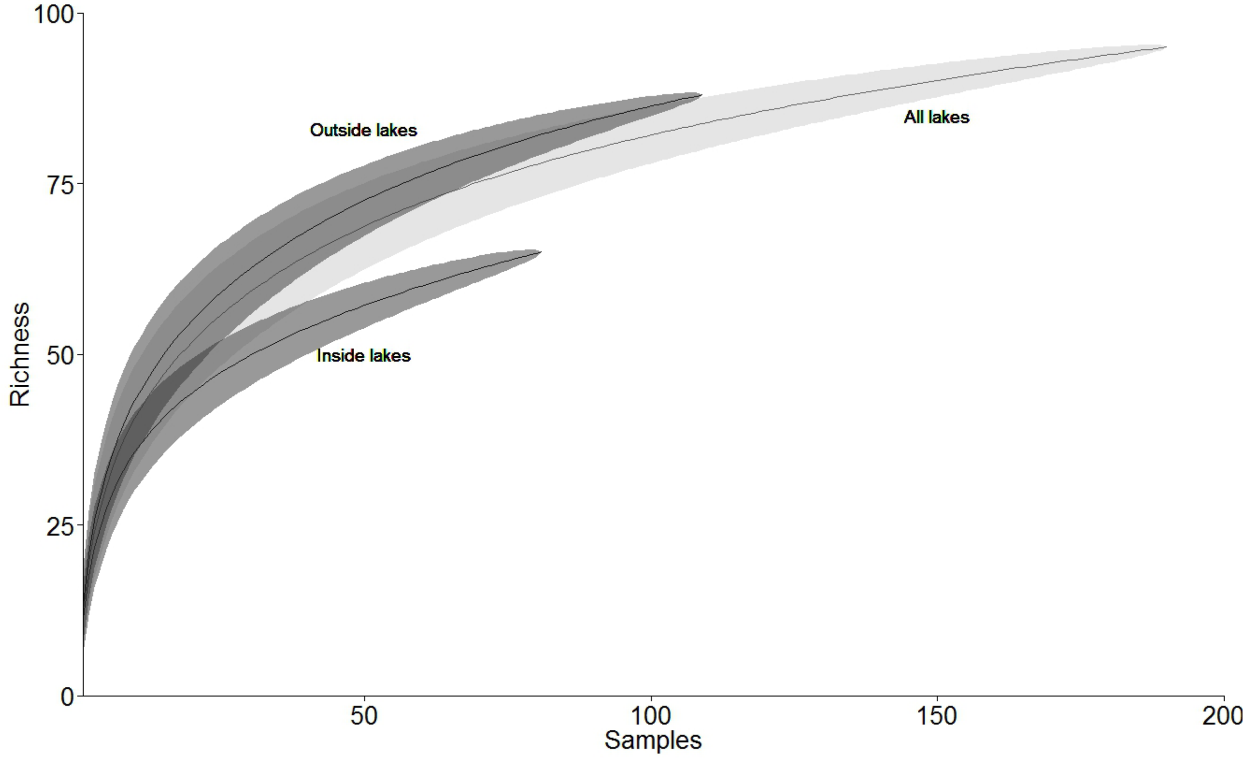

Figure3: Sample-Based rarefaction Curves with all the samples from study 3 (All lakes), and divided between lakes inside the

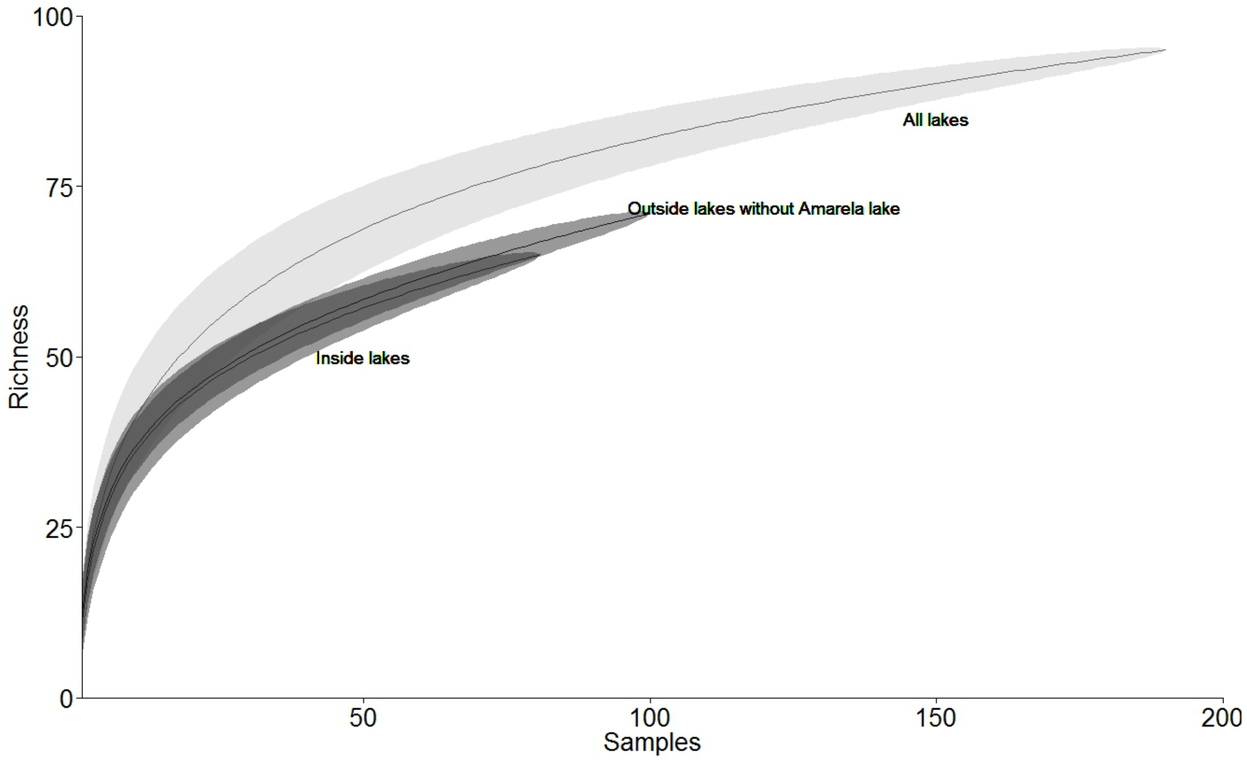

Figure4: Sample-Based rarefaction Curves with all the samples from study 3 (All lakes), and divided between lakes inside the RDSP (Inside lakes) and lakes outside the RDSP without Amarela lake (Outside lakes without Amarela lake).

Study 2, conducted in the littoral and limnetic regions of Patos lake included 41 new taxa to the previous species list for the region. The most representative group was Rotifera (21 species), followed by Amoeba Testacea (13 species), Cladocera (5 species) and Copepoda (2 species). The species Lepadella minoruoides Koste and Robertson, 1983, Ptygura furcillata (Kellicott, 1889) and Lecane eutarsa Harring and Myers, 1926 with previous records only in the Amazon Basin, were identified in the littoral region of Patos lake.

The comparison between different types of studies confirms the importance of long-term biodiversity studies. Regarding only the Copepoda, Cladocera and Rotifera species from the seven lakes sampled in study 1 (long-term monthly samples) and comparing them to the richness of the same seven lakes in study 3 (spatial sampling with quarterly samplings during one year), 77 species were common to both studies, 6 species were recorded only in study 3 and 127 species only in study 1. The importance of littoral zones must also be pointed out, since all new records for the state of Minas Gerais were identified in samples collected in this region.

An incomplete survey on the zooplankton diversity reported 551 zooplankton species for Minas Gerais state, 151 Protozoa, 300 Rotifera, 68 Cladocera, 30 Copepoda and 2 of insect larvae (Eskinazi-Sant'Anna et al. 2005) and another recent study updated the Cladocera group up to 94 species (Santos-Wisniewski 2010). Although these data show a substantial richness, they may be underestimated owing to the lack of information from some major basins of the state, such as Jequitinhonha, Paranaíba, and Grande and from some groups, such as Protozoa. The data published on Brazil's freshwater zooplankton biodiversity accounts for 457 Rotifera species (34% recorded in RDSP), 112 Cladocera species (49% recorded in RDSP) and 196 Copepoda species (13% recorded in RDSP) (Ismael et al. 1999). For the neotropical biogeographic region 682 Rotifera species (25% recorded in RDSP) are reported, 186 Cladocera species (29% recorded in RDSP) and 561 Copepoda species (4 % recorded in RDSP) (Boxshall & Defaye 2008, Forró et al. 2008, Segers 2008). The high richness of zooplankton species in RDSP lakes and surrounding region (less than 0.01% of Brazil's area) draws attention to regional as well as nationwide relevance of this system to aquatic biodiversity.

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References

ALLAN, J.D. 1976. Life history patterns in zooplankton. Am. Nat. 110:165-176.

BARBOSA, F.A.R.& TUNDISI, J.G. 1980. Primary production of phytoplankton and environmental characteristics of a shallow quarternary lake at Eastern Brasil. Arch. Hydrobiol. 90(2):139-161.

BONECKER, C.C., LANSAC-TÔHA, F.A. & STAUB, A. 1994. Qualitative study of rotifers in different environments of the High Paraná River flooplain (MS), Brazil. Revista Unimar 16:1-16.

BOXSHALL, G.A. & DEFAYE, D. 2008. Global diversity of copepods (Crustacea: Copepoda) in freshwater. Hydrobiologia. 595:195–207

BOZELLI, R.L. 1992. Composition of the zooplankton community of Batata and Mussurá Lakes and of the Trombetas River, State of Pará, Brazil. Amazoniana 12(2): 239–261.

COLE, G.A. 1983. Textbook of Limnology. The C.V. Mosby Company, St. Louis

DUDGEON, D., ARTHINGTON, A.H., GESSNER, M.O., KAWABATA, Z., KNOWLER, D., LÉVÊQUE, C., NAIMAN, R.J., PRIEUR-RICHARD, A.H., SOTO, D. & STIASSNY. M.L.J. 2006. Freshwater biodiversity: importance, threats, status, and conservation challenges. Biol. Rev. 81(2):163–182.

DUSSART, B.H. 1987. Sur quelques Mesocyclops (Crustacea, Copepoda) d'Amerique du Sud. Amazoniana 10:149-161.

EFRON, B. & TIBSHIRANI, R. 1993. An Introduction to the Bootstrap. Chapman & Hal. New York.

ELMOOR-LOUREIRO, L.M.A. 1997. Manual de Identificação de cladóceros límnicos do Brasil. Universa, Brasília.

ESKINAZI-SANT'ANNA, E.M., MAIA-BARBOSA, P.M., BRITO, S.L. & RIETZLER, A.C. 2005. Zooplankton Biodiversity of Minas Gerais State: a Preliminary Synthesis of Present Knowledge. Acta Limnol. Brasil. 17(2):199-218.

FONSECA, G.A.B. 1985. The vanishing Brazilian Atlantic forest. Biol. Conserv. 34(1):17-34.

FORRÓ, L., KOROVCHINSKY, N.M., KOTOV, A.A. & PETRUSEK, A. 2008. Global diversity of cladocerans (Cladocera; Crustacea) in freshwater. Hydrobiologia 595:177–184.

GOMES-SOUZA, M.B. 2008. Guia das Tecamebas – Bacia do Rio Peruaçu – Minas Gerais: subsídio para a conservação e monitoramento da Bacia do Rio São Francisco. Editora UFMG, Belo Horizonte.

GONTIJO, B. M. & BRITTO, C.Q. 1997. Identificação e classificação dos impactos ambientais no Parque Florestal Estadual do Rio Doce – MG. GEONOMOS. 5(2):43-48.

GOTELLI, N. & COLWELL, R.K. 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecol. Lett. 4:379-391

KOSTE, W. 1978. Rotatoria. Die Rädertiere Mitteleuropas. Ein Bestimmungswerk berg. Von Max Voigt. Überordnung Monogononta. Volume I-II. Gebruder Borntrager, Berlim

KOSTE, W. & ROBERTSON, B. 1983. Taxonomic studies of the Rotifera (Phylum Aschelminthes) from a Central Amazonian varzea lake, Lago Camaleão (Ilha de Marchantaria, Rio Solimões, Amazonas, Brazil). Amazoniana. 8(2):225-254.

LAMPARELLI, M.C. 2004. Graus de trofia em corpos d'água do Estado de São Paulo: avaliação dos métodos de monitoramento. Tese de Doutorado, Universidade de São Paulo, São Paulo.

LANSAC-TÔHA, F.A., BONECKER, C.C., VELHO, L.F.M. & LIMA, A.F. 1997. Comunidade zooplanctônica; In A planície de inundação do alto rio Paraná: aspectos físicos, químicos, biológicos e socioeconômicos (A.E.A.M. Vazzoler, A.A.Agostinho & N.S. Hahn, ed.). Editora da Universidade Estadual de Maringá, Maringá, p.117-155.

LANSAC-TÔHA, F.A, BONECKER, C.C, VELHO, L.F.M., SIMÕES, N.R., DIAS, J.D., ALVES, G.M. & TAKAHASHI, E.M. 2009. Biodiversity of zooplankton communities in the Upper Paraná River floodplain: interannual variation from long-term studies. Braz. J. Biol. = Rev. Bras. Biol. 69(Suppl 2):539-49. http://www.ncbi.nlm.nih.gov/pubmed/19738961.

LATINI, A.O. & PETRERE Jr, M. 2004. Reduction of native fish fauna by alien species: an example from Brazilian freshwater tropical lakes. Fisheries. Manag. Ecol. 11(2): 71-79.

MACKERETH, F.J.H., HERON, J. & TALLING, J.F. 1978. Water analysis. Freshwater Biological Association, Scientific Publication Nº 36,.Titus Wilson and Son, Kendal.

MAIA-BARBOSA, P.M., PEIXOTO, R.S. & GUIMARÃES, A.S. 2008. Zooplankton in littoral waters of a tropical lake: a revisited biodiversity. Braz. J. Biol. 68(Suppl 4):1069–1078.

MAIA-BARBOSA, P.M., BARBOSA, L.G., BRITO, S.L., GARCIA, F., BARROS, C.F.A., SOUZA, M.B.G., MELLO, N., GUIMARÃES, A.S. & BARBOSA, F.A.R. 2010. Limnological changes in Dom Helvécio Lake (South-East Brazil): natural and anthropogenic causes. Braz. J. Biol. = Rev. Bras. Biol. 70(3):795–802.http://www.scielo.br/scielo.php?pid=S1519-69842010000400010&script=sci_arttext.

MATSUMURA-TUNDISI, T. 1986. Latitudinal distribution of Calanoida Copepods in freshwater aquatic systems of Brazil. Braz. J. Biol. = Rev. Bras. Biol. 46(3):527-553.

MATSUMURA-TUNDISI, T. & TUNDISI, J.G. 2011. Checklist dos Copepoda Calanoida de água doce do Estado de São Paulo. Biota Neotrop. 11(1a): http://www.biotaneotropica.org.br/v11n1a/pt/fullpaper?bn0251101a2011+pt

MELLO, C.L., METELO, C.M.S., SUGUIO, K. & KOHLER, H.C. 1999. Quaternary sedimentation, neotectonics, and evolution of the Doce river middle valley lake system (southeastern Brazil). Revista do Instituto Geológico. 20:29–36.

MITTERMEIER, R.A., MYERS, N., THOMSEN, J.B.,FONSECA,G.A.B. da & OLIVIERI, S. 1998. Biodiversity hotspots and major tropical wilderness areas: approaches to setting conservation priorities. Conserv. Biol. 12:516-520.

MORETTO, E.M., 2001. Diversidade zooplanctônica e variáveis limnológicas das regiões limnética e litorânea de cinco lagoas do vale do Rio Doce-MG, e suas relações com o entorno. Dissertação de Mestrado.Universidade de São Paulo, São Carlos

MYERS, N., MITTERMEIER, R.A., MITTERMEIER, C.G., FONSECA, G.A.B da & KENT, J. 2000. Biodiversity hotspots for conservation priorities. Nature 403:853–858.

PAGGI, J.C., & JOSÉ DE PAGGI, S. 1990. Zooplâncton de ambientes lóticos e lênticos do rio Paraná médio. Acta Limnol.Brasil. 3:685-719.

PINTO-COELHO, R.M., BEZERRA-NETO, J.F., MIRANDA, F., MOTA, T.G., RESCK, R., SANTOS, A.M., MAIA-BARBOSA, P.M., MELLO, N.A.S.T., MARQUES, M.M., CAMPOS, M.O. & BARBOSA, F.A.R. 2008. The inverted trophic cascade in tropical plankton communities: impacts of exotic fish in the Middle Rio Doce lake district, Minas Gerais, Brazil. Braz. J. Biol. = Rev. Bras. Biol. 68:1025–37. http://www.ncbi.nlm.nih.gov/pubmed/19197473.

RAMSAR. 2010. The RAMSAR List of Wetlands of International Importance. Electronic Database accessible at http://www.ramsar.org/pdf/sitelist_order.pdf.

REID, J.W. 1985. Chave de identificação e lista de referências bibliográficas para as espécies continentais sulamericanas de vida livre da ordem Cyclopoida (Crustacea, Copepoda). Boletim Zoológico da Universidade de São Paulo. 9:17-143.

ROCHA C.E.F. 1998. New morphological characters useful for the taxonomy of the genus Microcyclops (Copepoda, Cyclopoida). J. Mar. Syst. 15:425–431.

ROCHA, O., SANTOS-WISNIEWSKI, M.J. & MATSUMURA-TUNDISI, T. Checklist dos Cladocera de água doce do Estado de São Paulo, Brasil. Biota Neotrop.11(1a):http://www.biotaneotropica.org.br/v11n1a/pt/abstract?inventory+bn0271101a2011.SANTOS-WISNIEWSKI,M.J.,MATSUMURA-TUNDISI, T., NEGREIROS, N.F., SILVA, L.C., SANTOS, R.M. and ROCHA, O. 2011. O estado atual do conhecimento da diversidade dos Cladocera (Crustacea, Branchiopoda) nas águas doces do estado de Minas Gerais. Biota Neotrop. 11(3): http://www.scielo.br/pdf/bn/v11n3/a24v11n3.pdf.

SEGERS,H.1995.Rotifera. The lecanidae (Monogononta). In Guides to the identification of the Microinvertebrates of the Continental Waters of the World (H.J. Dumont & T. Nogrady, ed.). SPB Academic Publishing, Amsterdam, The Netherlands.

SEGERS, H. 2008. Global diversity of rotifers (Rotifera) in freshwater. Hydrobiologia 595:49-59.

SEGERS, H. & DUMONT, H.J. 1995. 102+ rotifer species (Rotifera: Monogononta) in Broa reservoir (SP., Brazil) on 26 August 1994, with the description of three new species. Hydrobiologia 316(3):183 – 197.

SEGERS, H and SMET, W.H. 2008. Diversity and endemism in Rotifera: a review, and Keratella Bory de St Vincent. Biodivers. Conserv. 17:303-316.

SENDACZ, S. 1993. Distribuição geográfica de alguns organismos zooplanctônicos na América do Sul. Acta Limnol.Brasil. 6:31-41.

SILVA, W.M. 2008. Diversity and distribution of the free-living freshwater Cyclopoida (Copepoda: Crustacea) in the Neotropics. Brazil. Braz. J. Biol. = Rev. Bras. Biol. 68:1099-1106.

SILVA, W.M. & MATSUMURA-TUNDISI, T. 2011. Checklist dos Copepoda Cyclopoida de vida livre de água doce do Estado de São Paulo, Brasil. Biota Neotrop. 11(1a):http://www.biotaneotropica.org.br/v11n1a/en/abstract?inventory+bn0261101a2011

SMIRNOV, N.N. 1996. Cladocera: the Chydorinae and Sayciinae (Chydoridae) of the world. In Guides to the identification of the Microinvertebrates of the Continental Waters of the World (H. J. Dumont, ed.). SPB Academic Publishing, Amsterdam, The Netherlands.

SOARES,F.S.,TUNDISI,J.G.&MATSUMURA-TUNDISI, T. 2011. Checklist de Rotifera de água doce do Estado de São Paulo, Brasil. Biota Neotrop. 11(1a):http://www.biotaneotropica.org.br/v11n1a/en/abstract?inventory+bn0231101a2011

TUNDISI, J.G. 1997. Climate. In Limnological Studies on the Rio Doce Valley Lakes, Brazil (J.G. Tundisi & Y. Saijo, ed.). Brazilian Academy of Sciences, São Carlos. p.7-11.

TUNDISI, J. G. & SAIJO, Y. 1997. Limnological Studies on the Rio Doce Valley Lakes, Brazil. Brazilian Academy of Sciences. University of São Paulo. São Carlos.

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Table 3: List of zooplankton species from 18 lakes of the middle Rio Doce basin, Minas Gerais, Brazil. * Data from Maia-Barbosa et al. (2008)

	Lakes Inside PERD										Lakes OutsidePERD									
	AN	CA	CE	DH		GA	GN	PT		SH	AC	AL	AM	BA	FE	FN	JA	PA	PI	VE
	Lim	Lim	Lim	Lim	Lit*	Lim	Lim	Lim	Lit	Lim	Lim	Lim	Lim	Lim	Lim	Lim	Lim	Lim	Lim	Lim
COPEPODA																				
Harpacticoida																				
Harpacticoida NI												1	1				1			1
Família Canthocamptidae																				
Attheyella fuhrmani Thieband, 1914					1															
Elaphoidella sp					1															
Família Parastenocarididae																				
Potamocaris sp.				1									1							
Cyclopoida																				
Família Cyclopidae																				
Ectocyclops herbsti Dussart, 1984					1				1											
Ectocyclops rubescens Brady, 1904					1				1				1							
Haplocyclops sp													1							
Homocyclops ater (Herrick, 1882)					1															
Macrocyclops albidus (Jurine, 1820)					1															
Mesocyclops longisetus (Thiébaud, 1914)					1								1							
Mesocyclops meridianus (Kiefer, 1926)		1			1				1		1		1							
Mesocyclops ogunnus Onabamiro, 1957				1	1				1											
Mesocyclops sp.	1		1	1			1	1		1		1			1	1		1	1	1
Metacyclops sp.				1											1					
Microcyclops alius Kiefer, 1935					1				1											
Microcyclops anceps (Richard, 1897)		1			1		1	1	1		1		1				1	1		
Microcyclops ceibaensis (Marsh, 1919)				1					1				1							
Microcyclops finitimus Dussart, 1984									1											
Neutrocyclops brevifurca (Lowndes, 1934)					1								1							
Paracyclops chiltoni (Thomson G.M., 1883)				1	1								1							
Thermocyclops minutus (Lowndes, 1934)	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1
Tropocyclops prasinus meridionalis (Kiefer, 1931)		1		1	1		1		1		1	1	1				1	1		1
Calanoida																				
Família Diaptomidae																				
Notodiaptomus cearensis (Wright S., 1936)								1	1											
Notodiaptomus dubius Dussart & Matsumura-Tundisi, 1985													1							
Notodiaptomus isabelae (Wright S., 1936)	1	1	1	1	1	1	1	1			1	1		1	1	1	1	1		1
subtotal	**3**	**5**	**3**	**9**	**16**	**2**	**5**	**5**	**10**	**2**	**5**	**5**	**13**	**2**	**4**	**3**	**5**	**5**	**2**	**5**
CLADOCERA																				
Família Bosminidae																				
Bosmina hagmanni Stingelin, 1904	1	1		1	1		1	1	1		1	1	1	1			1	1		1
Bosmina freyi De Melo & Hebert, 1994		1		1			1													

Bosmina tubicen Brehm, 1953	1	1		1	1	1	1	1	1	1	1	1	1	1		1	1	1		1
Bosminopsis deitersi Richard, 1895		1		1	1		1		1	1	1	1	1	1			1	1		1
Família Chydoridae																				
Alona dentifera (Sars, 1901)													1							
Alona glabra Sars, 1901					1								1							
Alona guttata Sars,1862		1			1				1				1							
Alona intermedia Sars, 1862													1							
Alona verrucosa Sars, 1901				1	1				1				1							
Alona spp.							1	1			1		1	1		1	1	1	1	1
Alonella clathratula Sars, 1896					1															
Alonella dadayi Birge, 1910		1			1		1	1	1				1				1			
Alonella lineolata Sars, 1901					1															
Chydorus eurynotus Sars, 1901		1			1		1				1		1				1			
Chydorus nitidulus (Sars, 1901)				1					1											
Chydorus pubescens Sars, 1901									1											
Chydorus sphaericus sens. lat.					1								1							
Coronatella monacantha (Sars, 1901)													1							
Coronatella poppei (Richard, 1897)		1			1		1						1							
Dadaya macrops (Daday, 1898)					1				1				1							
Dunhevedia odontoplax Sars, 1901					1				1											
Ephemeroporus barroisi (Richard, 1894)					1		1		1		1		1				1	1		
Ephemeroporus hybridus (Daday, 1905)				1									1							
Ephemeroporus tridentatus (Bergamin, 1931)		1			1				1											
Euryalona brasiliensis Brehm & Thomsen, 1936													1							
Karualona muelleri (Richard, 1897)							1						1							
Leydigia sp.				1									1							
Leydigiopsis curvirostris Sars, 1901					1															
Leydigiopsis ornata Daday, 1905					1															
Notoalona sculpta (Sars, 1901)					1															
Oxyurella ciliata Bergamin, 1931					1															
Família Daphnidae																				
Ceriodaphnia cornuta Sars, 1886		1		1	1			1	1		1	1	1	1			1	1		1
Ceriodaphnia silvestrii Daday, 1902	1	1		1	1		1	1	1		1		1				1	1		
Daphnia ambigua Scourfield, 1947				1							1									
Daphnia gessneri Herbst, 1967		1																		
Daphnia laevis Birge, 1878	1	1		1	1		1	1			1		1				1	1		
Scapholeberis armata (Herrick, 1882)		1			1				1		1		1				1			
Simocephalus mixtus Sars, 1903					1															
Simocephalus serrulatus (Koch, 1841)				1	1				1								1			
Simocephalus sp.													1				1	1		
Família Ilyocryptidae																				
Ilyocryptus spinifer Herrick, 1882	1	1			1		1	1	1	1	1		1	1			1	1		
Família Macrothricidae																				

Grimaldina brazzai Richard, 1892													1							
Macrothrix elegans Sars, 1901					1		1		1				1							
Macrothrix paulensis (Sars, 1900)					1			1	1											
Macrothrix squamosa Sars, 1901		1			1				1				1							
Macrothrix sp.							1						1				1	1		
Streblocerus pygmaeus Sars, 1901				1					1											
Família Moinidae																				
Moina minuta Hansen, 1899		1		1			1				1		1							
Moina reticulata (Daday, 1905)				1					1				1							
Família Sididae																				
Diaphanosoma birgei Korineck, 1981		1		1	1		1	1	1	1	1	1	1	1	1	1	1	1		1
Diaphanosoma brevireme Sars, 1901	1			1				1	1				1	1						
Diaphanosoma fluviatile Hansen, 1899									1											
Diaphanosoma spinulosum Herbst, 1967							1						1							
Pseudosida bidentada Herrick, 1884					1				1				1							
Pseudosida ramosa (Daday, 1904)									1				1							
subtotal	**6**	**18**	**0**	**18**	**32**	**1**	**18**	**11**	**27**	**4**	**14**	**5**	**37**	**8**	**1**	**3**	**16**	**12**	**1**	**6**
ROTIFERA																				
Ordem Ploima																				
Família Asplanchnidae																				
Asplanchna sp.							1		1		1						1	1		
Família Brachionidae																				
Anuraeopsis fissa Gosse, 1851		1			1		1	1	1				1				1			
Anuraeopsis navicula Rousselet, 1911				1	1			1	1		1		1				1			
Anuraeopsis sp.	1	1	1	1		1		1		1	1	1	1	1	1	1	1	1	1	1
Brachionus angularis Gosse, 1851	1	1	1	1	1		1		1	1	1	1	1	1			1	1	1	1
Brachionus bidentatus Anderson, 1889		1		1																
Brachionus calyciflorus Pallas, 1766		1											1					1		
Brachionus dolabratus Harring, 1914	1	1	1	1				1			1	1		1	1		1	1	1	1
Brachionus falcatus Zacharias, 1898	1	1	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1
Brachionus forficula Wierzejski, 1891				1																
Brachionus mirus Daday, 1905	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Brachionus quadridentatus Hermann, 1783				1	1			1	1		1		1				1	1		
Kellicottia bostoniensis (Rousselet, 1908)		1			1						1						1			
Keratella americana Carlin, 1943	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Keratella cochlearis (Gosse, 1851)	1	1		1	1						1		1			1	1	1		
Keratella lenzi Hauer, 1953		1		1	1			1	1		1		1	1			1	1		
Keratella tropica (Apstein, 1907)		1		1	1		1	1	1	1			1				1	1		
Plationus patulus macracanthus (Daday, 1905)		1											1							
Plationus patulus (Müller, 1786)	1	1		1	1		1	1	1		1		1	1			1	1		1
Platyias leloupi Gillard, 1967									1				1							
Platyias quadricornis (Ehrenberg, 1832)	1	1			1		1	1	1		1		1				1	1		
Platyias quadricornis quadricornis (Ehrenberg, 1832)													1							

Platyias sp.																	1			
Família Dicranophoridae																				
Dicranophorus epicharis Harring & Myers, 1928					1				1											
Dicranophorus sp.							1						1				1			
Família Epiphanidae																				
Epiphanes clavulata (Ehrenberg, 1832)													1							
Família Euchlanidae																				
Dipleuchlanis propatula (Gosse, 1886)		1			1				1				1					1		
Dipleuchlanis sp.							1													
Euchlanis dilatata Ehrenberg, 1832				1	1				1				1							
Euchlanis incisa Carlin, 1939		1			1				1				1				1			
Euchlanis meneta Myers, 1930					1		1						1							
Família Gastropodidae																				
Ascomorpha ecaudis Perty, 1850								1	1		1		1				1	1		
Ascomorpha ovalis (Bergendal, 1892)				1													1			
Ascomorpha saltans Bartsch, 1870					1								1							
Ascomorpha sp.	1	1	1	1				1			1	1	1	1				1	1	1
Gastropus hyptomus (Ehrenberg, 1838)				1									1							
Gastropus stylifer (Imhof, 1891)				1									1							
Família Lecanidae																				
Lecane aculeata (Jakubski, 1912)							1		1											
Lecane arcula Harring, 1914				1	1				1				1							
Lecane armata Thomasson, 1971					1		1		1											
Lecane braziliensis Segers, 1993					1				1											
Lecane bulla (Gosse, 1851)	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lecane clara (Bryce, 1892)				1									1							
Lecane doryssa Harring, 1914					1								1							
Lecane closterocerca (Schmarda, 1859)				1	1		1		1				1							
Lecane cornuta (Müller, 1786)	1				1		1	1	1		1		1	1			1			
Lecane crepida Harring, 1914					1			1	1				1							
Lecane curvicornis (Murray, 1913)	1	1			1		1		1		1		1		1		1	1		
Lecane decipiens (Murray, 1913)				1					1				1							
Lecane elegans Harring, 1914													1							
Lecane eutarsa Harring & Myers, 1926									1											
Lecane flexilis (Gosse, 1886)							1						1							
Lecane furcata (Murray, 1913)					1			1	1				1							
Lecane haliclysta Harring & Myers, 1926					1				1				1							
Lecane hamata (Stokes, 1896)					1		1	1	1				1					1		
Lecane hornemanni (Ehrenberg, 1834)	1				1		1		1				1				1			1
Lecane inconspicua Segers & Dumont, 1993											1									
Lecane inermis (Bryce, 1892)					1								1							
Lecane inopinata Harring & Myers, 1926									1				1							
Lecane leontina (Turner, 1892):		1		1	1		1	1	1		1		1	1			1	1		

Lecane ludwigii (Eckstein, 1883)				1	1		1	1	1				1							1
Lecane luna (Müller, 1776)				1			1		1		1		1				1			
Lecane lunaris (Ehrenberg, 1832)	1	1	1	1	1		1	1	1		1	1	1	1	1	1	1	1	1	1
Lecane monostyla (Daday, 1897)				1	1		1	1	1		1		1				1			
Lecane nana (Murray, 1913)								1	1											
Lecane obtusa (Murray, 1913)					1														1	
Lecane papuana (Murray, 1913)	1						1						1				1			
Lecane rhopalura (Harring & Myers, 1926)								1												
Lecane proiecta Hauer, 1956							1													
Lecane psammophila (Wiszniewski, 1932)					1															
Lecane pusilla Harring, 1914					1								1							
Lecane pyriformis (Daday, 1905)					1				1				1							
Lecane quadridentata (Ehrenberg, 1830)		1			1		1		1		1		1							
Lecane rhytida Harring & Myers, 1926				1					1											
Lecane scutata (Harring & Myers, 1926)							1					1	1	1		1				1
Lecane signifera (Jennings, 1896)		1			1		1		1		1		1							
Lecane stichaea Harring, 1913				1									1							
Lecane stichoclysta Segers, 1993														1						
Lecane subtilis Harring & Myers, 1926									1				1			1				
Lecane uenoi Yamamoto, 1951									1				1							
Família Lepadellidae																				
Colurella obtusa (Gosse, 1886)									1		1									
Colurella sulcata (Stenroos, 1898)				1	1				1											
Colurella uncinata (Müller, 1773)									1				1							
Colurella uncinata bicuspidata (Ehrenberg, 1832)					1				1											
Colurella tesselata									1											
Colurella sp.								1	1		1		1				1			
Lepadella (Heterolepadella) spp.									1											
Lepadella (Lepadella) latusinus (Hilgendorf, 1899)					1				1				1							
Lepadella (Lepadella) cristata (Rousselet, 1893)					1		1		1				1					1		
Lepadella (Lepadella) donneri Koste, 1972				1	1				1											
Lepadella (Lepadella) elongata Koste, 1992									1											
Lepadella (Lepadella) minoruoides Koste & Robertson, 1983								1	1											
Lepadella (Lepadella) ovalis (Müller, 1786)		1			1				1				1				1			
Lepadella (Lepadella) patella (Müller, 1773)					1		1	1	1		1		1				1			
Lepadella (L.) patella oblonga (Ehrenberg, 1834)													1							
Lepadella (Lepadella) quinquecostata (Lucks, 1912)					1															
Lepadella (Lepadella) rhomboides (Gosse, 1886)									1				1					1		
Lepadella (Lepadella) rottenburgi (Lucks, 1912)									1											
Lepadella (Lepadella) triptera (Ehrenberg, 1832)				1	1				1											
Lepadella (Lepadella) spp.	1	1			1		1	1	1		1		1			1	1	1		1
Squatinella lamellaris (Müller, 1786)					1				1				1							
Família Mytilinidae																				

Lophocharis salpina (Ehrenberg, 1834)					1				1											
Mytilina acanthophora Hauer, 1938											1		1				1	1		
Mytilina bisulcata (Lucks, 1912)				1			1	1	1		1		1				1	1		
Mytilina mucronata (Müller, 1773)							1													
Mytilina ventralis (Ehrenberg, 1830)				1			1	1	1				1					1	1	
Mytilina ventralis ventralis (Ehrenberg, 1830)					1								1							
Mytilina sp.		1											1							
Família Notommatidae																				
Cephalodella rotunda Wulfert, 1937													1							
Cephalodella forficula (Ehrenberg, 1830)					1				1				1							
Cephalodella gibba (Ehrenberg, 1830)									1				1							
Cephalodella spp.		1			1		1	1	1		1		1				1			
Monommata aequalis (Ehrenberg, 1830)		1		1																
Monommata sp.					1		1		1				1					1		
Notommata copeus Ehrenberg, 1834									1											
Notommata spp.									1				1							
Resticula sp.									1											
Notommatidae NI		1									1		1					1		
Família Scaridiidae																				
Scaridium longicaudum (Müller, 1786)									1											
Família Synchaetidae																				
Polyarthra dolichoptera Idelson, 1925													1							
Polyarthra sp.	1	1		1	1		1	1	1	1	1		1	1			1	1	1	
Synchaeta sp.													1							
Família Trichocercidae																				
Trichocerca bicristata (Gosse, 1887)							1		1				1							
Trichocerca bidens (Lucks, 1912)									1											
Trichocerca iernis (Gosse, 1887)					1				1				1							
Trichocerca scipio (Gosse, 1886)							1						1							
Trichocerca elongata braziliensis (Murray, 1913)					1				1				1							
Trichocerca cavia (Gosse, 1886)									1											
Trichocerca cylindrica (Imhof, 1891)								1	1											
Trichocerca chattoni (de Beauchamp, 1907)					1			1		1	1									
Trichocerca flagellata Hauer, 1937													1							
Trichocerca macera (Gosse, 1886)													1							
Trichocerca insignis (Herrick, 1885)									1				1							
Trichocerca pusilla (Jennings, 1903)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Trichocerca rattus (Müller, 1776)				1	1		1					1	1					1		
Trichocerca similis (Wierzejski, 1893)					1		1	1	1		1		1	1			1	1		1
Trichocerca stylata (Gosse, 1851)	1	1		1	1					1	1		1	1	1		1		1	1
Trichocerca tenuior (Gosse, 1886)													1							
Trichocerca tigris (Müller, 1786)									1											
Família Trichotriidae																				

Trichotria tetractis (Ehrenberg, 1830)					1		1		1				1				1		1	
Macrochaetus collinsii (Gosse, 1867)					1		1		1				1				1			
Macrochaetus longipes Myers, 1934		1			1				1				1							
Macrochaetus sericus (Thorpe, 1893)				1	1		1		1				1				1	1		
Macrochaetus sp.								1			1	1			1	1	1	1		
Ordem Flosculariaceae																				
Família Conochilidae																				
Conochilus (Conochiloides) coenobasis (Skorikov, 1914)					1				1		1		1				1	1		
Conochilus (Conochiloides) dossuarius Hudson, 1885				1				1	1				1							
Conochilus (Conochiloides) natans (Seligo, 1900)													1							
Conochilus (Conochilus) unicornis Rousselet, 1892				1							1		1				1			
Conochilus sp.	1	1		1			1	1	1	1	1	1	1	1	1	1	1	1		1
Família Filiniidae																				
Filinia longiseta (Ehrenberg, 1834)	1	1		1	1		1			1	1	1	1	1	1		1	1		1
Filinia opoliensis (Zacharias, 1898)				1			1		1									1		
Filinia pejleri Hutchinson, 1964													1							
Filinia terminalis (Plate, 1886)								1	1											
Família Flosculariidae																				
Beauchampiella eudactylota (Gosse, 1886)													1							
Ptygura elsteri Koste, 1972									1											
Ptygura furcillata (Kellicott, 1889)									1											
Ptygura libera Myers, 1934	1	1	1	1		1	1	1		1	1	1	1	1	1	1	1	1	1	1
Ptygura spp.				1				1	1											
Sinantherina sp.					1			1	1				1	1			1			
Família Hexarthridae																				
Hexarthra intermedia (Wiszniewski, 1929)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Família Testudinellidae																				
Testudinella amphora Hauer, 1938					1				1											
Testudinella parva (Ternetz, 1892)							1		1											
Testudinella emarginula (Stenroos, 1898)									1											
Testudinella mucronata (Gosse, 1886)													1							
Testudinella ohlei Koste, 1972					1		1		1											
Testudinella patina (Hermann, 1783)				1	1		1		1				1							
Ordem Collothecaceae																				
Família Collothecidae																				
Collotheca tenuilobata (Anderson, 1889)													1							
Collotheca sp.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Subclasse Bdelloidea																				
Bdeloidea	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Família Philodinidae																				
Dissotrocha aculeata (Ehrenberg, 1832)	1			1	1				1		1		1			1		1	1	
Dissotrocha macrostyla (Ehrenberg, 1838)													1							
Dissotrocha sp.							1				1									

Macrotrachela sp.							1				1									
Rotaria neptunia (Ehrenberg, 1830)													1							
Rotaria sp.							1													
subtotal	**27**	**41**	**14**	**54**	**81**	**7**	**61**	**47**	**109**	**17**	**51**	**19**	**119**	**26**	**17**	**17**	**54**	**45**	**20**	**23**
PROTOZOA																				
Rhizopoda																				
Família Arcellidae																				
Arcella brasiliensis Cunha, 1913													1							
Arcella arenaria Greeff, 1866													1							
Arcella irregularis Motti, 1941													1							
Arcella conica (Playfair, 1917)					1			1	1				1							
Arcella costata Ehrenberg, 1847					1				1				1							
Arcella crenulata Deflandre, 1928													1							
Arcella dentata Ehrenberg, 1838					1															
Arcella discoides Ehrenberg, 1843					1				1				1							
Arcella discoides pseudovulgaris (Deflandre, 1928)								1	1											
Arcella gibbosa Pénard, 1890					1								1							
Arcella hemisphaerica Perty, 1852					1				1				1							
Arcella hemisphaerica undulata Deflandre, 1928								1	1											
Arcella megastoma Pénard, 1902					1				1				1							
Arcella mitrata Leidy, 1879									1											
Arcella mitrata spectabilis Deflandre, 1928													1							
Arcella rota Daday, 1905					1				1											
Arcella rotundata Playfair, 1917													1							
Arcella rotundata aplanata Deflandre, 1928					1				1											
Arcella vulgaris Ehrenberg, 1830					1				1				1							
Arcella vulgaris undulata Deflandre, 1928					1				1											
Arcella vulgaris penardi Deflandre, 1928													1							
Arcella sp.													1				1	1		
Família Centropyxidae																				
Centropyxis aculeata (Ehrenberg, 1838)					1				1				1				1			
Centropyxis aerophila Deflandre, 1929					1								1							
Centropyxis arcelloides Pénard, 1902													1							
Centropyxis delicatula Pénard, 1902					1															
Centropyxis cassis (Wallich, 1864)													1							
Centropyxis constricta (Ehrenberg, 1841)					1								1							
Centropyxis discoides (Pénard, 1890)					1				1				1							
Centropyxis ecornis (Ehrenberg, 1841)					1								1							
Centropyxis gibba Deflandre, 1929					1				1				1							
Centropyxis hirsuta Deflandre, 1929					1				1				1							
Centropyxis minuta Deflandre, 1929					1				1				1							
Centropyxis platystoma Pénard, 1890									1				1							
Centropyxis spinosa Cash, 1905					1				1				1							

Centropyxis spp.					1				1				1					1		
Família Difflugiidae																				
Cucurbitella madagascariensis G. L. & Th, 1980													1							
Cucurbitella mespiliformis Pénard, 1902													1							
Difflugia acuminata Ehrenberg, 1838					1				1				1							
Difflugia acuminata acaulis Perty, 1852									1											
Difflugia bacillariarum Perty, 1849													1							
Difflugia lucida Pénard, 1890													1							
Difflugia congolensis G.L. & Th., 1958													1							
Difflugia corona Wallich, 1864									1				1							
Difflugia curvicaulis Pénard, 1899													1							
Difflugia difficilis Thomas, 1955													1							
Difflugia elegans Pénard, 1890					1				1				1							
Difflugia globularis (Wallich, 1864)													1							
Difflugia gramen Pénard, 1902					1				1				1							
Difflugia kabylica G.L. & Th., 1958									1				1							
Difflugia kempnyi (Stepanek), 1953									1				1							
Difflugia lanceolata Pénard, 1890					1				1											
Difflugia limnetica Levander, 1900								1	1				1							
Difflugia lithophila Pénard, 1902													1							
Difflugia lobostoma Leidy, 1877									1				1							
Difflugia lobostoma globulosa Playfair, 1917									1											
Difflugia lobostoma multilobata G.L. & Thomas, 1958									1											
Difflugia muriformis G.L. & Th., 1958									1				1							
Difflugia oblonga Ehrenberg, 1838					1				1				1							
Difflugia pseudogramen G.L. & Th., 1960													1							
Difflugia sarissa Li Sun Tai, 1931													1							
Difflugia tuberculata (Wallich, 1864)													1							
Difflugia stellastoma Vucetich, 1989					1															
Difflugia spp.									1				1							
Protocucurbitella coroniformis G.L. & Th., 1960									1				1							
Família Lesquereusiidae																				
Lesquereusia epistomium Penard, 1902								1	1				1							
Lesquereusia gibbosa G.L. & Th., 1959													1							
Lesquereusia globulosa G.L. & Th., 1959									1											
Lesquereusia mimetica Pénard, 1911													1							
Lesquereusia modesta Rhumbler, 1895					1				1				1							
Lesquereusia spiralis Ehrenberg, 1840					1				1				1							
Netzelia labeosa Beyens & Chardez, 1997									1											
Netzelia oviformis (Cash, 1909)					1				1				1							
Netzelia tuberculata (Wallich, 1864)									1				1							
Netzelia wailesi (Ogden, 1980)					1				1				1							
Quadrulella symmetrica (Wallich, 1863)					1															

Família Hyalospheniidae																				
Nebela sp.					1								1							
Difflugiella spp.					1				1											
Família Trigonopyxidae																				
Cyclopyxis eurystoma (Deflandre, 1929)									1											
Cyclopyxis kahli (Deflandre, 1929)					1															
Cyclopyxis sp.													1							
Família Cyphoderiidae																				
Cyphoderia ampulla (Gray, 1873)													1							
Família Euglyphidae																				
Euglypha acanthophora (Ehrenberg, 1841)					1				1				1							
Euglypha brachiata Pénard, 1902					1				1											
Euglypha ciliata (Ehrenberg, 1848)													1							
Euglypha filifera Pénard, 1890									1				1							
Euglypha laevis (Ehrenberg, 1845) Perty, 1849					1				1											
Euglypha strigosa Ehrenberg, 1871					1															
Euglypha tuberculata Dujardin, 1841					1															
Família Trinematidae																				
Trinema enchelys (Ehrenberg, 1838)					1				1				1							
Trinema lineare Pénard, 1890													1							
Família Phryganellidae																				
Phryganella dissimulatoris Chardez, 1969					1				1											
Phryganella hemisphaerica Pénard, 1902									1											
Família Pseudodifflugiidae																				
Pseudodifflugia sp.													1							
Família Plagiopyxidae																				
Bullinullaria sp.													1							
Ciliophora																				
Família Epistylididae																				
Epistylis spp.													1							
Campanella sp.													1							
Família Vorticelidae																				
Vorticella sp.													1				1			
Zoothamnium spp.													1							
subtotal	**0**	**0**	**0**	**0**	**43**	**0**	**0**	**5**	**53**	**0**	**0**	**0**	**74**	**0**	**0**	**0**	**3**	**2**	**0**	**0**
TOTAL	**36**	**64**	**17**	**81**	**172**	**10**	**84**	**68**	**199**	**23**	**70**	**29**	**243**	**36**	**22**	**23**	**78**	**64**	**23**	**34**

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Dispersal spectrum of four forest types along an altitudinal range of the Brazilian Atlantic Rainforest

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Abstract: In ecological communities, the proportion of plant species with different dispersal syndromes is known as the dispersal spectrum, which can result from different selective pressures such as climate. This is because variations in temperature, humidity, atmospheric pressure and precipitation result in distinct flora and fauna among different sites. If climate conditions along an altitudinal range act as a strong direct or indirect selective pressure on dispersal syndromes, the dispersal spectrum among plant communities in different altitudes should be distinct. We organized the dispersal syndromes in five hierarchical levels according to the levels of detail in diaspore morphology and, consequently, different degrees of specificity to the dispersers. Then we identified, within each hierarchical level, the syndromes of tree species of four forest types of the Atlantic Rainforest along a 1200 m altitudinal range in Southeast Brazil. Among 327 species, we found two syndromes in the most general hierarchical level (abiotic and biotic dispersal), three in the following level (wind, self and animal), three in the intermediate level (barochory, autochory and endozoochory), two in the forth level (mammal and bird), and 12 syndromes in the most specific level, all of which were related to the morphology of diaspores dispersed by wind, autochory, mammals and birds. The dispersal spectrum in the five hierarchical levels was similar among the four forest types. Overall, the majority of species is dispersed by biotic agents, considered here as animals and the parent plant itself. Within biotic agents, the most important are animals, specifically birds. Most bird-dispersed species present drupoid diaspores. Our results indicate that the selective pressures on dispersal syndromes originated from climate conditions that vary with altitude are not strong, hence resulting in the same dispersal spectrum among the forest types.

Keywords: *animal dispersal, biotic dispersal, bird dispersal, hierarchy of classification of dispersal syndromes.*

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Resumo: Dentro de uma comunidade, a proporção de espécies vegetais com diferentes síndromes de dispersão é chamada de espectro de dispersão, o qual pode resultar de distintas pressões seletivas, como o clima. Isso ocorre porque variações na temperatura, umidade, pressão atmosférica e precipitação resultam em flora e fauna distintas entre locais. Assim, podemos esperar que o espectro de dispersão de comunidades vegetais em diferentes altitudes seja distinto se as condições climáticas ao longo do gradiente altitudinal atuarem como pressão seletiva direta ou indireta sobre as síndromes. Nós hierarquizamos as síndromes de dispersão em cinco níveis, de acordo com o detalhamento da morfologia dos diásporos e, consequentemente, seus diferentes graus de especificidade com os dispersores. Identificamos, em cada um dos níveis hierárquicos, as síndromes de espécies arbóreas de quatro formações florestais da Mata Atlântica ao longo de um gradiente altitudinal de 1200 m no sudeste do Brasil. Entre 327 espécies, encontramos duas síndromes no nível hierárquico mais geral (dispersão abiótica e biótica), três no nível seguinte (vento, própria planta parental e animais), três no nível intermediário (barocoria, autocoria e endozoocoria), duas no quarto nível (mamíferos e aves) e 12 síndromes no nível mais específico, relacionadas à morfologia dos diásporos dispersos pelo vento, autocoria, mamíferos e aves. O espectro de dispersão nos cinco níveis foi similar nas quatro formações florestais. De forma geral, a maior parte das espécies é dispersa por agentes bióticos, aqui considerados animais e a própria planta parental. Dentre os agentes bióticos, os mais importantes são os animais, especificamente as aves. A maioria das espécies dispersas pelas aves apresenta diásporos drupóides. Nossos resultados indicam que as pressões seletivas sobre as síndromes de dispersão ocasionadas pelas condições climáticas que variam com a altitude não são fortes. Assim, a ausência destas pressões seletivas resulta em um espectro de dispersão similar entre as formações florestais em diferentes altitudes.

Palavras-chave: *dispersão biótica, hierarquia de classificação das síndromes de dispersão, ornitocoria, zoocoria.*

Introduction

Seeds, fruits, infructescences and other dispersal units are generically called diaspores. Diaspore dispersal is a dynamic process of diaspore transportation away from the parent plant. This transportation can be performed by biotic agents, such as animals and the parent plant itself, or by abiotic agents, such as wind and water (van der Pijl 1972). Diaspores generally show adaptations for dispersal by a specific agent (Willson et al. 1990), which is known as dispersal syndrome. Therefore, the syndromes indicate the most likely primary dispersal agent of a particular plant species (van der Pijl 1972).

Dispersal syndromes have been extensively described by Ridley (1930) and van der Pijl (1972). For example, within biotic dispersal syndromes, animal-dispersed diaspores can be either fleshy or dry. Many different types of animals consume the former, which is known as endozoochory; the latter cling externally to the body of animals, a form of dispersal known as epizoochory. Endozoochorous diaspores present characteristics that are specifically attractive to particular groups of animals, such as ants (although they transport diaspores externally to their bodies to later remove their fleshy portion inside the nest), fishes, reptiles, birds or mammals. Conversely, mammal-dispersed diaspores present characteristics that result in their dispersal by distinct groups of mammals (Ridley 1930, van der Pijl 1972). Therefore, there are different levels of detail in diaspore morphology and, consequently, different degrees of specificity to the dispersers. In the given example, biotic agents would be considered level 1 in a hierarchical classification of dispersal syndromes, as well as abiotic agents; animal dispersal would be level 2, as well as self dispersal by the parent plant and the abiotic dispersal by water and wind; endozoochory and epizoochory would both be level 3, as well as different forms of self dispersal (autochory and barochory); ant, fish, reptile, bird and mammal dispersal would all be level 4, and dispersal by the distinct groups of mammals would be level 5 in the hierarchy, as well as the different forms of autochory, water and wind dispersal (for a more detailed explanation of the dispersal syndromes please see the “Protocol for the classification of dispersal syndromes” at supplementary material 1).

Despite the clear hierarchical organization of the dispersal syndromes, no author has yet proposed formal hierarchical levels within them. This organization is needed in studies that compare dispersal distances, demographic consequences of dispersal (*e.g.*, the spatial distribution of seeds and seedlings) or the proportion of species with different dispersal syndromes in ecological communities. Restraining diaspore morphology and consequently its most likely dispersal agent should enable the evaluation of underlying patterns of dispersal opposed to the great variation that emerges when syndromes from different hierarchical levels are considered.

Birds are important dispersal agents, particularly in the tropics (Gentry 1982, Willson et al. 1989, Pedroni 2001). The diaspores they eat show very different morphologies, such as seeds with fleshy appendage, seeds without any nutritional reward (known as mimetic seeds), and fleshy fruits with few up to many seeds (*i.e.* drupoid and baccoid diaspores, respectively). Seeds with fleshy appendages, seeds without any nutritional reward and seeds from drupoid diaspores are larger than seeds from baccoid diaspores. Thus, the former may only be dispersed by large-bodied birds (Wheelwright 1985), which can swallow the whole diaspore and carry the large seed(s). Small birds can sometimes swallow large diaspores, but they are less willing or able to carry the mass of ballast associated with large seeds (Mack 1993). Therefore, small birds are most likely to only peck at the pulp of large diaspores and do not act as dispersers of large seeds. On the other hand, seeds from baccoid diaspores can be dispersed by both small and large birds, with the number of seeds carried varying with the size of the bird in relation to the size of the diaspore, which may be swallowed whole or have a portion pecked at. Therefore, the different types of bird-dispersed diaspores are likely to present dissimilar patterns of seed deposition in the environment as well as distinct implications for seed germination and establishment of the new individuals (Howe et al. 1985). Because of the different selective pressures on each type of bird-dispersed diaspore, it is necessary to divide them into different groups into level 5 of the hierarchy of dispersal syndromes.

Even though it is relatively easy to identify seed dispersal syndromes based on diaspore morphology alone, not necessarily can we predict which agent is actually acting as a disperser. This is especially critical for animal dispersal, since seed dispersal mutualisms are clearly unspecialized (Herrera 1985, 2002). Most plants lack attributes that require special handling by particular species of animals (Herrera 2002, Burns et al. 2009, but see Moran et al. 2004); thus, dispersers rarely show preferences for particular diaspore traits and often consume seeds and fruits indiscriminately (*e.g.*, Herrera 1985, Burns et al. 2009, but see Carlo et al. 2003). Nevertheless, specialized relationships can arise on coarser taxonomic scales, among wide ‘guilds’ of diaspores and animals (Lomáscolo et al. 2008, Hollander & Vander Wall 2009, but see Fischer & Chapman 1993). This suggests that the diaspore morphology described in syndromes belonging to upper levels of the hierarchy proposed herein can be used with good reliability to predict the set of dispersal agents of a given plant species. On the other hand, biotic syndromes in levels 4 and 5 may hardly correspond to the actual set of dispersal agents.

This may be considered a shortcoming for the widespread use of dispersal syndromes, especially the ones in the lower levels of the hierarchy. Nevertheless, diaspore morphology is likely to restrict the agents that act as real dispersers, unregard of their taxonomic group, and these dispersers may deposit seeds in the environment in similar fashion. For instance, many diaspores with characteristics considered attractive to birds are also consumed by mammals. Because seeds belonging to drupoid diaspores are larger than those belonging to baccoid diaspores, the former are only likely to be dispersed by large birds and mammals (Wheelwright 1985), while the latter can be dispersed by both small and large animals. Large animals have larger home ranges (Kelt & Van Vuren 2001) and may carry seeds over longer distances than smaller animals (Seidler & Plotkin 2006). As a consequence, seeds belonging to drupoid diaspores may be deposit more scattered in the environment than seeds from baccoid diaspores, which may show some clumping due to dispersal by small animals. Hence, diaspores with similar morphology should be linked to the similar demographic consequences of seed dispersal, mediated by different dispersal agents. Because of that, we believe that the biotic syndromes proposed in levels 4 and 5 should be considered in studies of dispersal syndromes.

In ecological communities, the proportion of plant species with different dispersal syndromes is known as the dispersal spectrum (van der Pijl 1972, Hughes et al. 1994), which can result from different selective pressures. The main pressures on dispersal strategies arise from frugivores (Mazer & Wheelwright 1993, Lord 2004), predation, competition among plant species for the same dispersers, climate seasonality and the environment in which the plants occur (Roth 1987, Almeida-Neto et al. 2008). Thus, forest types at different altitudes may have different dispersal spectra due to variations in temperature, humidity, atmospheric pressure and precipitation (Willson et al. 1990), all of which result in distinct flora and fauna along an altitudinal range.

The state park “Parque Estadual da Serra do Mar” (PESM hereafter), Southeast Brazil, is the largest continuous stretch of preserved Atlantic Rainforest in Brazil and extends from sea level to 1200 m of altitude (SOS Mata Atlântica/INPE/ISA 1998, Alves et al. 2010). Therefore, it is an excellent site for the investigation of dispersal spectrum changes with altitude. Both temperature and rainfall decrease with increasing altitude (Banco de Dados Climáticos do Brasil), and the different climate along the altitudinal range has resulted in distinct forest types, each with its own floristic composition (Joly et al. 2012). Therefore, we should also expect changes in the dispersal spectrum along the altitudinal range due to selective pressures imposed by climate on seed dispersal mechanisms.

As other tropical forests, the Atlantic Rainforest presents 45% up to 90% of shrub and/or tree species dispersed by animals (Pedroni 2001, Almeida-Neto et al. 2008). Animal dispersal is positively related to rainfall and hence tends to be more common at low altitudes (Willson et al. 1989, Vicente et al. 2003). However, Almeida-Neto et al. (2008) found that animal dispersal in the Atlantic Rainforest is negatively related to temperature, which suggests the importance of seed dispersal by animals may actually increase with increasing altitude. Therefore, the relation between animal dispersal and altitude should be further explored in order to depict the relative importance of rainfall and temperature on the dispersal spectrum.

Within endozoochorous species, bird dispersal is more common than mammal dispersal (Gentry 1982, Willson et al. 1989). In a 1900 m altitudinal range of the Atlantic Rainforest, Almeida-Neto et al. (2008) found predominance of bird-dispersed species at higher altitudes, while mammal-dispersed species were more frequent at lower altitudes. Last, within abiotic dispersal, wind and self-dispersed species are more frequent at higher altitudes, where the climate is drier and vegetation more open (van der Pijl 1972, Campassi 2006). Although some studies have shown the influence of climate on dispersal spectrum changes with altitude, the detailed hierarchical levels within dispersal syndromes we previously described have never been taken into account.

This study aimed to (1) develop a hierarchical organization of dispersal syndromes for tree species, which include four divisions within bird dispersal based on diaspore morphology, and (2) identify the syndromes within each hierarchical level for tree species of four forest types along the altitudinal range of PESM. After identifying the syndromes, we determined the dispersal spectrum within each hierarchical level in the four forest types. Then we specifically asked whether the dispersal spectrum differed among the forest types.

We expect that dispersal by biotic agents, mainly by animals that consume diaspores and specifically by birds, should prevail among tree species at PESM, as found in other studies carried out in the Brazilian Atlantic Rainforest (*e.g.*, Pedroni 2001, Campassi 2006, Kinoshita et al. 2006, Almeida-Neto et al. 2008, Silva & Rodal 2009). However, differently from previous studies, the dispersal spectrum within different hierarchical levels of the dispersal syndromes will be used, including the divisions within bird-dispersed diaspores. We hypothesize that, if climate conditions along the altitudinal range of PESM act as a strong selective pressure on dispersal syndromes, there should be differences in the dispersal spectrum among the forest types. For example, if rainfall imposes a stronger pressure, animal dispersal should be more common at lower altitudes. On the other hand, if temperature imposes a stronger pressure, animal dispersal should be more common at higher altitudes. The differences found in the dispersal spectrum along the altitudinal range should reflect the key importance of certain dispersal agents in the different environments, as found by other authors (*e.g.*, van der Pijl 1972, Roth 1987, Willson et al. 1990, Hughes et al. 1994, Pedroni 2001, Campassi 2006, Almeida-Neto et al. 2008).

Material and Methods

1. *Study site*

The Brazilian Atlantic Forest is considered one of the world’s hotspots for biodiversity conservation (Myers et al. 2000), with only about 12% of its original cover remaining in fragments larger than 3 ha (Fundação SOS Mata Atlântica). The largest continuous remnant includes the state park PESM (23°34′ - 23°17′ S e 45°02′ - 45°11′ W), which encompasses the mountain range of “Serra do Mar” along the northern coast of the state of São Paulo, SE Brazil. PESM comprises 315,000 ha (SOS Mata Atlântica/INPE/ISA 1998) ranging from 0 m to 1200 m above sea level (a.s.l.; Alves et al. 2010). The geological and topological complexity of “Serra do Mar” results in extremely heterogeneous habitats and microclimates (Suguio & Martin 1978, Alves et al. 2010), reflected in the different forest types present at the study site (Alves et al. 2010, Joly et al. 2012).

In 2006-2007, researchers from the Theme Project "Functional Gradient" (Biota/FAPESP 03/12595-7) installed 14 non-contiguous, permanent 1 ha plots at the four forest types present along the altitudinal range of PESM. Plot establishment and tree sampling followed the RAINFOR field manual (Phillips et al. 2009, Joly et al. 2012). One plot was placed at the Restinga Forest (up to 10 m a.s.l. in sandy soil; Restinga hereafter), five plots at the Lowland Atlantic Rainforest (between 5 m and 50 m a.s.l.; Lowland hereafter), four plots at the Submontane Atlantic Rainforest (between 50 m and 500 m a.s.l.; Submontane hereafter) and four plots were installed at the Montane Atlantic Rainforest (between 500 m and 1200 m a.s.l.; Monane hereafter; Veloso et al. 2001, Joly et al. 2012). In this study, we collected data at one plot of each forest type. Because floristic composition and community structure are very similar among plots installed at the same forest type (Joly et al. 2012), we believe the results presented further are representative of the different forest types of the Atlantic Rainforest at the study site.

At the low portion of "Serra do Mar", mean temperatures range from 18.4°C in July to 25.5°C in February. A dry season is absent and mean rainfall ranges from 11 mm in July to 376 mm in January. At the high portion of "Serra do Mar", mean temperatures are a little lower and range from 16.4°C in July to 23.2°C in February. Again, a dry season is absent, but there is less rainfall than at the low portion of the mountain range (278 mm in February and 20 mm in July; EMBRAPA). Nevertheless, Submontane and Montane are frequently covered by clouds and mist brought by oceanic winds (Silva-Dias et al. 1995), which increase humidity but reduce light availability to plants (Sousa Neto 2008).

Soils along the altitudinal range are shallow and nutrient poor. However, the soil of Restinga is sandier and poorer than the soils of the other forest types (Martins 2010). Soil humidity, total carbon and nitrogen, and ammonia and nitrate concentrations increase with altitude. Conversely, decomposition rates, and N_2O and CO_2 emissions from the soil to the atmosphere decrease with altitude (Sousa Neto 2008).

2. *Species studied*

The researchers from the Theme Project sampled, collected and identified every living tree (including palms) with stem DBH $\geqslant$ 4.8 cm inside the 14 plots. Voucher specimens are deposited in the herbariums of the University of Campinas (UEC), "Instituto Agronômico de Campinas" (IAC) and 'Universidade Estadual Paulista "Júlio de Mesquita Filho"' *campus* Rio Claro (HRCB; Joly et al. 2012).

We identified the dispersal syndrome within all hierarchical levels of the species sampled at the four study plots. Unidentified individuals at the family level and lacking diaspores in the voucher material were not included in the analysis. Undetermined species of known families had their dispersal syndrome assigned when the families had only one syndrome. Conversely, we were unable to identify the syndrome of undetermined species belonging to families with more than one syndrome, except in cases where the diaspores had been collected. Therefore, the syndrome of undetermined species with different types of diaspores in the same family was described as non-identified (NI hereafter).

3. *Dispersal syndromes*

We conducted a review of the syndromes that occur at tree species and elaborated a protocol of identification where the references used can be found ("Protocol for the classification of dispersal syndromes" at supplementary material 1). The diaspore characteristics presented were extracted from specialized literature rather than based on fruits and seeds of the species studied. This makes our classification wide enough to be used by other authors and at other study systems. Based on the protocol, we also prepared a diagram (Figure 1) that establishes the hierarchical classification of the dispersal syndromes in five levels, each composed of several groups.

We created four divisions within bird dispersal based on the following morphological characteristics: (1) seeds with sarcotesta, fleshy aril or ariloid structures; (2) seeds with colours that mimics external fleshy appendages or a juicy aspect; (3) few or many seeds per diaspore, and (4) size of seeds in relation to the diaspore. As a result, the divisions created were seeds with fleshy appendage, seeds without any nutritional reward, drupoid diaspores and baccoid diaspores (Figure 1).

Diaspores dispersed by mammals present very different morphologies and are attractive to distinct groups of mammals. Because of that, syndromes of mammal-dispersed diaspores originally received their names according to the taxonomic group of animals that act as the dispersal agent (*e.g.*, Ridley 1930, van der Pijl 1972, Janzen & Martin 1982, Herrera 1989). However, in the classification here proposed, all other groups belonging to level 5 were designated based on the morphology of the diaspores, such as those previously described for bird dispersal. So, in order for all groups of level 5 to have the same classification criteria, we proposed new terms for the syndromes of mammal dispersal. The new terms were based on the main morphological characteristics of the diaspores in each mammal-dispersed group, which may be related to a taxonomic group of dispersal agent (Figure 1).

As one can note in Figure 1, some dispersal syndromes are unfiled to all hierarchical levels. For example, within abiotic dispersal syndromes (level 1), both wind and water-dispersed diaspores (level 2) reach a high level of detail without showing intermediate levels. In the case of wind dispersal, there are dust, balloon, plumed, winged, ballist and roller diaspores (van der Pijl 1972). We prefer to file them directly to level 5 instead of 3 because they present very specific morphology that, analogously to biotically dispersed diaspores, enables their classification into the more detailed level of the hierarchy. The lack of intermediate levels for abiotic dispersal may suggest that the diversification of diaspore morphology resulting from selective pressures imposed by biotic agents is greater than those imposed by abiotic agents.

To identify the dispersal syndromes, we observed the morphological characteristics of diaspores in the voucher material deposited in the Herbarium UEC. Since few species were collected with diaspores, we also used plant images and drawings, type descriptions in the literature, and/or material collected outside PESM. Even though diaspores may be dispersed by animals belonging to different taxonomic groups, we based our classification on the dispersal syndromes proposed by Ridley (1930) and van der Pijl (1972), and, more specifically, on diaspore morphology. Though many species are subject to secondary dispersal by animals or water, for the purpose of this study we examined only the primary phase of dispersal (Seidler & Plotkin 2006).

4. *Data analysis*

We used chi-square tests to compare the frequency of occurrence of syndromes within each hierarchical level among

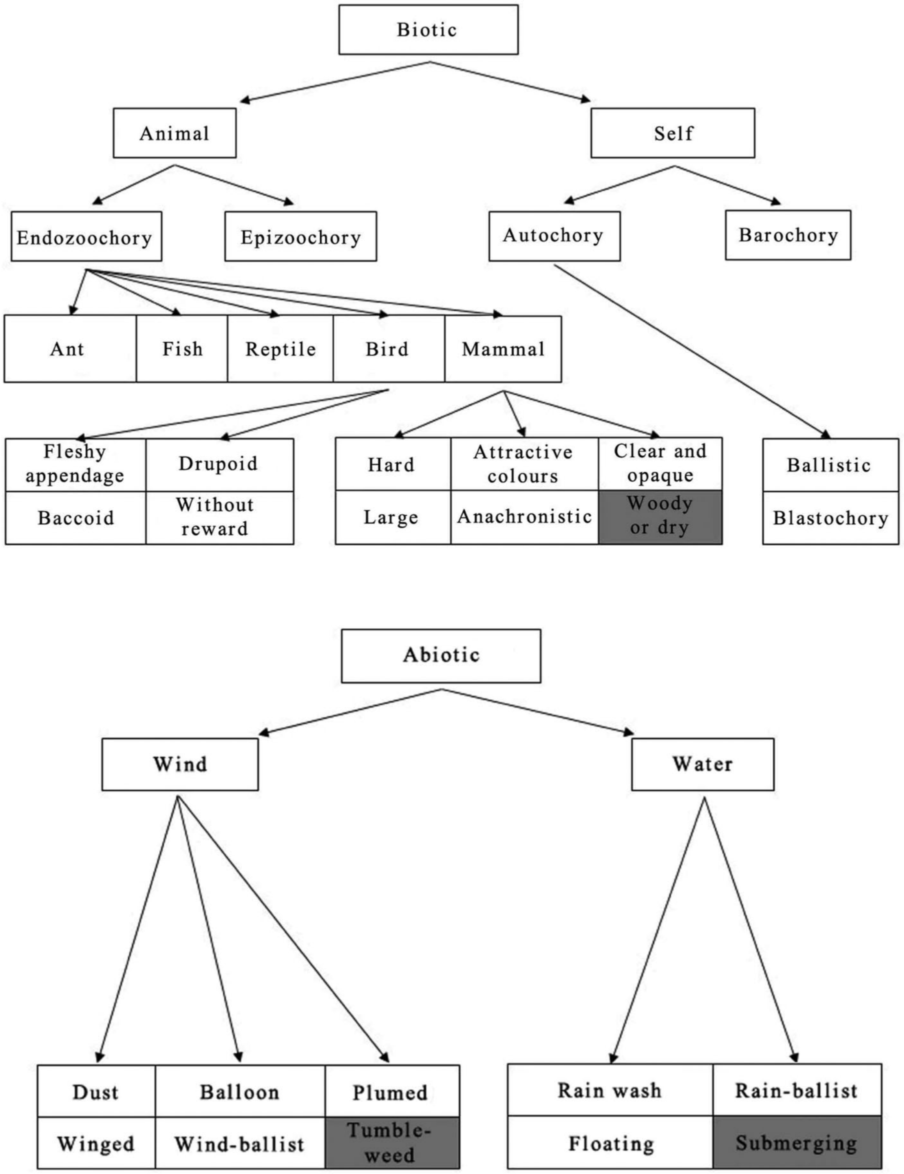

Figure 1. Diagram with five hierarchical levels of dispersal syndromes. Syndromes in grey boxes are those that definitely do not occur in tree species. For further explanation, please see the "Protocol for the classification of dispersal syndromes" at supplementary material 1.

the four forest types. The expected values for each level were the total number of species with identified syndromes in the four forest types together divided by the number of syndromes within the hierarchical level. We also used chi-square tests to compare the frequency of occurrence of syndromes within each hierarchical level in each of the four forest types. The expected values for level 1 were the total number of species with identified syndromes divided by two (biotic and abiotic dispersal). The expected values for further hierarchical levels were based on the proportion of species belonging to syndromes from the upper level. For example, for level 2, the expected values of animal and self dispersal were the number of biotically dispersed species divided by two, and the expected values of wind and water dispersal were the number of abiotically dispersed species divided by two. We did not perform any comparison among the syndromes of level 3, because all animal-dispersed species (level 2) presented endozoochorous diaspores (level 3), and the syndromes of epizoochory, autochory and barochory (all level 3) were represented by less than five species. For level 5, we performed chi-square tests for the different types of bird-dispersed diaspores alone, for the different types of mammal-dispersed diaspores alone, and for all types of bird, mammal and wind-dispersed diaspores together. All tests were performed for categories with sample size of at least five species, with $\alpha = 0.05$ (Zar 1999).

Results

We listed 83 species at Restinga, 137 at Lowland, 149 at Submontane and 144 at Montane. Because some species occurred in more than one forest type, we obtained a final list with 327 species for the four study plots. Within these species, one was NI at Restinga (corresponding to 1.2% of the species in this forest type), three were NI at Lowland (2.2%), three were undetermined at Montane (2.1%) and 13 were NI at

Table 1. Comparisons of the frequency of occurrence of dispersal syndromes within the same hierarchical level (please see Figure 1) among four forest types of the Atlantic Rainforest in SE Brazil. In all cases, d.f. = 3, except for the last comparison where d.f. = 12.**Tabela 1:** Comparações da frequência de ocorrência das síndromes de dispersão de um mesmo nível hierárquico (favor ver Figura 1) entre quatro tipos florestais da Mata Atlântica no sudeste do Brasil. Em todos os casos, g.l. = 3, com exceção da última comparação, na qual g.l. = 12.

Syndromes	χ^2	*P*
Level 1: abiotic agents x biotic agents	4.07	0.25
Level 2: wind x animal	4.05	0.26
Level 4: mammal x bird	0.66	0.88
Level 5: seeds with fleshy appendage attached x drupoid diaspores	0.29	0.96
Level 5: diaspores with attractive colours x (hard + clear and opaque + large diaspores)	3.15	0.37
Level 5: seeds with fleshy appendage attached x drupoid diaspores x diaspores with attractive colours x (hard + clear and opaque + large diaspores) x winged diaspores	4.88	0.18

Montane (9.0%). The list of all tree species sampled at the four forest types and their dispersal syndromes belonging to the five hierarchical levels proposed herein can be found at supplementary material 2.

As one travels through the diagram that organizes the hierarchical levels of the dispersal syndromes (Figure 1), the variation in diaspore morphology and in the group of dispersal agent decreases from the upper to the lower levels. As a result, the characteristics of the syndromes become more specific from the upper to the lower levels.

The frequency of occurrence of dispersal syndromes within each of the five hierarchical levels did not differ among the four forest types ($P > 0.05$; Table 1).The overall dispersal spectrum of the Atlantic Rainforest at PESM presents more species dispersed by biotic agents, mainly animals that consume diaspores and specifically birds, which disperse drupoid diaspores (Figure 2).

Species were dispersed 6.8 to 15.8 times more by biotic than by abiotic agents ($\chi^2 = 338.10$, $P < 0.001$, d.f. = 3). The frequency of animal dispersal was higher and that of wind dispersal lower than expected based on the proportion of species dispersed by biotic and abiotic agents, respectively ($\chi^2 = 244.37$, $P < 0.001$, d.f. = 3). Wind dispersal was the only abiotic syndrome found in the forest types. Among animal-dispersed species, bird dispersal was 2.7 to 3.5 times more common than mammal dispersal ($\chi^2 = 117.86$, $P < 0.001$, d.f. = 3; Figure 3).

Within bird dispersal, there was 3.3 to 4 times more drupoid diaspores than seeds with fleshy appendage attached ($\chi^2 = 324.78$, $P < 0.001$, d.f. = 3). Within mammal dispersal, there was 1.8 to 4.7 times more diaspores with attractive colours (corresponding to those attractive to primates) than hard (rodents), clear and opaque (bats), and large diaspores (Carnivora) together ($\chi^2 = 168.17$, $P < 0.001$, d.f. = 3; Table 2). For further explanation on names, please see the "Protocol for the classification of dispersal syndromes" at supplementary material 1.

Considering all syndromes of level 5, drupoid diaspores, diaspores with attractive colours and winged diaspores occurred at higher frequencies than expected based on the proportion of bird, mammal and wind-dispersed species respectively. Seeds with fleshy appendage attached occurred at a similar frequency to the expected based on the proportion of bird-dispersed species. Conversely, hard, clear and opaque, and large diaspores occurred less frequently than expected based on the proportion of mammal-dispersed species ($\chi^2 = 563.81$, $P < 0.001$, d.f. = 12; Table 2).

Discussion

In this study, we propose five hierarchical levels for the classification of dispersal syndromes based entirely on diaspore morphology. Using this classification, we found a similar dispersal spectrum along the altitudinal range of PESM, which is contrary to the expectation based on previous studies carried on the Atlantic Rainforest and elsewhere (*e.g.*, van der Pijl 1972, Roth 1987, Willson et al. 1990, Hughes et al. 1994, Pedroni 2001, Almeida-Neto et al. 2008). Even though climate is an important determinant of floristic composition along the altitudinal range (Joly et al. 2012), it probably does not act as a strong selective pressure on dispersal syndromes, hence resulting in the same dispersal spectrum among the forest types. Alternatively, the selective pressures imposed by rainfall and temperature may counteract each other and result in a similar dispersal spectrum along the altitudinal range. Future studies should also investigate whether the main groups of animal dispersers change along the altitudinal range, so the dispersal spectrum can be correlated with the dispersers at the study site.

Almost 90% of tree species at PESM are dispersed by biotic agents, particularly animals, which is the highest proportion of animal dispersal described for tropical forests elsewhere (Pedroni 2001, Kinoshita et al. 2006, Almeida-Neto et al. 2008, Silva & Rodal 2009). This great proportion of animal-dispersed species at PESM is likely to be related to high rainfall throughout the year in the mountain range of "Serra do Mar" and the high abundance of vertebrate frugivores in tropical forests (Gentry 1982, Willson et al. 1989, Vicente et al. 2003, Almeida-Neto et al. 2008). Most animal-dispersed species at PESM are attractive to birds, as described in other studies (Gentry 1982, Willson et al. 1989, Almeida-Neto et al. 2008). Nevertheless, bird dispersal is 2.7 to 3.5 times more frequent than mammal dispersal at our study site, which is a much higher proportion than the previous described 2:1 for the Neotropics (Gentry 1982, Almeida-Neto et al. 2008). Bird dispersal is likely to have great implications for seed deposition patterns and, consequently, for plant demography. This is because these animals deposit high quantities of seeds in specific sites (Debussche & Isenmann 1994, Takahashi & Kamitani 2004), such as near plants with many fruit (Pizo & Almeida-Neto 2009), taller plants that enable birds to better visualize both preys and predators (McDonnell 1986, Debussche & Isenmann 1994), and forest gaps (Debussche & Isenmann 1994, but also see Loiselle et al. 1996 and Martini & Santos 2007).

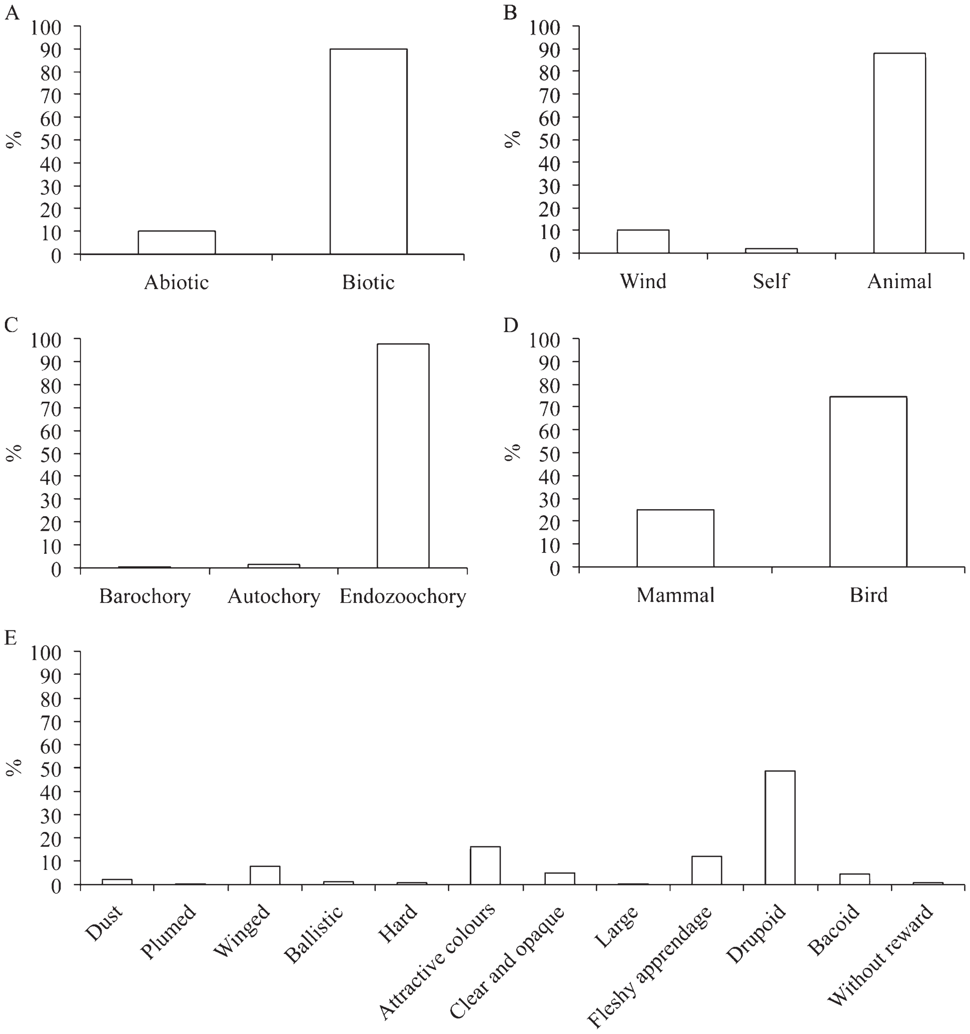

Figure 2. Dispersal spectrum within five hierarchical levels of dispersal syndromes (**A – E**; please see Figure 1) for the Atlantic Rainforest tree species in SE Brazil.

Most ornithochorous species found at PESM have drupoid diaspores, which are highly likely to be dispersed by large birds. The majority of mammal-dispersed species have diaspores dispersed by primates, which are large animals and can carry the diaspores distantly from the parent trees (Seidler & Plotkin 2006). Because large animals have larger home ranges (Kelt & Van Vuren 2001) and may carry seeds over longer distances than smaller animals (Seidler & Plotkin 2006), the seeds and seedlings of species dispersed by them can benefit by escaping mortality due to competition, predation and pathogen infestation near the parent plant. Conversely, seeds and seedlings can also benefit from colonization of new habitats (Wang & Smith 2002).

We found low occurrence of species dispersed by wind and the parent plant itself at PESM. Wind dispersal is predominant in regions of dry climate (van der Pijl 1972), unlike the Atlantic Rainforest. Previous studies in this type of forest also found few species dispersed by the parent plant itself (Vieira et al. 2002). Possibly, the low frequency of dispersal by wind and the parent plant itself arises from the low reproductive success of adults that release their diaspores in dense vegetation where they cannot travel long distances (Roth 1987). Additionally, the high diversity of animal dispersers at tropical forests has likely acted as a selective force driving the evolution of diaspores with characteristics attractive to animals.

This study shows that there are no differences in the dispersal spectrum among different forest types along an altitudinal range in the Atlantic Rainforest at PESM. This indicates that probably the selective pressures on dispersal syndromes resulting from climate conditions that vary within this range are not strong or counteract each other, hence resulting in the same dispersal spectrum among the forest types. The high frequency of animal-dispersed species, specifically bird-dispersed ones, contributes to the same dispersal spectrum among forest types. The high occurrence of these syndromes indicates that frugivorous animals, especially birds, are very important for the maintenance of communities in the Atlantic Rainforest unregard of altitude.

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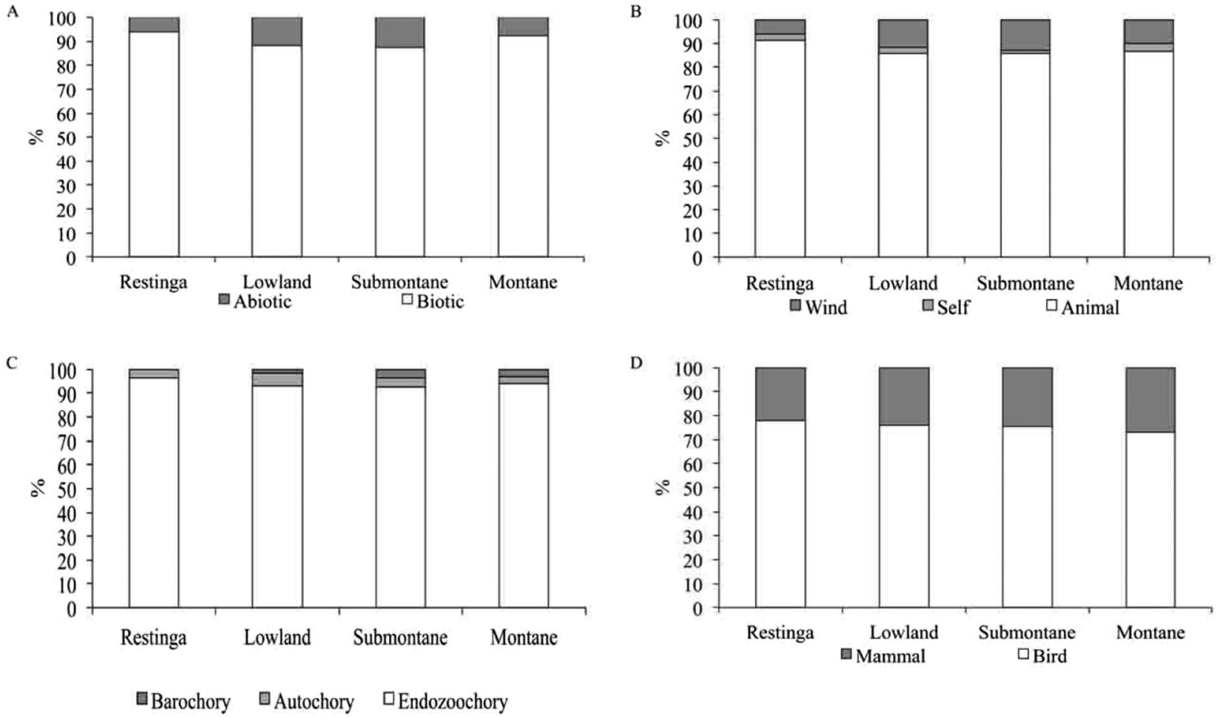

Figure 3. Percentage of occurrence of dispersal syndromes within four hierarchical levels (**A – D**; please see Figure 1) for four forest types of the Atlantic Rainforest in SE Brazil.

Table 2. Percentage of occurrence of dispersal syndromes of level 5 (please see Figure 1) for four forest types of the Atlantic Rainforest in SE Brazil. The syndromes of the immediate previous level are given for convenience.**Tabela 2:** Porcentagem de ocorrência das síndromes de dispersão do nível 5 (favor ver Figura 1) em quatro tipos florestais da Mata Atlântica no sudeste do Brasil. As síndromes do nível imediatamente anterior são dadas por conveniência.

Dispersal syndromes		**Forest type**			
Previous level	**Level 5**	**Restinga**	**Lowland**	**Submontane**	**Montane**
Bird dispersal	Seeds with fleshy appendage attached	14.52	14.02	12.24	15.41
	Druposporés	47.83	49.93	49.33	47.56
	Baccaspores	7.06	2.16	3.36	2.98
	Seeds without any nutritional reward	2.35	0.00	0.67	0.00
Mammal dispersal	Hard diaspores	0.00	0.00	0.67	1.19
	Diaspores with attractive colours	12.95	15.97	16.96	17.54
	Clear and opaque diaspores	5.88	3.59	2.68	6.55
	Large diaspores	1.18	0.72	0.67	0.00
Autochory	Ballistic release	2.35	1.44	0.67	0.60
Wind dispersal	Dust diaspores	0.00	2.88	4.03	1.79
	Plumed diaspores	0.00	0.72	0.67	0.00
	Winged diaspores	5.88	8.57	8.05	6.38

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References

ALMEIDA-NETO, M., CAMPASSI, F., GALETTI, M., JORDANO, P. & OLIVEIRA-FILHO, A. 2008. Vertebrate dispersal syndromes along the Atlantic forest: broad-scale patterns and macroecological correlates. Global Ecol. Biogeogr. 17(4):503-513. doi: http://dx.doi.org/10.1111/j.1466-8238.2008.00386.x

ALVES, L.F., VIEIRA, S.A., SCARANELLO, M.A., CAMARGO, P.B., SANTOS, F.A.M., JOLY, C.A. & MARTINELLI, L.A. 2010. Forest structure and abovegroung biomass variation along an elevational gradient of tropical Atlantic moist forest (Brazil). Forest Ecol. Manag. 260 (5):679-691. doi: http://dx.doi.org/10.1016/j.foreco.2010.05.023

BURNS, K.C., CAZETTA, E., GALETTI, M., VALIDO, A. & SCHAEFER, H.M. 2009. Geographic patterns in fruit colour diversity: do leaves constrain the colours of fleshy fruits? Oecologia 159(2):337-343. doi: http://dx.doi.org/10.1007/s00442-008-1227-3

CAMPASSI, F. 2006. Padrões geográficos das síndromes de dispersão e características dos frutos de espécies arbustivo-arbóreas em comunidades vegetais da Mata Atlântica. Tese de mestrado, Universidade de São Paulo, Escola Superior de Agricultura ''Luiz de Queiroz'', Piracicaba.

CARLO, T.A., COLLAZO, J.A. & GROOM, M.J. 2003. Avian fruit preferences across a Puerto Rican forested landscape: pattern consistency and implications for seed removal. Oecologia 134(1):119-131. doi: http://dx.doi.org/10.1007/s00442-002-1087-1

DEBUSSCHE, M. & ISENMANN, P. 1994. Bird-dispersed seed rain and seedling establishment in patchy Mediterranean vegetation. Oikos 69(3):414-426. doi: http://dx.doi.org/10.2307/3545854

EMBRAPA. http://www.bdclima.cnpm.embrapa.br. Last access in 30/05/2010.

FISCHER, K.E. & CHAPMAN, C.A. 1993. Frugivores and fruit syndromes: differences in patterns at the genus and species level. Oikos 66(3):472-482. doi: http://dx.doi.org/10.2307/3544942

FUNDAÇÃO SOS MATA ATLÂNTICA. www.sosmatatlantica.org.br. Last access in 23/04/2011.

GENTRY, A.H. 1982. Patterns of neotropical plant species diversity. Evol. Biol. 15:1-84. doi: http://dx.doi.org/10.1007/978-1-4615-6968-8_1

GOMIERO, L.M., SOUZA, U.P. & BRAGA, F.M.S. 2007. Reprodução e alimentação de *Rhamdia quelen* (Quoy & Gaimard, 1824) em rios do Núcleo Santa Virgínia, Parque Estadual da Serra do Mar, São Paulo, SP. Biota Neotrop. 7(3):127-133. http://www.biotaneotropica.org.br/v7n3/pt/abstract?article+bn01907032007 (last access in 23/07/2013). doi: http://dx.doi.org/10.1590/S1676-06032007000300015

HERRERA, C.M. 1985. Determinants of plant-animal coevolution: the case of mutualistic dispersal of seeds by vertebrates. Oikos 44(1):132-144. doi: http://dx.doi.org/10.2307/3544054

HERRERA, C.M. 1989. Frugivory and seed dispersal by carnivorous mammals, and associated fruit characteristics, in undisturbed Mediterranean habitats. Oikos 55(2):250-262. doi: http://dx.doi.org/10.2307/3565429

HERRERA, C.M. 2002. Seed dispersal by vertebrates. In Plant-animal interactions: an evolutionary approach (C.M. Herrera & O. Pellmry, ed). Blackwell Scientific Publications, Oxford, p.185-208.

HOLLANDER, J.L. & VANDER WALL, S.B. 2009. Dispersal syndromes in North American *Ephedra*. Int. J. Plant Sci. 170(3):323-330. doi: http://dx.doi.org/10.1086/596334

HOWE, H.F., SCHUPP, E.W. & WESTLEY, L.C. 1985. Early consequences of seed dispersal for a neotropical tree (*Virola surinamensis*). Ecology 66(3):781-791. doi: http://dx.doi.org/10.2307/1940539

HUGHES, L., DUNLOP, M., FRENCH, K., LEISHMAN, M.R., RICE, B., RODGERSON, L. & WESTOBY, M. 1994. Predicting dispersal spectra: a minimal set of hypotheses based on plant attributes. J. Ecol. 82(4):933-950. doi: http://dx.doi.org/10.2307/2261456

JANSON, C.H. 1983. Adaptation of fruit morphology to dispersal agents in a neotropical forest. Science 219(4581):187-189. doi: http://dx.doi.org/10.1126/science.219.4581.187

JANZEN, D.H. & MARTIN, P.S. 1982. Neotropical anachronisms: the fruits the Gomphotheres ate. Science 215(4528):19-27. doi: http://dx.doi.org/10.1126/science.215.4528.19

JOLY, C.A., ASSIS, M.A., BERNACCI, L.C., TAMASHIRO, J.Y., CAMPOS, M.C.R., GOMES, J.A.M.A., LACERDA, M.S., SANTOS, F.A.M., PEDRONI, F., PEREIRA, L.S., PADGURSCHI, M.C.G., PRATA, E.M., RAMOS, E., TORRES, R.B., ROCHELLE, A., MARTINS, F.R., ALVES, L.F., VIEIRA, S.A., MARTINELLI, L.A., CAMARGO, P.B.C., AIDAR, M.P.M., EISENLOHR, P.V., SIMÕES, E., VILLANI, J.P. & BELINELLO, R. 2012. Florística e fitossociologia em parcelas permanentes da Mata Atlântica do sudeste do Brasil ao longo de um gradiente altitudinal. Biota Neotrop. 12(1):123-145. http://www.biotaneotropica.org.br/v12n1/en/abstract?article+bn01812012012 (last access in 23/07/2013). doi: http://dx.doi.org/10.1590/S1676-06032012000100012

KELT, D.A. & VAN VUREN, D.H. 2001. The ecology and macroecology of mammalian home range area. Am. Nat. 157(6):637-645. doi: http://dx.doi.org/10.1086/320621

KINOSHITA, L.S., TORRES, R.B., FORNI-MARTINS, E.R., SPINELLI, T., AHN, Y.J. & CONSTÂNCIO, S.S. 2006. Composição florística e síndromes de polinização e de dispersão da mata do Sítio São Francisco, Campinas, SP, Brasil. Acta Bot. Bras. 20(2):313-327. doi: http://dx.doi.org/10.1590/S0102-33062006000200007

LOISELLE, B.A., RIBBENS, E. & VARGAS, O. 1996. Spatial and temporal variation of seed rain in a Tropical Lowland Wet Forest. Biotropica 28(1):82-95. doi: http://dx.doi.org/10.2307/2388773

LOMÁSCOLO, S.B., SPERANZA, P. & KIMBALL, R.T. 2008. Correlated evolution of fig size and color supports the dispersal syndromes hypothesis. Oecologia 156(4):783-796. doi: http://dx.doi.org/10.1007/s00442-008-1023-0

LORD, J.M. 2004. Frugivore gape size and the evolution of fruit size and shape in southern hemisphere floras. Austral Ecol. 29(4):430-436. doi: http://dx.doi.org/10.1111/j.1442-9993.2004.01382.x

MACK, A.L. 1993. The sizes of vertebrate-dispersed fruits: a neotropical-palaeotropical comparison. Am. Nat. 142(5):840-585. doi: http://dx.doi.org/10.1086/285575

MARTINI, A.M.Z. & SANTOS, F.A.M. 2007. Effects of distinct types of disturbance on seed rain in the Atlantic forest of NE Brazil. Plant Ecol. 190(1):81-95. doi: http://dx.doi.org/10.1007/s11258-006-9192-6

MARTINS, S.C. 2010. Perdas de nitrogênio pela emissão de óxido nitroso (N_2O) e sua relação com a decomposição da serapilheira e biomassa de raízes na floresta de Mata Atlântica. Tese de doutorado, Universidade de São Paulo, Piracicaba.

MAZER, S.J. & WHEELWRIGHT, N.T. 1993. Fruit size and shape: allometry at different taxonomic levels in bird-dispersed plants. Evol. Ecol. 7(6):556-575. doi: http://dx.doi.org/10.1007/BF01237821

MCDONNELL, M.J. 1986. Old field vegetation height and the dispersal pattern of bird-disseminated woody plants. B. Torrey Bot. Club 113(1):6-11. doi: http://dx.doi.org/10.2307/2996227

MORAN, C., CATTERALL, C.P., GREEN, R.J. & OLSEN, M.F. 2004. Functional variation among frugivorous birds: implications for rainforest seed dispersal in a fragmented subtropical landscape. Oecologia 141(4):584-595. doi: http://dx.doi.org/10.1007/s00442-004-1685-1

MYERS, N., MITTERMEIER, R.A., MITTERMEIER, C.G., FONSECA, G.A.B. & KENT, J. 2000. Biodiversity hotspots for conservation priorities. Nature 403(6772):852-858. doi: http://dx.doi.org/10.1038/35002501

PEDRONI, F. 2001. Aspectos da estrutura e dinâmica da comunidade arbórea na Mata Atlântica de planície e encosta em Picinguaba, Ubatuba, SP. Tese de doutorado, Universidade Estadual de Campinas, Campinas.

PHILLIPS, O., BAKER, T., FELDPAUSCH, T. & BRIENEN, R. 2009. RAINFOR field manual for plot establishment and remeasurement. http://www.rainfor.org/en/manuals. Last access in 27/11/2013.

PIZO, M.A. & ALMEIDA-NETO, M. 2009. Determinants of fruit removal in *Geonoma pauciflora*, an understorey palm of neotropical forests. Ecol. Res. 24(6):1179-1186. doi: http://dx.doi.org/10.1007/s11284-009-0599-0

RIDLEY, H.N. 1930. The dispersal of plants throughout the world. L. Reeve & CO., LTD., Ashford.

ROTH, I. 1987. Stratification of a tropical forest as seen in dispersal types. Dr. W. Junk Publishers, Dordrecht.

SEIDLER, T. & PLOTKIN, J.B. 2006. Seed dispersal and spatial pattern in tropical trees. PLOS Biol. 4(11):2132-2137. doi: http://dx.doi.org/10.1371/journal.pbio.0040344

SILVA, M.C.N.A. & RODAL, M.J.N. 2009. Padrões das síndromes de dispersão de plantas em áreas com diferentes graus de pluviosidade, PE, Brasil. Acta Bot. Bras. 23(4):1040-1047. doi: http://dx.doi.org/10.1590/S0102-33062009000400014

SILVA-DIAS, M.A.E., VIDALE, P.E. & BLANCO, C.M.R. 1995. Case study and numerical simulation of the summer regional circulation in São Paulo, Brazil. Bound.-Lay. Meteorol. 74(4):371-388. doi: http://dx.doi.org/10.1007/BF00712378

SOS MATA ATLÂNTICA/INPE/ISA. 1998. Atlas da evolução dos remanescentes florestais e ecossistemas associados ao domínio da Mata Atlântica no período 1990–95. SOS Mata Atlântica/INPE/ISA, São Paulo.

SOUSA NETO, E.R. 2008. Perdas de nitrogênio pela emissão de óxido nitroso (N_2O) e sua relação com a decomposição da serapilheira e biomassa de raízes na floresta de Mata Atlântica. Tese de mestrado, Universidade de São Paulo, Piracicaba.

SUGUIO, K. & MARTIN, L. 1978. Quaternary marine formations of the states of São Paulo and southern Rio de Janeiro. In International Symposium on Coastal Evolution in the Quaternary. Universidade de São Paulo, São Paulo, p. 55.

TAKAHASHI, K. & KAMITANI, T. 2004. Factors affecting seed rain beneath fleshy-fruited plants. Plant Ecol. 174(2):247-256. doi: http://dx.doi.org/10.1023/B:VEGE.0000049105.30878.25

VAN DER PIJL, L. 1972. Principles of dispersal in higher plants. 2 ed. Springer-Verlag, Würzburg.

VELOSO, H.P., RANGEL-FILHO, A.L.R. & LIMA, J.C.A. 2001. Classificação da vegetação brasileira, adaptada a um sistema universal. IBGE, Rio de Janeiro.

VICENTE, A., SANTOS, A.M.M. & TABARELLI, M. 2003. Variação no modo de dispersão de espécies lenhosas em um gradient de precipitação em em floresta seca e úmida no nordeste do Brasil. In Ecologia e conservação da caatinga (I. Leal, M. Tabarelli & J.M.C. Silva, ed). Editora Universitária da UFPE, Recife, p.201-231.

VIEIRA, D.L.M., AQUINO, F.G., BRITO, M.A., FERNANDES-BULHÃO, C. & HENRIQUES, R.P.B. 2002. Síndromes de dispersão de espécies arbustivo-arbóreas em cerrado *sensu stricto* do Brasil Central e savanas amazônicas. Rev. Bras. Bot. 25(2):215-220. doi: http://dx.doi.org/10.1590/S0100-84042002000200009

WANG, B.C. & SMITH, T.B. 2002. Closing the seed dispersal loop. Trends Ecol. Evol. 17(8):379-385. doi: http://dx.doi.org/10.1016/S0169-5347(02)02541-7

WHEELWRIGHT, N.T. 1985. Fruit size, gape width, and the diets of fruit-eating birds. Ecology 66(3):808-818. doi: http://dx.doi.org/10.2307/1940542

WILLSON, M.F., IRVINE, A.K. & WALSH, N.G. 1989. Vertebrate dispersal syndromes in some Australian and New Zealand plant communities, with geographic comparisons. Biotropica 21(2):133-147. doi: http://dx.doi.org/10.2307/2388704

WILLSON, M.F., RICE, B.L. & WESTOBY, M. 1990. Seed dispersal spectra: a comparison of temperate plant communities. J. Veg. Sci. 1(4):547-562. doi: http://dx.doi.org/10.2307/3235789

ZAR, J.H. 1999. Biostatistical analysis. 4 ed. Prentice-Hall, Upper Saddle River.

Supplementary material 1: Protocol for the classification of dispersal syndromes

This protocol includes a description of diaspore and vegetative characteristics that will help to identify all forms of diaspore dispersal. The exception are the following forms that are absent from tree species or that do not present common traits that indicate a dispersal syndrome: (1) dispersal by slugs, which does not constitute a dispersal syndrome (Gervais et al. 1998, Tuerke et al. 2010); (2) dispersal by earthworms, which also does not constitute a dispersal syndrome (Milcu et al. 2006); (3) dispersal by bees, described for only two tree species with fruits that produce resin or wax (Wallace & Trueman 1995, Wallace et al. 2008); (4) dispersal by beetles, mainly described for dung beetles, which collect faeces containing seeds primarily dispersed by vertebrates (Vulinec 2002). However, beetles have also been found ingesting fruit pulp with seeds of one parasitic species in the Mediterranean region (de Vega et al. 2011); (5) dispersal by weta, giant flightless crickets in New Zealand (Burns 2006, Duthie et al. 2006); (6) ant-dispersed species that form ant gardens and only occur in epiphytes (Ule 1905 *apud* van der Pijl 1972, van der Pijl 1972); (7) ant-dispersed species with short stems that droop to the ground when the seeds are ripe, which can only occur in herbaceous plants (Handel & Beattie 1990); (8) dispersal by tree-frogs, found only in a single bromeliad species (Silva et al. 1989); (9) woody or dry fruits with small hard seeds produced by herbaceous plants; (10) tumbleweeds, restricted to herbaceous plants, and (11) diaspores that submerge in water, which only occur in aquatic species (van der Pijl 1972). The main studies reviewed for the elaboration of this protocol were: Ridley (1930), van der Pijl (1972), Roth (1987), Herrera (1989), Banack (1998), Laubhann & Puff (2002) and Dumont (2003). All characteristics described here can be observed in herbarium specimens, photographs, diagrams and information about the species in the literature.

The protocol is organized into hierarchical levels, according to the diagram in Fig. 1 presented in the paper. The diagram establishes a hierarchical classification of the dispersal syndromes in five levels, each composed of several groups. At each subsequent level of the hierarchy, the morphological characteristics of the diaspores are given in greater detail, thus further specifying the disperser agents. As a result, the characteristics of the syndromes become more specific from the upper levels to the lower levels. Nevertheless, some dispersal syndromes are unfiled to all hierarchical levels. This happens because some diaspores reach a high level of detail without showing intermediate levels and, thus, are classified directly into level 5 of the hierarchy.

A list of all tree species sampled at four forest types of the Atlantic Rainforest in Southeast Brazil and their dispersal syndromes belonging to the five hierarchical levels proposed herein can be found at supplementary material 2. In this protocol, we only give examples of species with dispersal syndromes that were not found at the study site.

1. Level 1: Dispersal by biotic agents

1.1. Level 2: Animal dispersal: animal-dispersed diaspores can either be consumed or stick externally to the body of animals (Ridley 1930, van der Pijl 1972).

1.1.1. Level 3: Endozoochory (diaspores consumed by animals): endozoochorous diaspores usually contain a fleshy portion, such as fruits with pulp and seeds with fleshy appendages attached. This fleshy portion primarily provides nutrients and energy to the animals (Ridley 1930, van der Pijl 1972, Hölldobler & Wilson 1990). The diaspores can present odour, attractive colours (bright yellow, orange, red, pink, purple, blue or black) and protection against premature consumption, such as green colour and unpalatable substances (van der Pijl 1972). The fruits may have hard or soft skin (Banack 1998, Dumont 2003), and a sweet flavour because, when ripe, their sugar content increases. Moreover, they become softer due to the presence of pectin (Raven 2007).

1.1.1.1. Level 4: Ant dispersal: the characteristic diagnosing this syndrome are seeds covered by an oleaginous external portion, which generally makes up the elaiosome. The lipid compounds are volatile and attract ants, which carry the seeds to their nest to feed on the oleaginous portion, eventually dispersing the seeds (Ridley 1930, van der Pijl 1972, Hölldobler & Wilson 1990). The groups of ant dispersal presented below are intended only to facilitate the identification of diaspores dispersed by ants and are not an actual level within the syndrome. One example of species dispersed by ants is *Mabea fistulifera* Mart.

i- Seeds with elaiosome attached: are characterized by the presence of a fleshy appendage externally to the seed. It is rich in lipids and is called the elaiosome (van der Pijl 1972, Hölldobler & Wilson 1990). It is usually white, contrasting with the seed, which is dark, hard, smooth and apparently difficult to destroy (van der Pijl 1972). One example of species that produce seeds with an elaiosome attached is *Mabea fistulifera*.

ii- Seeds that secrete lipids by the testa: are characterized by the presence of an oleaginous material distributed throughout the whole fleshy testa. Sometimes, this material can be found in small parts of the inflorescence that remain attached to the seeds (Ridley 1930, van der Pijl 1972). Species of *Ficus* secrete lipids by the testa, but we classified the five species of this genus found in the forest types studied as mammal-dispersed, with clear and opaque diaspores (correspondent to those attractive to bats; item 1.1.1.5.3.) because they presented more characteristics of this syndrome than of ant dispersal.

When the seed has no elaiosome attached or oleaginous material distributed throughout its fleshy testa, characteristics of the parent plant may indicate the occurrence of dispersal by ants. In this case, the plants can facilitate the encounter of the diaspores by ants, and also provide food and/or shelter for them. Therefore, while foraging on the plant, the ants find the diaspores and take them to their nests (Ridley 1930, van der Pijl 1972, Handel & Beattie 1990). The characteristics of the parent plants indicating the occurrence of dispersal by ants are:

iii- Form of diaspore presentation: dehiscent fruits (open spontaneously during maturation) that remain open for a long time and infructescences with seeds that are easily accessible (Handel & Beattie 1990, Gonçalves & Lorenzi 2007). A herbaceous species with the latter form of presentation of its diaspores is *Urera baccifera* (L.) Gaudich. ex Wedd.

iv- Plants with extra-floral nectaries (EFNs) or post-floral nectaries (PFNs): nectaries are glands that produce nectar, a secretion rich in sugars. EFNs are usually located on the stem, the petiole or the leaf blade (van der Pijl 1972, Hölldobler & Wilson 1990, Gonçalves & Lorenzi 2007). The PFNs are located next to the fruits and secrete nectar even during fruit development (van der Pijl 1972, Ferri et al. 1981). One example of species with EFNs is *Acacia pycnantha* Benth.

v- Plants with formicaries: formicaries are spaces in the leaf or on the stem that serve as shelter for ants (Hölldobler & Wilson 1990). A herbaceous species with formicaries is *Tococa formicaria* Mart..

vi- Plants with food bodies: food bodies are small, pearl-like epidermal structures, showing basal constriction. Lipids and glycogen are the major metabolites of these structures, which may be associated with EFNs and formicaries. The food bodies are located in different parts of the plant, such as in the rachis (main vein of compound leaves) and pinnule (last leaflets of leaves with blades divided close to the main vein), or at the base of the petiole (Ferri et al. 1981, Gonçalves & Lorenzi 2007). One example of species that have food bodies are those belonging to *Acacia*.

1.1.1.2. Level 4: Fish dispersal: occurs in species that grow on riverbanks or in flooded sites. Their diaspores are heavy and fall off the parent plant into the water where they may either sink or float. These diaspores may have hard skin, which can only be opened by the jaws of fish, and many small, hard seeds, which are not damaged during the passage through the digestive tract (van der Pijl 1972, Kubitzki & Ziburski 1994). One example of species dispersed by fish is *Eugenia inundata* DC.

1.1.1.3. Level 4: Reptile dispersal (performed by lizards, alligators and turtles): is characterized by fruits equipped with odour (van der Pijl 1972), usually with a red or orange colour (Klimstra & Newsome 1960), and that develop close to the ground or fall off from the parent plant when ripe. Some species have fruits equipped with hard skin (van der Pijl 1972). One example of species dispersed by reptiles is *Celtis australis* L.

1.1.1.4. Level 4: Bird dispersal: diaspores dispersed by birds are bright and show contrasting colours, such as red and black, orange and black, and black or dark blue with light colours; contrast between the diaspores and leaves; contrast between the diaspores and its coloured auxiliary organs. The diaspores usually have an edible part, such as the fruit pulp or fleshy appendages attached to the seed. However, there are some bird-dispersed seeds that do not have an edible part, although their colour is attractive to birds and resembles seeds with fleshy appendages or fleshy fruits. These seeds are commonly referred to as mimetic (van der Pijl 1972, Laubhann & Puff 2002), although there are other hypotheses for the evolution of such colour pattern (see Peres & van Rossmalen 1996, Foster & Delay 1998 and Galetti 2002). When immature, bird-dispersed diaspores have an external protection against premature consumption; the seeds also have a protection from premature digestion (van der Pijl 1972). The diaspores are easily accessible to birds, such as hanging fruit and/or seeds (van der Pijl 1972, Roth 1987), rarely have an odour (van der Pijl 1972) and are small (≤ 2 cm; Willson et al. 1989). Due to the great variation of bird-dispersed diaspores, they can be classified according to their morphology into the following groups:

1.1.1.4.1. Level 5: Seeds with fleshy appendage attached: are characterized by seeds fully or partially covered by sarcotesta, aril or ariloid structures (Barroso et al. 1999). These appendages provide a contrasting colour with the seed. The seeds are exposed in hard-skinned dehiscent fruits (van der Pijl 1972, Laubhann & Puff 2002).

1.1.1.4.2. Level 5: Drupoid diaspores: are characterized by diaspores with a single or just a few seeds (the species analysed showed up to six), which are large in relation to the diaspore. The exocarp, or skin of the fruit or fruitlet, has attractive colours to birds and is not rigid. Drupoid diaspores are indehiscent (do not open during maturation; Gonçalves & Lorenzi 2007). During the dispersal event, mainly large-bodied birds can swallow the whole diaspore and carry its large seeds (Wheelwright 1985). Small birds can sometimes swallow diaspores with a single or just a few large seeds, but they are less willing or able to carry the mass of ballast associated with them (Mack 1993). Therefore, small birds are most likely to only peck at the pulp of drupoid diaspores and do not act as dispersers of their large seeds.

1.1.1.4.3. Level 5: Baccoid diaspores: are characterized by diaspores with dozens or hundreds of small seeds immersed in the pulp. The exocarp has attractive colours to birds and is not rigid. Baccoid diaspores are indehiscent. During the dispersal event, a bird carries several seeds belonging to the same baccoid diaspore: the number of seeds varies with the size of the bird in relation to the size of the diaspore, which may be swallowed whole or have a portion pecked at. The terms drupoid and baccoid diaspores were here employed because, even though there are classifications for fruits in the literature, there are no specific terms for diaspores (either a single fruit, or a fruitlet from a compound fruit or infructescence) with these characteristics.

1.1.1.4.4. Level 5: Seeds without any nutritional reward: are characterized by seeds with colours similar to that of seeds with a fleshy appendage so that they appear to have one. Seeds without nutritional reward may also appear to be juicy, similar to a fleshy fruit. However, they are hard and dry (van der Pijl 1972, Laubhann & Puff 2002).

1.1.1.5. Level 4: Mammal dispersal: the diaspores are usually large (> 2 cm; Ridley 1930, van der Pijl 1972) and the seeds are protected from premature digestion. Some fruits have an external protection against premature consumption, while the edible portion in others has a green colour even when ripe. The ripe fruits may have a strong odour, which is typical of diaspores dispersed by mammals (van der Pijl 1972). Mammal-dispersed fruits have a watery pulp (van der Pijl 1972, Albuquerque 2001) and hard or soft skin (Banack 1998, Dumont 2003), lie outside the foliage attached to the stem or near the ground, and fall off the parent plant continuously. Attractive colours are not always present (van der Pijl 1972). Mammals can also disperse dry fruits, or consume large seeds with yellow or orange fleshy appendages. Due to the great variation of mammal-dispersed diaspores, they can be classified according to their morphology into the following groups:

1.1.1.5.1. Level 5: Hard diaspores (attractive to rodents): are often equipped with a hard exocarp (van der Pijl 1972), green pericarp and one or more seeds (Ridley 1930). The typical odour found in mammal-dispersed fruits is absent (van der Pijl 1972). Some fruits belonging to this group are fleshy, made up of red, green or yellow capsules, with seeds surrounded by a white pulp (Ridley 1930). Seeds with hard, waxy ariloid structures attached also belong to this group (van der Pijl 1972).

1.1.1.5.2. Level 5: Diaspores with attractive colours (attractive to primates): are characterized by the most coloured fruits amongst those dispersed by mammals (van der Pijl 1972), with black, purple, pink, yellow, orange or grey-green colours (Ridley 1930). The fruits belonging to this group may have hard or soft skin, a strong odour (but not a rotten smell) and juiciness (van der Pijl 1972). Seeds with a yellow or orange aril (Ridley 1930, van der Pijl 1972), much larger than those dispersed by birds, also belong to this group (Ridley 1930).

1.1.1.5.3. Level 5: Clear and opaque diaspores (attractive to bats): are characterized by clear and opaque colours (van der Pijl 1972), in shades of purple, blue, green, yellow, yellow-green, white or orange. They contrast with the darker foliage and make the diaspores more easily seen at night by bats (Dumont 2003). Clear and opaque diaspores are unprotected and exposed on branches, generally have a watery pulp (van der Pijl 1972, Albuquerque 2001) and may be equipped with hard or soft skin (Banack 1998, Dumont 2003). They often have a strong odour, conferred by aromatic compounds; the odour is not necessarily a rotten smell and may be imperceptible to humans. The fruit shape is highly variable and may be spherical to cob-shaped (M.A.R. Mello personal communication). The fruits are of different sizes (Dumont 2003) and occur mainly in the families Araceae, Clusiaceae, Cucurbitaceae, Moraceae, Piperaceae, Solanaceae and Urticaceae (van der Pijl 1972, Mello et al. 2008).

1.1.1.5.4. Level 5: Large diaspores (attractive to mammals belonging to the order Carnivora): are characterized by fruits that are much heavier (2.23 g ± 4.05 g) than those dispersed by birds and other mammals (with the exception of diaspores with attractive colours and anachronistic fruits), rich in pulp (68.9% ± 18.6% of fresh fruit mass) and with many seeds (60 ± 258 seeds/fruit; Herrera 1989). They also have a specific odour and commonly fall off the parent plant when ripe. Their colours are attractive, such as red, black, and mainly brown, white, blue and green (Ridley 1930, Herrera 1989). The fruits of this group generally belong to herbaceous plants and to species of Arecaceae (Ridley 1930, van der Pijl 1972).

1.1.1.5.5. Level 5: Anachronistic fruits: are characterized by very large, indehiscent fruits (much larger than those belonging to the other syndromes) with a pulp rich in oil, sugar or nitrogen compounds. They lack any attractive colour. The hardness, size and weight of these fruits are similar to those consumed by large African mammals. These features indicate that the anachronistic fruits were dispersed by the South American megafauna, which became extinct about 10,000 years ago. After the extinction of these animals, there might have been a population decline of the plant species dispersed by them, although some would still remain viable due to sporadic dispersal by other agents (Janzen & Martin 1982, Guimarães Jr. et al. 2008). Other characteristics of anachronistic fruits are the presence of seeds enclosed within a hard or thick endocarp, or soft or fragile seeds that are very small or embedded in a hard portion of the fruit (Janzen & Martin 1982). Examples of species of this group are: *Crescentia alata* Kunth, *Enterolobium cyclocarpum* (Jacq.) Griseb. and *Hippomane mancinella* L.

1.1.2. Level 3: Epizoochory (or exozoochory; diaspores that cling externally to the body of animals): the diaspores do not have an edible portion and therefore do not provide resources for animals. They also do not have attractive colours and odour, and have a rough texture (Sorensen 1986) and adhering mechanisms such as thorns, barbs, hairs (usually hard and curved), hooks or sticky exudates (van der Pijl 1972, Sorensen 1986, Raven 2007) which allow the diaspores to stick to animal scales, feathers and fur. The diaspores may be dry fruits that are easily detached from the parent plant when ripe. They develop near the ground and occur mainly in herbaceous species (Ridley 1930, van der Pijl 1972). Examples of herbaceous epizoochorous species are: *Acanthospermum hispidum* DC., *Bidens laevis* (L.) B.S.P. and *Desmodium psilophyllum* Schlecht.; we did not find any example of a tree species with this syndrome.

1.2. Level 2: Self dispersal (dispersal performed by the parent plant itself):

1.2.1. Level 3: Autochory (dispersal performed actively by the parent plant): is characterized by diaspores with brown or pale colours (Roth 1987). Autochorous diaspores can be released from the parent plant in two ways:

1.2.1.1. Level 5: Explosive or ballistic release: is characterized by seeds and fruits with structures or mechanisms (turgor and hygroscopic movements) that shoot the diaspores away from the parent plant. They are usually dry fruits (van der Pijl 1972, Albuquerque 2001).

1.2.1.2. Level 5: Blastochory: is characterized by the growth of branches with fruits at the tip, causing the seeds to fall further away from the parent plant (van der Pijl 1972). Examples of herbaceous species of this group are: *Aegilops ovata* L. and *Erodium ciconium* (L.) L'Hér.; we did not find any example of a tree species with blastochorous diaspores.

1.2.2. Level 3: Barochory (fall of the diaspores because of gravity): is characterized by diaspores with aerodynamic shapes such as a round one, and a relatively large mass (van der Pijl 1972). Some barochorous species have dry fruits (such as capsules that open at the sept; Gonçalves & Lorenzi 2007), from which the seeds are detached (Albuquerque 2001).

2. Level 1: Dispersal by abiotic agents

2.1. Level 2: Wind dispersal: is characterized by dry fruits without attractive colours, which is often brown. The fruits are equipped with numerous seeds of generally small mass (van der Pijl 1972). Wind-dispersed diaspores can be classified according to their morphological characteristics into the following groups:

2.1.1. Level 5: Dust diaspores: are characterized by very small and light weighted seeds (about 10^{-6} g; van der Pijl 1972).

2.1.2. Level 5: Balloons: are characterized by small seeds with testa in the shape of a balloon, or balloon-shaped fruits such as inflated and indehiscent pods. Sometimes this shape is provided by an auxiliary organ such as a bracteole or the perianth (van der Pijl 1972). One example of species of this group is *Colutea arborescens* L.

2.1.3. Level 5: Plumed diaspores: have hairs originated from different structures. The hairs can be long (single or more than one) or occur in tufts (van der Pijl 1972). Some plumed seeds are encased in a capsule or pod and the hairs expand externally to the fruit. These hairs can be thin, simple, straight and silky; branched or tangled; or form a woolly mass (Ridley 1930). The diaspores belonging to this group have well-developed, smooth, silky hairs, different from the hard ones of epizoochorous diaspores (Sorensen 1986).

2.1.4. Level 5: Winged diaspores: are characterized by one or more flattened protrusions called wings, which may originate from the seed, the fruit or auxiliary organs (van der Pijl 1972).

2.1.5. Level 5: Wind-ballists (anemoballists): are characterized by diaspores that are released explosively after a gust of wind. They are heavier than wind-dispersed diaspores belonging to the other groups (van der Pijl 1972). One herbaceous species of this group is *Papaver somniferum* L.; we did not find any example of a tree species dispersed ballistically by wind.

2.2. Level 2: Water dispersal: occurs mainly in plants from aquatic environments (Ridley 1930, van der Pijl 1972), but has also been described for a herbaceous species in the Atlantic Rainforest (Pizo & Morellato 2002). The diaspores can often float, at least for short distances, and are heavier than those dispersed by wind (Ridley 1930, van der Pijl 1972). One example of a species dispersed by water is *Cocos nucifera* L. Water-dispersed diaspores can be classified according to their morphological characteristics into the following groups:

2.2.1. Level 5: Rain wash (ombrohydrochory): is characterized by brown coloured dry fruits equipped with numerous seeds, as in some wind-dispersed diaspores. However, they are heavier than the latter (van der Pijl 1972). Examples of herbaceous species of this group are: *Geigeria acaulis* (Sch. Bip.) Benth & Hook. Ex Oliv. & Hiern., *Leptaleum filifolium* (Willd.) DC. and *Sedum acre* L.; we did not find any example of a tree species with rain wash dispersal.

2.2.2. Level 5: Rain-ballists: are characterized by seeds that are released explosively from the fruit driven by rainfall. The seeds are released from cup-shaped fruits, by a catapult mechanism of the fruit or through fruit pores (van der Pijl 1972, Pizo & Morellato 2002). The latter was described for *Bertolonia mosenii* Cogn. (Melastomataceae), a perennial herb of the Atlantic Rainforest: the rainfall squeezes the seeds out of the triangular capsule-fruit through pores present at its vertices (known as the squirt-corner mechanism). The seeds are obovate (oval-shaped, with a wider part toward the apex of the seed) and cleaved (club-shaped, with a dilated portion on the extremities; Ferri et al. 1981, Pizo & Morellato 2002), contrasting with the seeds released from cup-shaped fruits, which are lenticular (lens-shaped; Pizo & Morellato 2002). Examples of herbaceous species of this group are: *Bertolonia mosenii*, *Ocimum basilucum* L. and *Thlaspi perfoliatum* L.; we did not find any example of a tree species dispersed ballistically by rain.

2.2.3. Level 5: Floating diaspores: are generally seeds that have both a waterproof testa and low density, which is possible due to the presence of aerenchyma, light albumen and cotyledons, or corky tissues (van der Pijl 1972). Examples of species of this group are: *Cocos nucifera* and *Hevea brasiliensis* (Willd. ex Adr. de Juss.) Muell-Arg.

Diaspores without specific morphological characteristics: are characterized by the absence of morphological features that allow us to identify the syndrome to which they belong.

References

ALBUQUERQUE, L.B. 2001. Polinização e dispersão de sementes em Solanáceas Neotropicais. Tese de doutorado, Universidade Estadual de Campinas, Campinas.

BANACK, S.A. 1998. Diet selection and resource use by flying foxes (genus *Pteropus*). Ecology 79(6):1949-1967. doi: http://dx.doi.org/10.1890/0012-9658(1998)079[1949:DSARUB]2.0.CO;2

BARROSO, G.M., MORIM, M.P., PEIXOTO, A.L. & ICHASO, C.L.F. 1999. Frutos e sementes, morfologia aplicada à sistemática de dicotiledôneas. Editora da Universidade Federal de Viçosa, Viçosa.

BURNS, K.C. 2006. Weta and the evolution of fleshy fruits in New Zealand. New Zeal. J. Ecol. 30(3):405-406.

DE VEGA, C, ARISTA, M., ORTIZ, P.L., HERRERA, C. M. & TALAVERA, S. 2011. Endozoochory by beetles: a novel seed dispersal mechanism. Ann. Bot. 107(4):629-637. doi: http://dx.doi.org/10.1093/aob/mcr013

DUMONT, E. 2003. Bats and fruits: an ecomorphological approach. In Bat ecology (T.H. Kunz & M.B. Fenton, ed). The University of Chicago Press, Chicago, p.398-429.

DUTHIE, C., GIBBS, G. & BURNS, K.C. 2006. Seed dispersal by weta. Science 311(5767):1575. doi: http://dx.doi.org/10.1126/science.1123544

FERRI, M.G., MENEZES, N.L. & MONTEIRO, W.R. 1981. Glossário ilustrado de botânica. Nobel, São Paulo.

FOSTER, M.S. & DELAY, L.S. 1998. Dispersal of mimetic seeds of three species of *Ormosia* (Leguminosae). J. Trop. Ecol. 14(4):389-411. doi: http://dx.doi.org/10.1017/S0266467498000303

GALETTI, M. 2002. Seed dispersal of mimetic fruits: parasitism, mutualism, aposematism or exaptation? In Seed dispersal and frugivory: ecology, evolution and conservation (D.J. Levey, W.R. Silva & Galetti, M., ed). CABI Publishing, Cambridge, p.177-191.

GERVAIS, J.A., TRAVESET, A. & WILLSON, M.F. 1998. The potential of seed dispersal by the Banana Slug (*Ariolimax columbianus*). Am. Midl. Nat. 140(1):103-110. doi: http://dx.doi.org/10.1674/0003-0031(1998)140[0103:TPFSDB]2.0.CO;2

GONÇALVES, E.G. & LORENZI, H. 2007. Morfologia vegetal: organografia e dicionário ilustrado de morfologia das plantas vasculares. Instituto Plantarum de Estudos da Flora, Nova Odessa.

GUIMARÃES JR., P.R.; GALETTI, M. & JORDANO, P. 2008. Seed dispersal anachronisms: rethinking the fruits extinct megafauna ate. PLOS One 3(3):e1745. doi: http://dx.doi.org/10.1371/journal.pone.0001745

HANDEL, S.N. & BEATTIE, A.J. 1990. Seed dispersal by ants. Sci. Am. 263(2):76-83. doi: http://dx.doi.org/10.1038/scientificamerican0890-76

HERRERA, C.M. 1989. Frugivory and seed dispersal by carnivorous mammals, and associated fruit characteristics, in undisturbed Mediterranean habitats. Oikos 55(2):250-262. doi: http://dx.doi.org/10.2307/3565429

HÖLLDOBLER, B. & WILSON, E.O. 1990. The ants. The Belknap Press, Cambridge.

JANZEN, D.H. & MARTIN, P.S. 1982. Neotropical anachronisms: the fruits the Gomphotheres ate. Science 215(4528):19-27. doi: http://dx.doi.org/10.1126/science.215.4528.19

KLIMSTRA, W.D. & NEWSOME, F. 1960. Some observations on the food coactions of the common Box Turtle (*Terrapene c. caroline*). Ecology 41(4):639-647. doi: http://dx.doi.org/10.2307/1931795

KUBITZKI, K. & ZIBURSKI, A. 1994. Seed dispersal in flood plain forest of Amazonia. Biotropica 26(1):30-43. doi: http://dx.doi.org/10.2307/2389108

LAUBHANN, D. & PUFF, C. 2002. Birds and bird colors - Flowers pollinated by birds; diaspores dispersed by birds. Examples from the flora of Thailand. Botanical Student Field Trip to Thailand February/March:153-170.

MACK, A.L. 1993. The sizes of vertebrate-dispersed fruits: a neotropical-palaeotropical comparison. Am. Nat. 142(5):840-585. doi: http://dx.doi.org/10.1086/285575

MELLO, M.A.R., KALKO, E.K.V. & SILVA, W.R. 2008. Diet and abundance of the bat *Sturnira lilium* (Chiroptera) in a Brazilian Montane Atlantic Forest. J. Mammal. 89(2):485-492. doi: http://dx.doi.org/10.1644/06-MAMM-A-411R.1

MILCU, A., SCHUMACHER, J. & SCHEU, S. 2006. Earthworms (*Lumbricus terrestris*) affect plant seedling recruitment and microhabitat heterogeneity. Funct. Ecol. 20(2):261-268. doi: http://dx.doi.org/10.1111/j.1365-2435.2006.01098.x

PERES, C.A. & VAN ROSSMALEN, M.G.M. 1996. Avian dispersal of mimetic seeds of *Ormosia lignivalvis* by terrestrial granivores: deception or mutualism? Oikos 75(2):249-258. doi: http://dx.doi.org/10.2307/3546248

PIZO, M.A. & MORELLATO, L.P.C. 2002. A new rain-operated seed dispersal mechanism in *Bertolonia mosenii* (Melastomataceae), a Neotropical rainforest herb. Am. J. Bot. 89(1):169-171. doi: http://dx.doi.org/10.3732/ajb.89.1.169

RAVEN, P.H., EVERT, R.F. & EICHHORN, S.E. 2007. Biologia vegetal. 7 ed. Editora Guanabara Koogan, Rio de Janeiro.

RIDLEY, H.N. 1930. The dispersal of plants throughout the world. L. Reeve & CO., LTD., Ashford.

ROTH, I. 1987. Stratification of a tropical forest as seen in dispersal types. Dr. W. Junk Publishers, Dordrecht.

SILVA, H.R., BRITO-PEREIRA, M.C. & CARAMASCHI, U. 1989. Frugivory and seed dispersal by *Hyla truncata*, a neotropical treefrog. Copeia 1989(3):781-783. doi: http://dx.doi.org/10.2307/1445517

SORENSEN, A.E. 1986. Seed dispersal by adhesion. ***Annu.*** Rev. ***Ecol.*** Syst. 17(1):443-463. doi: http://dx.doi.org/10.1146/annurev.es.17.110186.002303

TUERKE, M., HEINZE, E., ANDREAS, K., SVENDSEN, S.M., GOSSNER, M.M. & WEISSER, W.W. 2010. Seed consumption and dispersal of ant-dispersed plants by slugs. Oecologia 163(3):681-693. doi: http://dx.doi.org/10.1007/s00442-010-1612-6

VAN DER PIJL, L. 1972. Principles of dispersal in higher plants. 2 ed. Springer-Verlag, Würzburg.

VULINEC, K. 2002. Dung beetle communities and seed dispersal in primary forest and disturbed land in Amazonia. Biotropica 34(2):297-309. doi: http://dx.doi.org/10.1111/j.1744-7429.2002.tb00541.x

WALLACE, H.M. & TRUEMAN, S.J. 1995. Dispersal of *Eucalyptus torelliana* seeds by the resin-collecting stingless bee, *Trigona carbonaria*. Oecologia 104(1):12-16. doi: http://dx.doi.org/10.1007/BF00365556

WALLACE, H.M., HOWELL, M.G. & LEE, D.J. 2008. Standard yet unusual mechanisms of long-distance dispersal: seed dispersal of *Corymbia torelliana* by bees. Divers. Distrib. 14(1):87-94. doi: http://dx.doi.org/10.1111/j.1472-4642.2007.00427.x

WHEELWRIGHT, N.T. 1985. Fruit size, gape width, and the diets of fruit-eating birds. Ecology 66(3):808-818. doi: http://dx.doi.org/10.2307/1940542

WILLSON, M.F., IRVINE, A.K. & WALSH, N.G. 1989. Vertebrate dispersal syndromes in some Australian and New Zealand plant communities, with geographic comparisons. Biotropica 21(2):133-147. doi: http://dx.doi.org/10.2307/2388704

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Supplementary material 2: List of tree species sampled at the Atlantic Rainforest in Southeast Brazil and their dispersal syndromes.

This list contains all tree species sampled at four forest types of the Atlantic Rainforest in Southeast Brazil. R means Restinga Forest, L means Lowland Atlantic Rainforest, S means Submontane Atlantic Rainforest, and M means Montane Atlantic Rainforest. The dispersal syndromes belonging to five hierarchical levels were identified. For an explanation of the hierarchical levels, please refer to the paper. NS means no syndrome and represents syndromes of the immediate previous level that do not present further specification of diaspore morphology for its classification in more specific levels. NI means non-identified syndrome.

Forest type	Family	Genera	Species	Level 1	Level 2	Level 3	Level 4	Level 5
R	Anacardiaceae	*Tapirira*	*guianensis*	Biotic	Animal	Endozoochory	Bird	Drupoid
S	Annonaceae	*Annona*	*cacans*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
M	Annonaceae	*Annona*	*dolabripetala*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
L, S	Annonaceae	*Annona*	*sericea*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
L, S, M	Annonaceae	*Guatteria*	*australis*	Biotic	Animal	Endozoochory	Bird	Drupoid
R	Annonaceae	*Guatteria*	sp. 4	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S	Apocynaceae	*Malouetia*	*cestroides*	Abiotic	Wind	NS	NS	Plumed
R, L	Apocynaceae	*Tabernaemontana*	*laeta*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
R	Aquifoliaceae	*Ilex*	*dumosa*	Biotic	Animal	Endozoochory	Bird	Drupoid
R	Aquifoliaceae	*Ilex*	*integerrima*	Biotic	Animal	Endozoochory	Bird	Drupoid
S	Aquifoliaceae	*Ilex*	sp.	Biotic	Animal	Endozoochory	Bird	Drupoid
R	Aquifoliaceae	*Ilex*	*theezans*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S	Araliaceae	*Dendropanax*	*cuneatus*	Biotic	Animal	Endozoochory	Bird	Drupoid
R	Araliaceae	*Oreopanax*	*capitatus*	Biotic	Animal	Endozoochory	Bird	Drupoid
R, L, M	Araliaceae	*Schefflera*	*angustissima*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S, M	Araliaceae	*Schefflera*	*calva*	Biotic	Animal	Endozoochory	Bird	Drupoid
R, L, S	Arecaceae	*Astrocaryum*	*aculeatissimum*	Biotic	Animal	Endozoochory	Mammal	Large
R	Arecaceae	*Bactris*	*setosa*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
R, L, S, M	Arecaceae	*Euterpe*	*edulis*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S	Arecaceae	*Syagrus*	*pseudococos*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
M	Arecaceae	Undetermined		Biotic	Animal	Endozoochory	NI	NI
M	Asteraceae	*Piptocarpha*	*macropoda*	Abiotic	Wind	NS	NS	Winged
L, S, M	Asteraceae	*Vernonanthura*	*discolor*	Abiotic	Wind	NS	NS	Winged
S, M	Asteraceae	*Vernonanthura*	*puberula*	Abiotic	Wind	NS	NS	Winged
S	Bignoniaceae	*Handroanthus*	*serratifolius*	Abiotic	Wind	NS	NS	Winged
M	Bignoniaceae	*Jacaranda*	*montana*	Abiotic	Wind	NS	NS	Winged
R	Bignoniaceae	*Jacaranda*	*puberula*	Abiotic	Wind	NS	NS	Winged
L, M	Boraginaceae	*Cordia*	*sellowiana*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S	Boraginaceae	*Cordia*	*taguahyensis*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Cardiopteridaceae	*Citronella*	*megaphylla*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S	Cardiopteridaceae	*Citronella*	*paniculata*	Biotic	Animal	Endozoochory	Bird	Drupoid
L	Caricaceae	*Jacaratia*	*spinosa*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
L	Celastraceae	*Maytenus*	*ardisiaefolia*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
L, M	Celastraceae	*Maytenus*	*gonoclada*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
R, M	Celastraceae	*Maytenus*	*litoralis*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
L, S	Celastraceae	*Maytenus*	sp. 2	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
M	Celastraceae	*Maytenus*	sp. 4	Biotic	Animal	Endozoochory	Bird	Fleshy appendage

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Table . Continued.

Forest type	Family	Genera	Species	Level 1	Level 2	Level 3	Level 4	Level 5
S	Celastraceae	*Maytenus*	*ubatubensis*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
L, S	Celastraceae	*Salacia*	*grandifolia*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
M	Chloranthaceae	*Hedyosmum*	*brasiliense*	Biotic	Animal	Endozoochory	Mammal	Clear and opaque
R, L, S	Chrysobalanaceae	*Couepia*	*venosa*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
R, L, S, M	Chrysobalanaceae	*Hirtella*	*hebeclada*	Biotic	Animal	Endozoochory	Bird	Drupoid
S, M	Chrysobalanaceae	*Licania*	*hoehnei*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
R	Clusiaceae	*Calophyllum*	*brasiliense*	Biotic	Animal	Endozoochory	Mammal	Clear and opaque
R	Clusiaceae	*Clusia*	*criuva* subsp. *parviflora*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
S	Clusiaceae	*Clusia*	*lanceolata*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
R, L, S	Clusiaceae	*Garcinia*	*gardneriana*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
R	Clusiaceae	*Kielmeyera*	*petiolaris*	Abiotic	Wind	NS	NS	Winged
L	Combretaceae	*Buchenavia*	*kleinii*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
L, S	Combretaceae	*Terminalia*	*januarensis*	Abiotic	Wind	NS	NS	Winged
L, M	Dichapetalaceae	*Stephanopodium*	*estrellense*	Biotic	Animal	Endozoochory	Bird	Drupoid
R, L, S	Elaeocarpaceae	*Sloanea*	*guianensis*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
R, L, M	Elaeocarpaceae	*Sloanea*	*hirsuta*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
L	Erythroxilaceae	*Erythroxylum*	sp.	Biotic	Animal	Endozoochory	Bird	Drupoid
L, M	Euphorbiaceae	*Alchornea*	*glandulosa*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
R, L, S, M	Euphorbiaceae	*Alchornea*	*triplinervia*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
M	Euphorbiaceae	*Croton*	*macrobothrys*	Biotic	Self	Autochory	NS	Ballistic
L	Euphorbiaceae	Euphorbiaceae sp.		Biotic	NI	NI	NI	NI
L, S	Euphorbiaceae	*Mabea*	*piriri*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
R	Euphorbiaceae	*Margaritaria*	*nobilis*	Biotic	Self	Autochory	NS	Ballistic
L	Euphorbiaceae	*Pausandra*	*morisiana*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
R	Euphorbiaceae	*Pera*	*glabrata*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
L, S	Euphorbiaceae	*Sapium*	*glandulosum*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
L	Euphorbiaceae	*Tetrorchidium*	*rubrivenium*	Biotic	Self	Autochory	NS	Ballistic
R	Fabaceae	*Abarema*	*brachystachya*	Biotic	Animal	Endozoochory	Bird	Without reward
R, S	Fabaceae	*Andira*	*fraxinifolia*	Biotic	Animal	Endozoochory	Mammal	Clear and opaque
R	Fabaceae	*Balizia*	*pedicellaris*	Abiotic	Wind	NS	NS	Winged
L, S	Fabaceae	*Copaifera*	*langsdorffii*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
L	Fabaceae	*Copaifera*	*trapezifolia*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
L, S	Fabaceae	*Dahlstedtia*	*pinnata*	Biotic	Self	Autochory	NS	Ballistic
L	Fabaceae	*Hymenaea*	*courbaril* var. *altissima*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
R, L, S	Fabaceae	*Inga*	*edulis*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
S	Fabaceae	*Inga*	*grazielae*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
M	Fabaceae	*Inga*	*lanceifolia*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
S, M	Fabaceae	*Inga*	*marginata*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
S	Fabaceae	*Inga*	*schinifolia*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
M	Fabaceae	*Inga*	*sessilis*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
L, S	Fabaceae	*Inga*	*striata*	Biotic	Animal	Endozoochory	Mammal	Attractive colours

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Forest type	Family	Genera	Species	Level 1	Level 2	Level 3	Level 4	Level 5
R	Fabaceae	*Inga*	*subnuda*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
S	Fabaceae	*Lonchocarpus*	*cultratus*	Abiotic	Wind	NS	NS	Winged
M	Fabaceae	*Machaerium*	*brasiliense*	Abiotic	Wind	NS	NS	Winged
M	Fabaceae	*Machaerium*	*nyctitans*	Abiotic	Wind	NS	NS	Winged
L, S	Fabaceae	*Myrocarpus*	*frondosus*	Abiotic	Wind	NS	NS	Winged
R, S	Fabaceae	*Ormosia*	*arborea*	Biotic	Animal	Endozoochory	Bird	Without reward
S	Fabaceae	*Piptadenia*	*paniculata*	Abiotic	Wind	NS	NS	Dust
L	Fabaceae	*Platymiscium*	*floribundum*	Abiotic	Wind	NS	NS	Winged
S	Fabaceae	*Pseudopiptadenia*	*leptostachya*	Abiotic	Wind	NS	NS	Winged
S, M	Fabaceae	*Pterocarpus*	*rohrii*	Abiotic	Wind	NS	NS	Winged
M	Fabaceae	*Senna*	*macranthera*	Biotic	Self	Barochory	NS	NS
S	Fabaceae	*Swartzia*	*langsdorffii*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
R, L	Fabaceae	*Swartzia*	*simplex* var. *grandiflora*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
M	Fabaceae	*Swartzia*	sp.	Biotic	Animal	Endozoochory	Mammal	Attractive colours
R, L, S	Fabaceae	*Tachigali*	*denudata*	Abiotic	Wind	NS	NS	Winged
S	Fabaceae	*Tachigali*	*multijuga*	Abiotic	Wind	NS	NS	Winged
L, S	Fabaceae	*Zolernia*	*ilicifolia*	Biotic	Animal	Endozoochory	Mammal	Clear and opaque
S	Humiriaceae	Humiriaceae sp.		Biotic	Animal	Endozoochory	Mammal	Attractive colours
M	Humiriaceae	*Vantanea*	*compacta*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
S	Lacistemaceae	*Lacistema*	*lucidum*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
R	Lacistemaceae	*Lacistema*	*pubescens*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
L, S	Lamiaceae	*Aegiphila*	*integrifolia*	Biotic	Animal	Endozoochory	Bird	Drupoid
R, S	Lamiaceae	*Vitex*	*cymosa*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Lauraceae	*Aniba*	*viridis*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Lauraceae	*Cinnamomum*	*triplinerve*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S, M	Lauraceae	*Cryptocarya*	*mandioccana*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
M	Lauraceae	*Cryptocarya*	*moschata*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
L, S, M	Lauraceae	*Cryptocarya*	*saligna*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
M	Lauraceae	*Cryptocarya*	sp.	Biotic	Animal	Endozoochory	Mammal	Attractive colours
R, L	Lauraceae	*Endlicheria*	*paniculata*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Lauraceae	Lauraceae sp. 2		Biotic	Animal	Endozoochory	NI	NI
M	Lauraceae	Lauraceae sp. 3		Biotic	Animal	Endozoochory	NI	NI
M	Lauraceae	Lauraceae sp. 4		Biotic	Animal	Endozoochory	NI	NI
L, S, M	Lauraceae	*Licaria*	*armeniaca*	Biotic	Animal	Endozoochory	Bird	Drupoid
S	Lauraceae	*Nectandra*	*nitidula*	Biotic	Animal	Endozoochory	Bird	Drupoid
R	Lauraceae	*Nectandra*	*oppositifolia*	Biotic	Animal	Endozoochory	Bird	Drupoid
R, M	Lauraceae	*Nectandra*	*psammophila*	Biotic	Animal	Endozoochory	Bird	Drupoid
S	Lauraceae	*Ocotea*	*beyrichii*	Biotic	Animal	Endozoochory	Bird	Drupoid
S	Lauraceae	*Ocotea*	*brachybotrya*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Lauraceae	*Ocotea*	*catharinensis*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Lauraceae	*Ocotea*	*daphnifolia*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S, M	Lauraceae	*Ocotea*	*dispersa*	Biotic	Animal	Endozoochory	Bird	Drupoid

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Table . Continued.

Forest type	Family	Genera	Species	Level 1	Level 2	Level 3	Level 4	Level 5
L, M	Lauraceae	*Ocotea*	*glaziovii*	Biotic	Animal	Endozoochory	Bird	Drupoid
R	Lauraceae	*Ocotea*	*rariflora*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Lauraceae	*Ocotea*	*silvestris*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Lauraceae	*Ocotea*	sp.	Biotic	Animal	Endozoochory	Bird	Drupoid
S	Lauraceae	*Ocotea*	*tabacifolia*	Biotic	Animal	Endozoochory	Bird	Drupoid
L	Lauraceae	*Ocotea*	*velloziana*	Biotic	Animal	Endozoochory	Bird	Drupoid
L	Lauraceae	*Rhodostemonodaphne*	*macrocalyx*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S	Lecythidaceae	*Cariniana*	*estrelensis*	Abiotic	Wind	NS	NS	Winged
L	Magnoliaceae	*Magnolia*	*ovata*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
R	Malpighiaceae	*Byrsonima*	*ligustrifolia*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
L, S	Malvaceae	*Eriotheca*	*pentaphylla*	Abiotic	Wind	NS	NS	Plumed
L, S	Malvaceae	*Quararibea*	*turbinata*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
M	Melastomataceae	Melastomataceae sp.		NI	NI	NI	NI	NI
S	Melastomataceae	*Meriania*	*calyptrata*	Biotic	Animal	Endozoochory	Bird	Baccoid
M	Melastomataceae	*Miconia*	*cabussu*	Biotic	Animal	Endozoochory	Bird	Baccoid
R	Melastomataceae	*Miconia*	*cinnamomifolia*	Biotic	Animal	Endozoochory	Bird	Baccoid
R	Melastomataceae	*Miconia*	*dodecandra*	Biotic	Animal	Endozoochory	Bird	Baccoid
R, L	Melastomataceae	*Miconia*	*prasina*	Biotic	Animal	Endozoochory	Bird	Baccoid
R	Melastomataceae	*Miconia*	*pusilliflora*	Biotic	Animal	Endozoochory	Bird	Baccoid
S, M	Melastomataceae	*Miconia*	sp. 1 (new species)	Biotic	Animal	Endozoochory	Bird	Baccoid
M	Melastomataceae	*Miconia*	sp. 2	Biotic	Animal	Endozoochory	Bird	Baccoid
S	Melastomataceae	*Miconia*	*tristis*	Biotic	Animal	Endozoochory	Bird	Baccoid
M	Melastomataceae	*Miconia*	*valtheri*	Biotic	Animal	Endozoochory	Bird	Baccoid
R, M	Melastomataceae	*Tibouchina*	*pulchra*	Abiotic	Wind	NS	NS	Dust
M	Melastomataceae	*Tibouchina*	sp.	Abiotic	Wind	NS	NS	Dust
L, S, M	Meliaceae	*Cabralea*	*canjerana* subsp. *canjerana*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
L, S, M	Meliaceae	*Cedrela*	*odorata*	Abiotic	Wind	NS	NS	Winged
M	Meliaceae	*Guarea*	*kuthiana*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
R, L, S, M	Meliaceae	*Guarea*	*macrophylla* subsp. *tuberculata*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
L, S, M	Meliaceae	*Trichilia*	*silvatica*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
M	Memecylaceae	*Mouriri*	*chamissoana*	Biotic	Animal	Endozoochory	Bird	Baccoid
M	Monimiaceae	*Mollinedia*	*argyrogyna*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S	Monimiaceae	*Mollinedia*	*boracensis*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Monimiaceae	*Mollinedia*	*elegans*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Monimiaceae	*Mollinedia*	*engleriana*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Monimiaceae	*Mollinedia*	*glabra*	Biotic	Animal	Endozoochory	Bird	Drupoid
L	Monimiaceae	*Mollinedia*	*lamprophylla*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Monimiaceae	*Mollinedia*	*ovata*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S, M	Monimiaceae	*Mollinedia*	*schottiana*	Biotic	Animal	Endozoochory	Bird	Drupoid
S, M	Monimiaceae	*Mollinedia*	sp. 1	Biotic	Animal	Endozoochory	Bird	Drupoid
L	Monimiaceae	*Mollinedia*	*triflora*	Biotic	Animal	Endozoochory	Bird	Drupoid

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Table . Continued.

Forest type	Family	Genera	Species	Level 1	Level 2	Level 3	Level 4	Level 5
L, S	Moraceae	*Brosimum*	*guianense*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
L	Moraceae	*Brosimum*	*lactescens*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
S	Moraceae	*Ficus*	cf. *hirsuta*	Biotic	Animal	Endozoochory	Mammal	Clear and opaque
L	Moraceae	*Ficus*	*glabra*	Biotic	Animal	Endozoochory	Mammal	Clear and opaque
R, L	Moraceae	*Ficus*	*insipida*	Biotic	Animal	Endozoochory	Mammal	Clear and opaque
L	Moraceae	*Ficus*	*pulchella*	Biotic	Animal	Endozoochory	Mammal	Clear and opaque
M	Moraceae	*Ficus*	sp.	Biotic	Animal	Endozoochory	Mammal	Clear and opaque
L, S	Moraceae	*Sorocea*	*bonplandii*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
L, S	Moraceae	*Sorocea*	*hilarii*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
R	Moraceae	*Sorocea*	*jureiana*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
R, L, S	Myristicaceae	*Virola*	*bichuyba*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
S	Myristicaceae	*Virola*	*gardneri*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
R	Myrtaceae	*Calyptranthes*	*concinna*	Biotic	Animal	Endozoochory	Bird	Drupoid
R, L, S, M	Myrtaceae	*Calyptranthes*	*lucida*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S, M	Myrtaceae	*Calyptranthes*	*rufa*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Myrtaceae	*Calyptranthes*	sp. 1	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S, M	Myrtaceae	*Calyptranthes*	*strigipes*	Biotic	Animal	Endozoochory	Bird	Drupoid
R, L, S, M	Myrtaceae	*Campomanesia*	*guaviroba*	Biotic	Animal	Endozoochory	Bird	Baccoid
L, S	Myrtaceae	*Campomanesia*	*laurifolia*	Biotic	Animal	Endozoochory	Bird	Baccoid
R	Myrtaceae	*Eugenia*	*astringens*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Myrtaceae	*Eugenia*	*batingabranca*	Biotic	Animal	Endozoochory	Bird	Drupoid
R	Myrtaceae	*Eugenia*	*brasiliensis*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S	Myrtaceae	*Eugenia*	*brevistyla*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Myrtaceae	*Eugenia*	*burkartiana*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S, M	Myrtaceae	*Eugenia*	*cerasiflora*	Biotic	Animal	Endozoochory	Bird	Drupoid
L	Myrtaceae	*Eugenia*	*cereja*	Biotic	Animal	Endozoochory	Bird	Drupoid
S	Myrtaceae	*Eugenia*	cf. *flamingensis*	Biotic	Animal	Endozoochory	Bird	Drupoid
S, M	Myrtaceae	*Eugenia*	*cuprea*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S	Myrtaceae	*Eugenia*	*excelsa*	Biotic	Animal	Endozoochory	Bird	Drupoid
R, L, S	Myrtaceae	*Eugenia*	*fusca*	Biotic	Animal	Endozoochory	Bird	Drupoid
R	Myrtaceae	*Eugenia*	*handroana*	Biotic	Animal	Endozoochory	Bird	Drupoid
L	Myrtaceae	*Eugenia*	*magnibracteolata*	Biotic	Animal	Endozoochory	Bird	Drupoid
R, L, S	Myrtaceae	*Eugenia*	*monosperma*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S, M	Myrtaceae	*Eugenia*	*obloganta*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Myrtaceae	*Eugenia*	*pisiformis*	Biotic	Animal	Endozoochory	Bird	Drupoid
L	Myrtaceae	*Eugenia*	*plicata*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S, M	Myrtaceae	*Eugenia*	*prasina*	Biotic	Animal	Endozoochory	Bird	Drupoid
S	Myrtaceae	*Eugenia*	*pruniformis*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Myrtaceae	*Eugenia*	sp. 1	Biotic	Animal	Endozoochory	Bird	Drupoid
L	Myrtaceae	*Eugenia*	sp. 3	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Myrtaceae	*Eugenia*	sp. 4	Biotic	Animal	Endozoochory	Bird	Drupoid

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Table . Continued.

Forest type	Family	Genera	Species	Level 1	Level 2	Level 3	Level 4	Level 5
M	Myrtaceae	*Eugenia*	sp. 5	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Myrtaceae	*Eugenia*	sp. 13	Biotic	Animal	Endozoochory	Bird	Drupoid
R	Myrtaceae	*Eugenia*	*speciosa*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S	Myrtaceae	*Eugenia*	*subavenia*	Biotic	Animal	Endozoochory	Bird	Drupoid
S	Myrtaceae	*Eugenia*	*ternatifolia*	Biotic	Animal	Endozoochory	Bird	Drupoid
S	Myrtaceae	*Eugenia*	*verticilata*	Biotic	Animal	Endozoochory	Bird	Drupoid
R	Myrtaceae	*Eugenia*	*verticillata*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S	Myrtaceae	*Marlierea*	*glazioviana*	Biotic	Animal	Endozoochory	Bird	Drupoid
R, L	Myrtaceae	*Marlierea*	*obscura*	Biotic	Animal	Endozoochory	Bird	Drupoid
S	Myrtaceae	*Marlierea*	*racemosa*	Biotic	Animal	Endozoochory	Bird	Drupoid
S, M	Myrtaceae	*Marlierea*	*silvatica*	Biotic	Animal	Endozoochory	Bird	Drupoid
R, L, S, M	Myrtaceae	*Marlierea*	*tomentosa*	Biotic	Animal	Endozoochory	Bird	Drupoid
S	Myrtaceae	*Myrceugenia*	*campestris*	Biotic	Animal	Endozoochory	Bird	Drupoid
S, M	Myrtaceae	*Myrceugenia*	*myrcioides*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S	Myrtaceae	*Myrcia*	*aethusa*	Biotic	Animal	Endozoochory	Bird	Drupoid
R	Myrtaceae	*Myrcia*	*brasiliensis*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Myrtaceae	*Myrcia*	*guianensis*	Biotic	Animal	Endozoochory	Bird	Drupoid
R	Myrtaceae	*Myrcia*	*insulares*	Biotic	Animal	Endozoochory	Bird	Drupoid
R	Myrtaceae	*Myrcia*	*multiflora*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S	Myrtaceae	*Myrcia*	*neoblanchetiana*	Biotic	Animal	Endozoochory	Bird	Drupoid
R	Myrtaceae	*Myrcia*	*pubipetala*	Biotic	Animal	Endozoochory	Bird	Drupoid
R	Myrtaceae	*Myrcia*	*racemosa*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S, M	Myrtaceae	*Myrcia*	*spectabilis*	Biotic	Animal	Endozoochory	Bird	Drupoid
R, M	Myrtaceae	*Myrcia*	*splendens*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S, M	Myrtaceae	*Myrciaria*	*floribunda*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Myrtaceae	Myrtaceae sp. 1		Biotic	Animal	Endozoochory	NI	NI
R	Myrtaceae	Myrtaceae sp. 2		Biotic	Animal	Endozoochory	NI	NI
M	Myrtaceae	Myrtaceae sp. 3		Biotic	Animal	Endozoochory	NI	NI
M	Myrtaceae	Myrtaceae sp. 9		Biotic	Animal	Endozoochory	NI	NI
M	Myrtaceae	Myrtaceae sp. 10		Biotic	Animal	Endozoochory	NI	NI
S	Myrtaceae	*Neomitranthes*	*glomerata*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Myrtaceae	*Pimenta*	*pseudocaryophyllus*	Biotic	Animal	Endozoochory	Bird	Drupoid
L	Myrtaceae	*Plinia*	*complanata*	Biotic	Animal	Endozoochory	Bird	Drupoid
S	Myrtaceae	*Plinia*	*edulis*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
R	Myrtaceae	*Syzygium*	*jambos*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
M	Nyctaginaceae	*Guapira*	*areolata*	Biotic	Animal	Endozoochory	Bird	Drupoid
S	Nyctaginaceae	*Guapira*	*hirsuta*	Biotic	Animal	Endozoochory	Bird	Drupoid
S, M	Nyctaginaceae	*Guapira*	*nitida*	Biotic	Animal	Endozoochory	Bird	Drupoid
R, L, S, M	Nyctaginaceae	*Guapira*	*opposita*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S	Ochnaceae	*Ouratea*	*parviflora*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S, M	Olacaceae	*Heisteria*	*silvianii*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S	Olacaceae	*Tetrastylidium*	*grandifolium*	Biotic	Animal	Endozoochory	Bird	Drupoid

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Table . Continued.

Forest type	Family	Genera	Species	Level 1	Level 2	Level 3	Level 4	Level 5
M	Opiliaceae	*Agonandra*	*excelsa*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
R, L, S, M	Phyllanthaceae	*Hieronyma*	*alchorneoides*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Piperaceae	*Piper*	*cernuum*	Biotic	Animal	Endozoochory	Mammal	Clear and opaque
R	Polygonaceae	*Coccoloba*	*glaziovii*	Biotic	Animal	Endozoochory	Bird	Drupoid
R	Primulaceae	*Myrsine*	*coriacea*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, M	Primulaceae	*Myrsine*	*gardneriana*	Biotic	Animal	Endozoochory	Bird	Drupoid
S, M	Primulaceae	*Myrsine*	*hermogenesii*	Biotic	Animal	Endozoochory	Bird	Drupoid
R	Primulaceae	*Myrsine*	*venosa*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S	Primulaceae	*Stylogyne*	*lhotskyana*	Biotic	Animal	Endozoochory	Bird	Drupoid
R	Proteaceae	*Euplassa*	*cantareirae*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
M	Proteaceae	*Euplassa*	*hoehnei*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
R, L	Proteaceae	*Roupala*	*montana* var. *brasiliensis*	Abiotic	Wind	NS	NS	Winged
M	Quiinaceae	*Quiina*	aff. *magallano-gomesii* (new species)	Biotic	Animal	Endozoochory	Mammal	Attractive colours
R, S	Rosaceae	*Prunus*	*myrtifolia*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S	Rubiaceae	*Alseis*	*floribunda*	Abiotic	Wind	NS	NS	Dust
R	Rubiaceae	*Amaioua*	*intermedia*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S, M	Rubiaceae	*Bathysa*	*australis*	Abiotic	Wind	NS	NS	Dust
L, S	Rubiaceae	*Bathysa*	*mendoncaei*	Abiotic	Wind	NS	NS	Dust
S	Rubiaceae	*Bathysa*	*stipulata*	Abiotic	Wind	NS	NS	Dust
M	Rubiaceae	*Chomelia*	*pedunculosa*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S	Rubiaceae	*Coussarea*	*accedens*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S	Rubiaceae	*Coussarea*	*meridionalis* var. *porophyla*	Biotic	Animal	Endozoochory	Bird	Drupoid
R, L, S	Rubiaceae	*Faramea*	*pachyantha*	Biotic	Animal	Endozoochory	Bird	Drupoid
L	Rubiaceae	*Faramea*	*picinguabae*	Biotic	Animal	Endozoochory	Bird	Drupoid
R	Rubiaceae	*Genipa*	*infundibuliformis*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
L, S	Rubiaceae	*Ixora*	*bracteolaris*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S, M	Rubiaceae	*Posoqueria*	*latifolia*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
S	Rubiaceae	*Psychotria*	*birotula*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Rubiaceae	*Psychotria*	*longipes*	Biotic	Animal	Endozoochory	Bird	Drupoid
S	Rubiaceae	*Psychotria*	*mapourioides*	Biotic	Animal	Endozoochory	Bird	Drupoid
S	Rubiaceae	*Psychotria*	*nuda*	Biotic	Animal	Endozoochory	Bird	Drupoid
S	Rubiaceae	*Psychotria*	*patentinervia*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Rubiaceae	*Psychotria*	*vellosiana*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, M	Rubiaceae	Rubiaceae sp. 1		NI	NI	NI	NI	NI
L	Rubiaceae	*Rudgea*	*coronata* subsp. *leiocarpoides*	Biotic	Animal	Endozoochory	Bird	Drupoid
S	Rubiaceae	*Rudgea*	*jasminoides*	Biotic	Animal	Endozoochory	Bird	Drupoid
L, S	Rubiaceae	*Rudgea*	*vellerea*	Biotic	Animal	Endozoochory	Bird	Drupoid
L	Rubiaceae	*Rustia*	*formosa*	Abiotic	Wind	NS	NS	Winged
L	Rubiaceae	*Simira*	*sampaioana*	Abiotic	Wind	NS	NS	Winged
L	Rubiaceae	*Simira*	*viridiflora*	Abiotic	Wind	NS	NS	Winged

Continued on next page

Table . Continued.

Forest type	Family	Genera	Species	Level 1	Level 2	Level 3	Level 4	Level 5
M	Rutaceae	Rutaceae sp.		NI	NI	NI	NI	NI
L	Rutaceae	*Zanthoxylum*	*fagara*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Sabiaceae	*Meliosma*	*sellowii*	Biotic	Animal	Endozoochory	Mammal	Clear and opaque
M	Salicaceae	*Casearia*	*obliqua*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
M	Salicaceae	*Casearia*	*paranaensis*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
S, M	Salicaceae	*Casearia*	*sylvestris*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
S	Sapindaceae	*Allophyllus*	*petiolatus*	Biotic	Animal	Endozoochory	Bird	Drupoid
S, M	Sapindaceae	*Cupania*	*furfuracea*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
R, L, S, M	Sapindaceae	*Cupania*	*oblongifolia*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
M	Sapindaceae	*Cupania*	*vernalis*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
R	Sapindaceae	*Matayba*	*elaeagnoides*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
M	Sapindaceae	*Matayba*	*guianensis*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
S	Sapindaceae	*Matayba*	*juglandifolia*	Biotic	Animal	Endozoochory	Bird	Fleshy appendage
L, S	Sapotaceae	*Chrysophyllum*	*flexuosum*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
M	Sapotaceae	*Chrysophyllum*	*inornatum*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
L, M	Sapotaceae	*Chrysophyllum*	*viride*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
L, S, M	Sapotaceae	*Ecclinusa*	*ramiflora*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
S	Sapotaceae	*Micropholis*	*crassipedicellata*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
M	Sapotaceae	*Micropholis*	*gardneriana*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
S, M	Sapotaceae	*Pouteria*	*caimito*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
S, M	Sapotaceae	*Pouteria*	*gardneri*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
L	Sapotaceae	*Pouteria*	*psammophila*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
L, S	Sapotaceae	*Pouteria*	*venosa*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
S	Sapotaceae	*Pradosia*	*lactescens*	Biotic	Animal	Endozoochory	Mammal	Attractive colours
L	Sapotaceae	Sapotaceae sp. 1		Biotic	Animal	Endozoochory	Mammal	Attractive colours
L	Sapotaceae	Sapotaceae sp. 2		Biotic	Animal	Endozoochory	Mammal	Attractive colours
S	Sapotaceae	Sapotaceae sp. 3		Biotic	Animal	Endozoochory	Mammal	Attractive colours
M	Solanaceae	*Aureliana*	*fasciculata*	Biotic	Animal	Endozoochory	Mammal	Clear and opaque
L	Solanaceae	Solanaceae sp.		Biotic	Animal	Endozoochory	NI	NI
M	Solanaceae	*Solanum*	aff. *refescens*	Biotic	Animal	Endozoochory	Mammal	Clear and opaque
M	Solanaceae	*Solanum*	*cinnamomum*	Biotic	Animal	Endozoochory	Mammal	Clear and opaque
M	Solanaceae	*Solanum*	*pseudoquina*	Biotic	Animal	Endozoochory	Mammal	Clear and opaque
M	Solanaceae	*Solanum*	sp. 1	Biotic	Animal	Endozoochory	Mammal	Clear and opaque
M	Solanaceae	*Solanum*	*swartizianum*	Biotic	Animal	Endozoochory	Mammal	Clear and opaque
M	Solanaceae	*Solanum*	*vellozianum*	Biotic	Animal	Endozoochory	Mammal	Clear and opaque
S, M	Thymelaeaceae	*Daphnopsis*	*schwackeana*	Biotic	Animal	Endozoochory	Bird	Drupoid
M	Undetermined	Undetermined	sp. 8	NI	NI	NI	NI	NI
M	Undetermined	Undetermined	sp. 9	NI	NI	NI	NI	NI
R, L, S, M	Urticaceae	*Cecropia*	*glaziovii*	Biotic	Animal	Endozoochory	Mammal	Clear and opaque
R, L, S, M	Urticaceae	*Coussapoa*	*microcarpa*	Biotic	Animal	Endozoochory	Mammal	Clear and opaque
M	Urticaceae	*Coussapoa*	sp. 1	Biotic	Animal	Endozoochory	Mammal	Clear and opaque
M	Urticaceae	*Coussapoa*	sp. 2	Biotic	Animal	Endozoochory	Mammal	Clear and opaque
L, S	Urticaceae	*Pourouma*	*guianensis*	Biotic	Animal	Endozoochory	Bird	Drupoid

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Floristic composition of the Montane Forest in the Almadina–Barro Preto axis, Southern Bahia, Brazil

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Abstract: The aim of this study is to survey the angiosperms of two montane forest remnants in the southern Bahia, Brazil: Corcovado (SCO) and Pedra Lascada (SPL). Both fragments are located in the municipality of Almadina and Barro Preto, respectively, and are 18 km distant from each other. We sampled 899 species of angiosperms distributed in 437 genera and 116 families. The SCO was the richest area with 678 species, distributed in 367 genera and 100 families. SPL showed 466 species in 269 genera and 88 families. The percentage of species identified was 85.8% and of this total, 37.7% are endemic to the Atlantic Forest, 11.2% are endemic to southern Bahia and northern Espírito Santo and 7% are disjunct between the Atlantic Forest and Amazon. The remaining percentages (44.3%) were of species widely distributed. The richest families in the two areas were Orchidaceae (10%), Rubiaceae (7%), Bromeliaceae (5.5%), Melastomataceae (4.2%) and Poaceae (4%). The richest genera were *Psychotria* (2%), *Piper* (1.8%), *Ocotea* (1.6%), *Vriesea* (1.5%) and *Peperomia* (1.4%). More than half of the recorded species showed non-arboreal habit, regarding life forms documented. That comes against the assertion that many authors in the tropical forests, where species richness in angiosperms is expected for non-woody species, especially in montane forests. Twelve species have been identified as new, but seven others already described from collections previously obtained in these two areas. Orchidaceae, Rubiaceae, Poaceae and Bromeliaceae showed significant richness in this study these families are commonly reported as the richest in other inventories in the Atlantic Forest in southern Bahia reinforcing their importance to the regional flora. The high levels of richness, endemism, and the growing numbers of new taxonomic discoveries from the SPL and SCO sites indicate the biological importance of these two forest remnants. The implementation of parks or other protected environmental reserves would be essential to the conservation of its species.
Keywords: *Atlantic Forest, Biodiversity conservation, Floristic survey and Remnant forests.*

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Resumo: O presente estudo objetivou inventariar as angiospermas de dois remanescentes florestais no sul da Bahia, Brasil. Os remanescentes se encontram nas Serras do Corcovado (SCO) e da Pedra Lascada (SPL), situados nos municípios de Almadina e Barro Preto, respectivamente, e distantes 18 km um do outro. Foram registradas 899 espécies de angiospermas distribuídas em 437 gêneros e 116 famílias. A SCO foi a área mais rica em espécies, com um total de 678 espécies distribuídas em 367 gêneros e 100 famílias, enquanto a SPL apresentou 466 espécies em 269 gêneros e 88 famílias. O percentual de espécies identificadas foi de 85,8%. Desse total, 37,7% são endêmicas da Floresta Atlântica e 11,2% são endêmicas do sul da Bahia e norte do Espírito Santo. A distribuição disjunta entre Florestas Atlântica e Amazônica foi constatada em 7% das espécies inventariadas. O percentual restante (44,3%) foi de espécies amplamente distribuídas no Brasil. As famílias mais ricas nas duas áreas foram Orchidaceae (com 10%), Rubiaceae (7%), Bromeliaceae (5,5%), Melastomataceae (4,2%) e Poaceae (4%). Já os gêneros mais ricos foram *Psychotria*, (com 2%), *Piper* (1,8%), *Ocotea* (1,6%), *Vriesea* (1,5%) e *Peperomia* (1,4%). Mais de

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metade das espécies registradas apresentaram hábito não-arbóreo com relação às formas de vida documentadas. Isso vem de encontro com a afirmativa de diversos autores de que em florestas tropicais a grande riqueza nas angiospermas é esperada para as espécies não-lenhosas, especialmente na Floresta Montana. Até o momento, doze espécies foram apontadas como novas, além de outras sete já descritas a partir das coleções obtidas anteriormente nessas duas áreas. Orchidaceae, Rubiaceae, Bromeliaceae e Poaceae apresentaram significativa riqueza nesse estudo e são famílias comumente reportadas como as mais ricas em outros inventários na Floresta Atlântica no sul da Bahia comprovando sua importância na flora local. Os altos índices de riqueza, endemismo e o crescente número de novidades taxonômicas provenientes de ambas as áreas indicam a importância biológica desses dois remanescentes. A implementação de parques ou demais reservas ambientais protegidas seriam essenciais para a conservação de suas espécies.

Palavras-chave: *Floresta Atlântica, Conservação da biodiversidade, Documentação florística e Remanescentes florestais.*

Introduction

The Atlantic Forest covers the east coast of Brazil and is the second largest tropical rainforest on the American continent. It comprises 1% to 8% of the world's biodiversity (Silva and Casteleti 2005) and is the largest hotspot in the country, comprising 17,691 plant species, including algae, bryophytes, ferns, lycophytes, gymnosperms, and angiosperms, 40% of which are endemic (Forzza et al. 2012). The Atlantic Forest is considered one of the most important phytogeographic domains for biodiversity preservation worldwide because it is extremely diversified, covering regions with various levels of species abundance, composition, and endemism (Silva and Casteleti 2005).

The abundance and diversity are thought to have resulted in the isolation of two large South American forest blocks: the Amazonian Forest and the Andean Forests (Silva and Casteleti 2005). The Atlantic Forest and the vast Amazonian domain are separated by an open corridor formed by seasonal vegetation, including the Caatinga in the northeast semi-arid region of Brazil; the Cerrado in the midwest; and the Chaco, a region of dry vegetation located in the central lowlands of South America (Argentia, Bolivia, and Paraguay), which separates the Atlantic domain from the Andean forests (Rizzini 1997, Silva and Casteleti 2005). The transition from the Atlantic Forest to the Caatinga in the semi-arid regions is relatively abrupt and occurs in northeastern Brazil, where a narrow strip of coastal forests (less than 50 km) is delimited by an equally narrow strip of seasonal semi-deciduous forests (Oliveira-Filho and Fontes 2000). In southeastern Brazil, the transition from coastal forests to the Cerrado biome involves a much larger extension of semi-deciduous forests, which extends southward and forms complex mosaics with the Cerrado vegetation to the west. In the south, these semi-deciduous forests also extend along the Paraná river basin in eastern Paraguay and northeastern Argentina, where they make a transition to the Chaco biome (Oliveira-Filho and Fontes 2000).

The isolation of the South American forest blocks has resulted in consistent demographic changes in forest populations during the Pleistocene and Holocene eras, followed by climate changes during the late Quarternary era (Carnaval and Moritz 2008). These changes have had a greater impact on the southern portion of the Atlantic Forest and resulted in the evolution of a unique biota (Oliveira-Filho and Ratter 1995, Carnaval and Moritz 2008). The Atlantic Forest is considered one of the most unique biogeographical zones in South America. It shows great variations in topography, pluviometric regimes, and phytogeographic units because of its wide latitude (approximately 27°), longitude (from the coast to the interior), and altitude (from the sea level to altitudes of approximately 2700 m) (Silva and Casteleti 2005). These elements have led to the floristic and physiognomic heterogeneity present across the entire area (Pinto et al. 1996, Oliveira-Filho and Fontes 2000).

Special importance should be given to the forest altitude, which accounts for several environmental factors, including variations in the availability of solar energy, resources, and the forest's potential to serve as refuge for immigrant species; this potential may be higher in the lowlands and lower in the more isolated montane areas (Lomolino 2001). In addition, higher altitudes lead to a reduction in the number of species because of the occurrence of more severe environmental conditions with an increase in the altitude (e.g., edaphic factors, temperature, wind speed, and rainfall) (Lieberman et al. 1996, Pendry and Proctor 1996).

Taken together, these factors result in a wide variation in the species composition of the Atlantic Forest and make this area a heterogeneous unit with regard to studies on biodiversity conservation (Silva and Casteleti 2005). The difference between ombrophilous and semi-deciduous forests is consistent from a floristic point of view and is closely correlated with the rainfall (Oliveira-Filho and Fontes 2000). In this respect, the arboreal flora of semi-deciduous forests is largely a subset of the flora of ombrophilous forests and probably gives rise to species capable of withstanding more prolonged dry seasons (Oliveira-Filho and Fontes 2000, Oliveira-Filho et al. 2005). In addition, changes in the flora of semi-deciduous forests are associated with an increase in length of the dry season, which is caused by an increase in the distance from the ocean. Furthermore, altitude variations and the corresponding temperature variations are closely correlated with the internal floristic differentiation in both ombrophilous and semi-deciduous forests (Oliveira-Filho and Fontes 2000). Notably, the difference between deciduous and semi-deciduous forests is probably linked to a combination of chemical properties of the soil, rainfall, and variations in the altitude and latitude (Oliveira-Filho and Ratter 1995). Therefore, the definition of the Atlantic Forest should be as broad as that of the Amazonian formations (Oliveira-Filho and Fontes 2000).

In this context, the Atlantic Forest of southern Bahia can be included among the wet forests of the Northeast, which extend from Pernambuco to northern Espírito Santo. It is represented by coastal forests that cover an area of approximately 100–200 km in width along the east coast of Brazil and by forests that become increasingly drier toward the interior. Therefore, open

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formations gradually change to ombrophilous forests, semi-deciduous forests, and seasonally dry deciduous forest as one moves from east to west (Gouvêa et al. 1976, Silva and Casteleti 2005). In these forests, the minimum annual rainfall of 1600 mm and a dry period of not more than 2 months per year reflect the separation between wet and seasonal forests, with wet forests being essentially evergreen and comprising less than 20% of deciduous trees (Thomas and Barbosa 2008). In addition, wet forests can be classified according to the altitude as follows: lowland (20–100 m), submontane (100–600 m), and montane (600–800 m) (Thomas and Barbosa 2008). However, Veloso (1992) defined other altitude ranges for these areas, with montane forests occurring at altitudes between 500 and 1500 m.

The coastal forests of southern Bahia may have provided refuge for the biodiversity present during the Pleistocene era. The continual identification of new species and the high level of endemism detected in other studies reinforce the evidence of the uniqueness of this relatively unexplored region (Mori et al. 1981, Thomas et al. 1998, Carnaval and Moritz 2008, Amorim et al. 2009). Of all the coastal areas of Brazil, coastal forests contain the highest number of endemic species of Myrtaceae (15 species), which are threatened with extinction (Carnaval and Moritz 2008, Murray-Smith et al. 2008).

To investigate the flora of the Montane Forest in southern Bahia, the present study aimed to produce an inventory of angiosperms in two vestigial areas of the Montane Forest located on the Almadina–Barro Preto axis in the cocoa-growing region of southern Bahia. Moreover, the present study aimed to investigate whether these vestigial areas differ in terms of abundance from other areas of vestigial forests located in nearby regions, for which floristic documentation exists. In southern Bahia, the abundance and endemism of vascular plants reportedly yields high levels of diversity (Thomas et al. 1998, Martini et al. 2007, Thomas et al. 2009, Amorim et al. 2009, Murray-Smith et al. 2008). Importantly, this floristic documentation provides more detailed information on the endemism, abundance, areas of occurrence of taxa, and identification of new species and may serve as the foundation for future studies on biome similarities, biogeography, and community structure (Giulietti et al. 2005, Funk 2006).

Material and Methods

Study areas

The study areas are located in the Montane Forest (Veloso, 1992) in the cocoa-growing region of the State of Bahia (Gouvêa, 1976), in the cities of Barro Preto [Serra da Pedra Lascada (SPL)] and Almadina [Serra do Corcovado (SCO)], which are approximately 18-km apart (Figure 1). The floristic richness of SLP has been reported previously (Amorim et al. 2009) and has been revised and extended in the present study.

SPL (14°46′S and 39°32′W) is a vestigial forest of approximately 300 ha that lies approximately 56 km from the coast, with altitudes ranging from 600 to 950 m above the sea level (Amorim et al. 2009). There is a rocky outcrop of the "inselberg" type on the eastern side of the slope. This outcrop is formed by granites and gnaisses from the Precambrian era, comprising ancient elements of the landscape (Porembski et al. 1998). SPL is primarily populated by rupicolous monocotyledons and exhibits particular edaphic and microclimatic conditions, revealing its importance from a geomorphological and topographical perspective (Figures 2B, C and D). This forest has some well-preserved areas, with trees 20 to 30 m in height, and a dense subforest. There is an abundance of epiphytes, particularly mosses, ferns, and lycophytes, which sometimes give the appearance of cloud forests as the altitude increases. The forest fragment surveyed has an irregular area and is sharply demarked by the adjacent cocoa plantations (*Theobroma cacao* L.) where the trees are cultivated under the *cabruca* system. This fragment also comprises regeneration areas and pasture lands (Amorim et al. 2009).

SCO (14°42′S and 39°36′W) is located at altitudes ranging from 400 to 1040 m above the sea level. It comprises an area of approximately 2500 ha and is located at a distance of 65 km from the coast; its slopes contain springs that form part of the river basin of Almada, the main river in the region. These springs ultimately provide water supply to the city of Almadina (Figure 2A). A part of the slope of SCO comprises a steep rocky outcrop of the "inselberg" type, which gives it a unique geomorphology. This outcrop is populated by a large number of vascular plants, particularly rupicolous flora such as Bromeliaceae and Orchidaceae (Figure 2E) (Porembski et al. 1998). The forest contains dense subforests, trees up to 35 m in height, and an abundance of epiphytes, giving it the appearance of a cloud forest at altitudes of 800 m above the sea level. There is an abundance of rupicolous species, particularly mosses, and the presence of various species of Cyatheaceae. Cocoa plantations, with trees cultivated under the *cabruca* system, and pasture lands are also common around SCO.

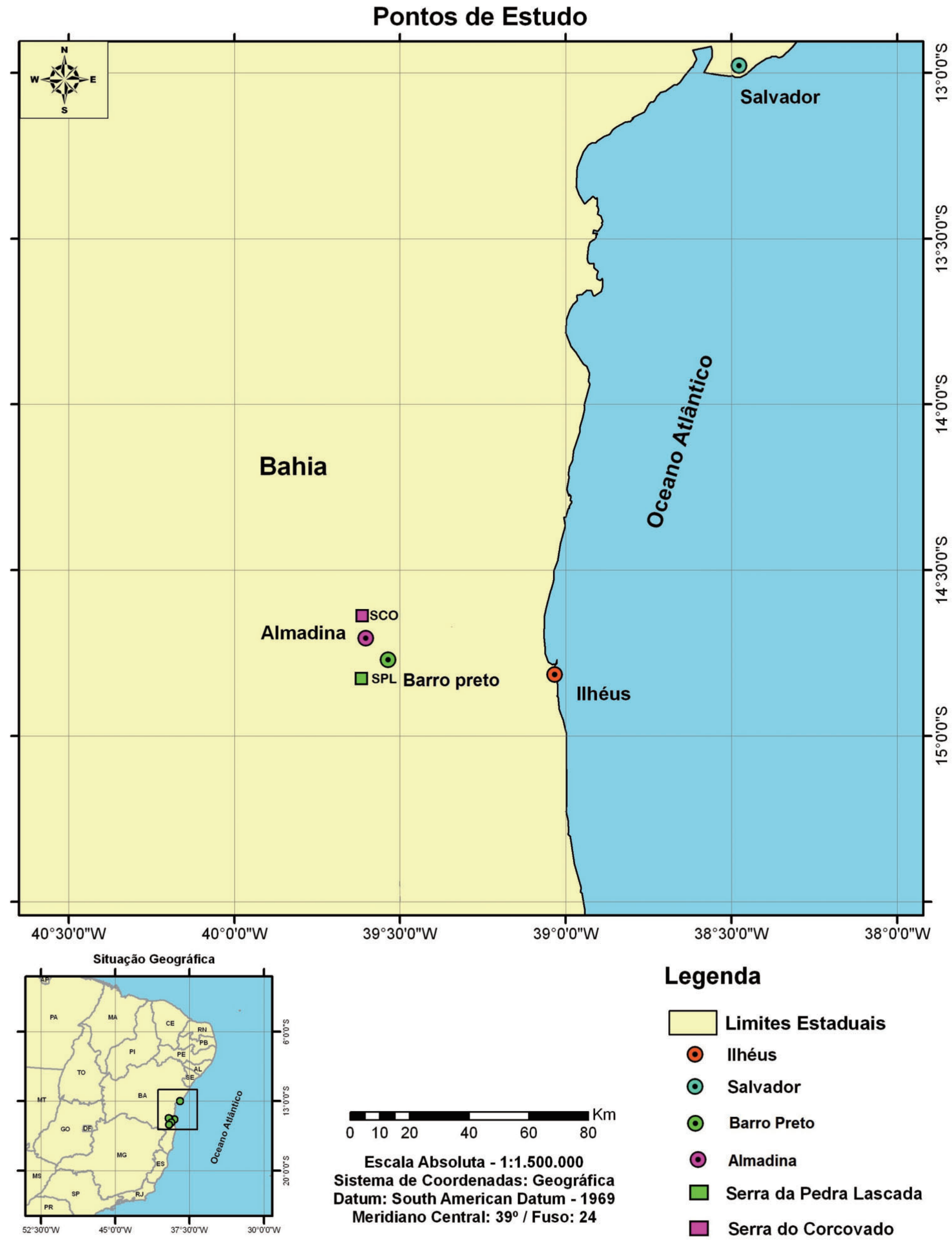
The climate of the region is warm and wet, with a dry season of the Af (Köppen) type (Peel et al. 2007). The average annual rainfall ranges between 1500 and 1750 mm, and the average daily rainfall varies between 50 and 100 mm. The average annual temperature varies between 23°C and 24°C, with a thermal range of 10°C to 14°C. The annual total potential evapotranspiration varies from 1200 to 1300, mm and the relative humidity is less than 80%.

Floristic Surveys

Eight field trips were conducted between July 2011 and June 2012, each lasting for 2 to 3 days. The surveys prioritized SCO because it is an area with large gaps in floristic documentation. These field trips, when added to the 12 previous trips (five in SCO and seven in SPL) conducted by various collaborators between 2004 and 2010, enabled the collections to be distributed throughout the year and increased the documentation of fertile specimens. Preliminary data from SPL used in this study had been previously published by Amorim et al. (2009).

The documentation of angiosperms was conducted through collection along the trails and access roads by careful visual examination with the aid of binoculars, with the aim of collecting the largest number of fertile species possible. Some trees were surveyed using climbing techniques to collect arboreal specimens and document the epiphytic flora. In addition, fallen trees and canopy branches were examined in detail. Sterile specimens were collected whenever their identification in the field was possible.

The material collected was prepared according to Fidalgo and Bononi (1989) and deposited in the CEPEC Herbarium. Duplicates were sent to the HUEFS and RB archives. Species were identified by literature search, comparison with the material deposited in the CEPEC, and consultation with specialists. The material identified was standardized in morphotypes and



[Above map] Study Point
[On map] Atlantic Ocean (all others are names of places)
[Small map to left] Geographical Location
[Right]
Key
State Borders (all others are names of places)
[Bottom Center]
Absolute Scale: 1:1500,00
System of Coordinates: Geographical
Datum: South American Datum, 1969
Central Meridian: 30°/Time zone: 24

Figure 1. Location of Serra da Pedra Lascada (SPL) and Serra do Corcovado (SCO) regions and their respective cities (Barro Preto and Almadina) in southern Bahia, Brazil.

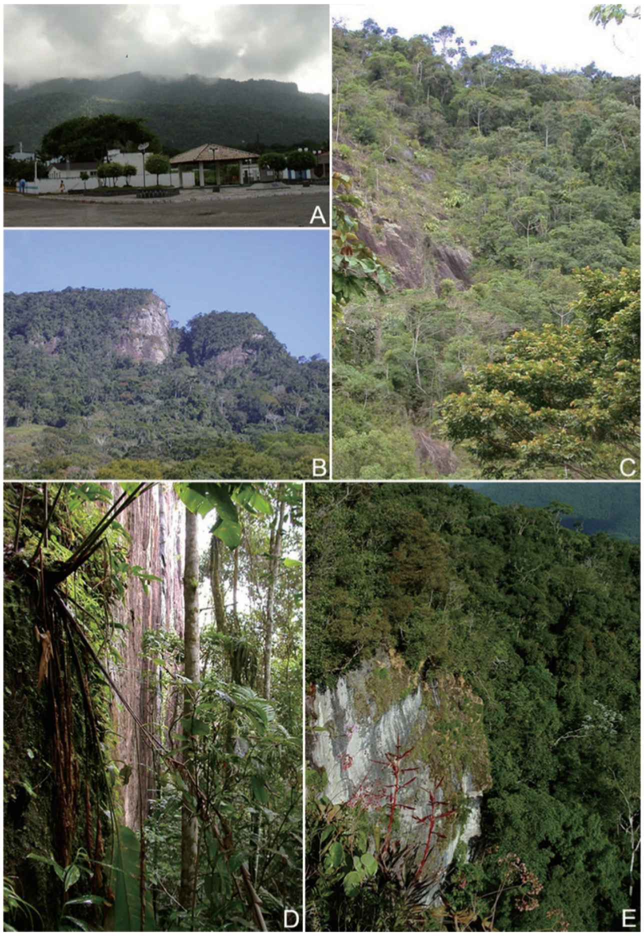


Figure 2. Serra do Corcovado (SCO) and Serra da Pedra Lascada (SPL) in the Montane Forest, southern Bahia, Brazil
A: General view of SCO from the urban center of Almadina. B: General view of SPL from the access road. C: Secondary vegetation on one of the slopes of SPL.
D: Interior of a mature forest in SPL showing the base of the inselberg. E: Vegetation at the top of the slope showing one of the exposed sides of the inselberg in SCO. Photos A and E were taken by André Paviotti. Photos B, C, and D were taken by André Amorim.

classified as proposed by APG III (2009). The specific epithets and citations of the authors of the species were standardized on the basis of the Lista de Espécies da Flora do Brasil (2012) [List of Species of the Brazilian Flora (2012)] and on the website The Plant List (2012). The occurrence of species and endemism were verified in the Lista de Espécies da Flora do Brasil (2012), Amorim et al. (2009), Thomas et al. (2003), and Stehmann et al. (2009). Endangered species were searched in the lists of Biodiversitas (2009) and MMA (2008).

Classification of life forms into arboreal, arbustive, epiphytic, hemiepiphytic, parasitic, and hemiparasitic followed the standard used by Amorim et al. (2009) and was obtained by field observation and, in some cases, from exsiccate labels of each taxon. Rupicolous speces are indicated in Table 1 with an asterisk (*). The percentage of contribution of these species was calculated and compared with that obtained in previous survey (Amorim et al. 2009) conducted in the Atlantic Forest in southern Bahia, which used a similar methodology and for which sample material is accessible in scientific archives such as CEPEC and RB.

Results

Floristic Survey

In the SCO and SPL areas, a total of 899 species of angiosperms, distributed in 437 genera and 116 families, was documented (Table 1). SCO was the area with a greater abundance, with 678 species distributed in 367 genera and 100 families. SPL comprised 466 species in 269 genera and 88 families. The percentage of species identified was 85.8% (772 species), 14% (124 species) and 0.5% (5 species) of which were identified only at the genus and family level, respectively.

Of the total species documented, 37.7% (291 species) are endemic to the Atlantic Forest and 11.2% (101 species) are endemic to southern Bahia and northern Espírito Santo (Figure 3). The remaining 44.3% species are widely distributed in Brazil. Most endemic species were arboreal (36%), followed by epiphytic (23.3%), arbustive (11%), climbing (10.7%), and herbaceous (7.6%) species. In total, 81 species (7%) had a disjunct distribution between the Atlantic and Amazonian forests.

In SCO and SPL, the five most abundant families were Orchidaceae (10%; 91 species), Rubiaceae (7%; 63 species), Bromeliaceae (5.5%; 50 species), Melastomataceae (4.2%; 38 species), and Poaceae (4%; 37 species). These families accounted for 30.7% of the documented species (Figure 4). In terms of the number of species, the five most abundant families in SCO were Orchidaceae (69 species), Rubiaceae (46 species), Bromeliaceae (33 species), Fabaceae (30 species), and Melastomataceae (28 species). In SPL, the families with the largest number of species were Orchidaceae (42 species), Rubiaceae (41 species), Bromeliaceae (30 species), Melastomataceae (27 species), and Poaceae (23 species).

In these two areas, the most abundant genera were *Psychotria* (18 species), *Piper* (17 species), *Ocotea* (15 species), *Vriesea* (14 species), and *Peperomia* (13 species) (Figure 5). In SCO, the number of genera represented by a single species totaled 34.2% (233 genera), and in SPL, it totaled 40% (185 genera). When both the areas were analyzed together, the percentage was only 29.4% (265 genera). In terms of the number of species, the most abundant genera in SCO were *Psychotria* (16 species), *Piper* (13 species), *Peperomia* and *Solanum* (11 species each), and *Anthurium*, *Ocotea*, and *Vriesea* (10 species each), whereas the most abundant genera in SPL were *Psychotria* (12 species), *Piper* (11 species), *Ocotea* and *Peperomia* (9 species each), and *Aechmea*, *Leandra*, *Miconia*, and *Vriesea* (8 species each).

Among the life forms documented in SCO, 35.2% of the species were arboreal, 21% were epiphytic/hemiepiphytic, 16.5% were arbustive/subarbustive, 14,6% were herbaceous, 11.5% were climbing, and 1.3% were hemiparasitic (Figure 6). In SPL, 33.7% of the species were arboreal, 23.8% were epiphytic/hemiepiphytic, 18,5% were arbustive/subarbustive, 13.4% were herbaceous, 10% were climbing, and 0.6% were hemiparasitic. In total, 17 species were rupicolous, and most of them belonged to the family Piperaceae. More than 50% of the species recorded were nonarboreal (64.8% in SCO and 66.3% in SPL). These values were similar to those found in previous studies performed in the same region (Figure 6, Table 2).

In SCO and SPL, the most abundant families in terms of liana species were Malpighiaceae (13 species), Asteraceae (12 species), Sapindaceae (9 species), Celastraceae (8 species), and Bignoniaceae, Fabaceae, and Cucurbitaceae (7 species each),

Table 1. List of species sampled on Serra do Corcovado and Serra da Pedra Lascada in the Montane Forest, southern Bahia, Brazil. Arb. = Arboreal, Shr. = Shrub, Epip. = Epiphyte, Hemiep.= Hemiepiphytes , Hemi-par. = Hemi-parasitic, Herb. = Herbaceous, Holopar. = Holoparasitic, Sub-shr. = Sub-shrub, Clim. = Climber; Collectors: AA = André Amorim, AF = André Fontana, Adriana Lobao AL =, DC = Domingos Cardoso, DM = Daniele Monteiro JJ = Jomar Jardim, JP = José Paixão, LD = Daneu Lucas, MC = Macielle Coelho, ML = Mardel Lopes, PF = Pedro Fiaschi, PO = Patricia Oliveira, RB = Rafael Borges, RP = Ricardo Perdiz, WT = Thomas Wayt. Domains: AM = Amazonian, CA = Caatinga CE = Cerrado, AF = Atlantic Forest, PA = Pampa, PAN = Pantanal. Category of threat: CR = Critically Endangered, EN = Endangered, LC = Least concern, NT = Near Threatened, VU = Vulnerable. * = rupicolous

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
ACANTHACEAE						
Aphelandra cf. *bahiensis* (Nees) Wassh.	Sub-shr.	JP 888		Atlantic Forest		
Aphelandra blanchetiana (Nees) Hook.	Sub-shr.		AA 4080	Atlantic Forest		
Aphelandra hirta (Klotzsch) Wassh.	Sub-shr.		AA 4080a	Atlantic Forest	Northeast	
Aphelandra nitida Nees & Mart.	Sub-shr.	PF 1635		Atlantic Forest		
Justicia sp.1	Sub-shr.		MC 338			
Justicia beyrichii (Nees) Lindau	Sub-shr.		AA 4242	Atlantic Forest	Northeast	
Justicia genuflexa Nees & Mart.	Herb.	LM 4926		Atlantic Forest		
Justicia cf. *symphyantha* (Nees) Lindau	Sub-shr.	JP 829	RB 476	Atlantic Forest		
Ruellia sp. 1	Sub-shr.	ML 357				
Ruellia sp. 2	Herb.	PF 1638				
Ruellia sp. 3	Herb.	MC 386				
Ruellia curviflora Nees & Mart.	Herb.	MC 689		Atlantic Forest		
Thunbergia fragrans Roxb.	Clim.	MC 454		Atlantic Forest		
ACHARIACEAE						
Carpotroche brasiliensis (Raddi) Endl.	Arb.	MC 415		Amazonian, Cerrado, Atlantic Forest		
AGAVACEAE						
Herreria sp. 1	Clim.	MC 475				
AMARANTACEAE						
Cyathula achyranthoides (Kunth) Moq.	Herb.	MC 696		Amazonian, Caatinga, Atlantic Forest		
ANACARDIACEAE						
Tapirira guianensis Aubl.	Arb.		RB 472	Amazonian, Caatinga, Cerrado, Atlantic Forest, Pampa, Pantanal		
ANNONACEAE						
Annonac. sp.1	Arb.	MC 594				
Annona acutiflora Mart.	Shr.		PF 1907	Atlantic Forest		
Annona cacans Warm.	Arb.	MC 762		Atlantic Forest		
Annona dollabripetala Raddi	Arb.	MC 614	PF 1915	Atlantic Forest		
Guatteria sp. 1	Arb.	LM 4913				
Guatteria australis A.St.-Hil.	Arb.	AL 720		Atlantic Forest		
Guatteria ferruginea A.St.-Hil.	Arb.	AL 722		Atlantic Forest		
Guatteria pogonopus Mart.	Arb.	ML 1126		Atlantic Forest		
Unonopsis sp. 1	Arb.	LM 4897				

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Table 1. Continued.

Family/Species	**Habit**	**SCO**	**SPL**	**Phytogeographic Domain**	**New Occurrence**	**Threat**
Unonopsis bahiensis Maas & Orava	Arb.	MC 405	WT 14294	Atlantic Forest		
Xylopsia sericea A. St.-Hil.	Arb.	JP 889		Amazonian, Cerrado, Atlantic Forest		
APOCYNACEAE						
Aspidosperma spruceanum Benth. ex Müll. Arg.	Arb.	PF 2929		Amazonian, Cerrado, Atlantic Forest		
Bahiella infundibuliflora J.F. Morales	Clim.	JP 903	RB 515	Atlantic Forest		
Forsteronia leptocarpa (Hook. & Arn.) A.DC.	Arb.		PF 1756	Atlantic Forest		
Himatanthus bracteatus (A.DC.) Woodson	Arb.	JP 899		Amazonian, Atlantic Forest		
Lacmellea pauciflora (Kuhlm.) Markgr.	Arb.	ML 721		Atlantic Forest		
Malouetia cestroides (Nees ex Mart.) Müll.Arg.	Arb.		RB 518	Atlantic Forest		
Mandevilla funiformis (Vell.) K. Schum.	Clim.	MC 712	AA 4785	Atlantic Forest		
Mandevilla permixta Woodson	Sub-shr.	RB 414		Atlantic Forest		
Orthosia parviflora (E.Fourn.) Liede & Meve.	Clim.	MC 852		Atlantic Forest		
Peltastes peltatus (Vell.) Woodson	Clim.	AA 8130		Cerrado, Atlantic Forest		
Rauvolfia grandiflora Mart. ex A.DC.	Arb.	PF 1615	JP 766	Atlantic Forest		
Tabernaemontana flavicans Willd. ex Roem. & Schult.	Arb.	MC 346		Amazonian, Cerrado, Atlantic Forest		
Tabernaemontana salzmannii A.DC.	Arb.	MC 473		Cerrado, Atlantic Forest		
APODANTHACEAE						
Apodanthes caseariae Poit.	Holopar.	ML 1112		Amazonian, Atlantic Forest	Northeast	
AQUIFOLIACEAE						
Ilex aff. *conocarpa* Reissek	Arb.	PF 2642		Atlantic Forest		
Ilex psammophila Mart. ex Reissek.	Arb.	MC 657		Atlantic Forest		
ARACEAE						
Anthurium sp.1	Epip.	DC 2135		Atlantic Forest		
Anthurium sp.2	Epip.	MC 380	PF 1830	Atlantic Forest		
Anthurium bellum Schott	Herb.	MC 400	AA 4079	Atlantic Forest		
Anthurium gladiifolium Schott	Epip.	MC 511	PF 1904	Atlantic Forest		
Anthurium gracile (Rudge) Lindl.	Epip.	MC 619		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Anthurium illepidum Schott	Hemiep.		FF 1494	Atlantic Forest		
Anthurium intermedium Kunth	Epip.	RP 836		Atlantic Forest		
Anthurium jilekii Schott	Epip.*	RB 554	ML 1106	Caatinga, Atlantic Forest		
Anthurium pentaphyllum (Aubl.) G.Don	Epip.	MC 838	PF 1856	Amazonian, Atlantic Forest, Pantanal		
Anthurium scandens (Aubl.) Engl.	Hemiep.	DC 2154	RB 503	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Anthurium solitarium Schott	Epip.	JP 866		Amazonian, Cerrado, Atlantic Forest		
Asterostigma riedelianum (Schott) Kuntze	Herb.	ML 1125	PF 1782	Atlantic Forest		

Continued on next page

Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
Heteropsis oblongifolia Kunth	Hemiep.		LD 428	Amazonian, Cerrado, Atlantic Forest		
Monstera adansonii Schott var. *klotzschiana* (Schott) Madison	Hemiep.	MC 403	AA 4209	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Philodendron sp. nova	Epip.	MC 466		Atlantic Forest		
Philodendron cordatum Kunth ex Schott	Hemiep.	MC 862	WT 14315	Atlantic Forest	Northeast	
Philodendron edmundoi G.M.Barroso	Hemiep.	MC 849	AA 4820	Atlantic Forest	Northeast	
Philodendron fragrantissimum (Hook.) G.Don	Hemiep.		AA 4818a	Amazonian, Atlantic Forest		
Philodendron hederaceum (Jacq.) Schott	Hemiep.	MC 755		Amazonian, Atlantic Forest		
Philodendron longilaminatum Schott	Hemiep.*		MC 430	Atlantic Forest		
Philodendron ornatum Schott	Epip.	MC 742		Amazonian, Caatinga, Atlantic Forest		
Philodendron pedatum (Hook.) Kunth	Hemiep.	MC 720	AA s.n.	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Philodendron propinquum Schott	Hemiep.	MC 836	JP 774	Atlantic Forest		
Philodendron recurvifolium Schott	Hemiep.	MC 859		Atlantic Forest		
Rhodospatha latifolia Poepp.	Hemiep.	ML 362	JP 780	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Stenospermation spruceanum Schott	Hemiep.*	MC 413	WT 14322	Amazonian, Cerrado, Atlantic Forest		
Syngonium vellozianum Schott	Hemiep.	MC 754		Amazonian, Atlantic Forest		
ARALIACEAE						
Dendropanax amorimii Fiaschi	Shr.		ML 321	Atlantic Forest		
Schefflera morototoni (Aubl.) Maguire, Steyerm. & Frodin	Arb.	ML 1230		Amazonian, Caatinga, Cerrado, Atlantic Forest, Pantanal		
Schefflera aff. *varisiana* Frodin	Arb.	JP 844	AA 4542	Atlantic Forest		
ARECACEAE						
Attalea oleifera Barb.Rodr.	Arb.	RB 373		Cerrado, Atlantic Forest		LR Lc
Bactris sp. 1	Arb.	RB 440		Atlantic Forest		
Bactris pickelli Burret	Shr.	RB 432	AA 4881	Atlantic Forest		VU
Bactris setosa Mart.	Arb.	AA 8138		Cerrado, Atlantic Forest		
Euterpe edulis Mart.	Arb.	MC 822	AA s.n.	Cerrado, Atlantic Forest		EN anexo I
Geonoma elegans Mart.	Shr.	MC 510	ML 305	Atlantic Forest		
Geonoma pauciflora Mart.	Shr.	WT 14170		Atlantic Forest		
Geonoma pohliana Mart.	Shr.	MC 845	AA 4208	Cerrado, Atlantic Forest		
Syagrus botryophora Mart.	Arb.	AA 8136		Atlantic Forest		LR nt
ARISTOLOCHIACEAE						
Aristolochia tamnifolia (Klotzsch) Duch.	Clim.	ML 1253		Cerrado, Atlantic Forest		

Continued on next page

Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
ASTERACEAE						
Asterac. sp.1	Herb.	MC 702				
Asterac. sp.2	Herb.	MC 831				
Achyrocline satureioides DC.	Herb.	RB 393		Cerrado, Atlantic Forest, Pampa		
Albertinia brasiliensis Spreng.	Clim.	ML 1257		Caatinga, Cerrado, Atlantic Forest		
Baccharis sp. 1	Herb.	MC 803				
Baccharis calvescens DC.	Shr.	MC 804	RB 514	Caatinga, Cerrado, Atlantic Forest		
Baccharis oblongifolia (Ruiz & Pav.) Pers.	Arb.		PF 1770	Amazonian, Cerrado, Atlantic Forest		
Baccharis singularis (Vell.) G.M. Barroso	Shr.	AA 8125		Atlantic Forest, Pampa		
Barrosoa atlantica R.M.King & H.Rob.	Herb.	RP 117		Atlantic Forest		
Calyptocarpus biaristatus (DC.) H.Rob.	Herb.	MC 799		Atlantic Forest		
Chaptalia nutans (L.) Pol.	Herb.	MC 692		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Conocliniopsis prasiifolia (DC.) R.M. King & H. Rob.	Herb.	RP 114		Caatinga, Cerrado, Atlantic Forest		
Cyrtocymura scorpioides (Lam.) H.Rob.	Sub-shr.	DC 2153	AA 4106	Amazonian, Cerrado, Atlantic Forest		
Diacranthera hebeclinia H.Rob.	Herb.	MC 506		Atlantic Forest		
Elephantopus mollis H.B.K.	Sub-shr.	MC 703	AA 4243	Amazonian, Caatinga, Cerrado, Atlantic Forest, Pampa, Pantanal		
Erechtites valerianifolius (Wolf) DC.	Herb.	RB 387		Caatinga, Cerrado, Atlantic Forest, Pampa		
Heterocondylus alatus (Vell.) R.M. King & H. Rob.	Shr.	RB 392		Caatinga, Cerrado, Atlantic Forest		
Lepidaploa cotoneaster (Willd. ex Spreng.) H. Rob.	Shr.	ML 374		Cerrado, Atlantic Forest		
Lepidaploa aff. *mucronifolia* (DC.) H.Rob.	Sub-shr.		PF 1546			
Mikania sp. 1	Clim.	RP 118				
Mikania argyreiae DC.	Clim.	WT 14172		Cerrado, Atlantic Forest		
Mikania buddleiaefolia DC.	Clim.	ML 738		Atlantic Forest	Northeast	
Mikania callineura Sch.Bip. ex Baker	Clim.		JP 571	Atlantic Forest	Northeast	
Mikania candolleana Gardner	Clim.		PF 1526	Cerrado, Atlantic Forest	Northeast	
Mikania aff. *hookeriana* DC.	Clim.		AA 4909	Atlantic Forest		
Mikania kubitzkii R.M.King & H.Rob.	Clim.		PF 2636	Atlantic Forest		
Mikania mattos-silvae R.M. King & H. Rob.	Clim.	PF 1620		Atlantic Forest		
Mikania trinervis Hook. & Arn.	Clim.	MC 379	AA 4241	Atlantic Forest		
Mikania ulei Hieron.	Clim.		AA 4077	Atlantic Forest		
Piptocarpha pyrifolia (DC.) Baker	Clim.	DC 2124		Atlantic Forest		
Solidago chilensis Meyen	Shr.		RB 502	Caatinga, Cerrado, Atlantic Forest, Pampa		
Synedrella nodiflora (L.) Gaertn.	Herb.	MC 695		Amazonian, Caatinga, Atlantic Forest		
Vernonanthura discolor (Less.) H.Rob.	Arb.		PF 1845	Cerrado, Atlantic Forest		
Vernonanthura vinhae (H. Rob.) H. Rob.	Shr.	RB 407		Atlantic Forest		

Continued on next page

Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
BEGONIACEAE						
Begonia sp.1	Herb.	RB 415	AA 4906	Atlantic Forest		
Begonia convolvulacea (Klotzsch) A.DC.	Hemiep.	WT 14166	AA 4912	Atlantic Forest		
Begonia digitata Raddi	Sub-shr.	MC 604	ML 347	Atlantic Forest		
Begonia fischeri Schrank	Herb.	DC 2143		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Begonia fruticosa (Klotzsch) A.DC.	Epip.	PF 2937	AA 4229	Atlantic Forest		
Begonia itaguassuensis Brade	Herb.	WT 14167	PF 1533	Atlantic Forest		
Begonia neglecta A.DC.	Herb.	MC 378	AA 4847	Atlantic Forest		
Begonia polygonifolia A.DC.	Hemiep.	WT 14164		Atlantic Forest		
Begonia smilacina A. DC.	Hemiep.	MC 617	AA 4527	Atlantic Forest		
BIGNONIACEAE						
Adenocalymma sp. 1	Clim.	MC 401	PF 1777	Atlantic Forest		
Adenocalymma comosum (Cham.) DC.	Clim.	MC 449		Atlantic Forest		
Amphilophium crucigerum (L.) L.G. Lohmann	Arb.	MC 566		Amazonian, Caatinga, Cerrado, Atlantic Forest, Pantanal		
Anemopaegma sp. 1	Clim.	ML 1239		Atlantic Forest		
Callichlamys latifolia (Rich.) K.Schum.	Clim.		ML 1177	Amazonian, Cerrado, Atlantic Forest, Pantanal		
Handroanthus heptaphyllus (Vell.) Mattos	Arb.	DC 2127		Cerrado, Atlantic Forest		
Jacaranda sp. 1	Arb.	MC 858		Atlantic Forest		
Lundia cordata (Vell.) DC.	Clim.	MC 409		Caatinga, Atlantic Forest		
Pleonotoma albiflora (Salzm. ex DC.) A.H.Gentry	Clim.		JP 771	Amazonian, Cerrado, Atlantic Forest, Pantanal		
Sparattosperma leucanthum (Vell.) K. Schum.	Arb.	PF 2926		Amazonian, Caatinga, Cerrado, Atlantic Forest, Pantanal		
Tabebuia elliptica (DC.) Sandwith	Arb.	ML 1286		Caatinga, Cerrado, Atlantic Forest		
Tanaecium jaroba Sw.	Clim.	ML 1248	ML 686	Amazonian, Pantanal, Atlantic Forest		
BORAGINACEAE						
Cordia sp. 1	Arb.	JP 840	MC 425	Atlantic Forest		
Cordia sp.2	Arb.		AA 4893	Atlantic Forest		
Cordia candida Vell.	Arb.	MC 573		Atlantic Forest		
Cordia ecalyculata Vell.	Arb.	PF 2916	AA 4218	Atlantic Forest		
Cordia cf. *superba* Cham.	Arb.	WT 14178 c		Caatinga, Cerrado, Atlantic Forest		
Cordia trichoclada DC.	Arb.	MC 515		Atlantic Forest		
Tournefortia gardneri A.DC.	Clim.		ML 340	Atlantic Forest		
Varronia curassavica Jacq.	Shr.	MC 733		Amazonian, Caatinga, Atlantic Forest		
Varronia tarodaea J.S.Mill.	Shr.	ML 739	JP 798	Atlantic Forest		

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Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
BROMELIACEAE						
Aechmea sp. 1	Epip.	MC 479	ML 678	Atlantic Forest		
Aechmea sp. 2	Epip.	MC 358	PF 2626	Atlantic Forest		
Aechmea sp. 3	Herb.	AA 8134		Atlantic Forest		
Aechmea conifera L.B.Sm.	Epip.	MC 741		Atlantic Forest	Bahia	
Aechmea digitata L.B.Sm. & R.W.Read	Epip.	AA 8135		Atlantic Forest		
Aechmea froesii (L.B.Sm.) Leme & J.A.Siqueira	Epip.		ML 685	Atlantic Forest		
Aechmea guaratingensis Leme & L. Kollmann	Epip.	RB 434		Atlantic Forest		
Aechmea miniata Beer ex Baker	Epip.	RB 530	WT 14308	Atlantic Forest		
Aechmea sulbahianensis Leme, Amorim & J.A.Siqueira	Epip.		ML 1169	Atlantic Forest		
Aechmea turbinocalyx Mez	Epip.		PF 1763	Atlantic Forest		
Aechmea viridipetala A.F.Costa & Amorim	Epip.		AA 4110	Atlantic Forest		
Aechmea viridostigma Leme & H.Luther	Epip.		PF 1560	Atlantic Forest		
Billbergia euphemiae E. Morren	Epip.	JP 873	RP 843	Atlantic Forest		
Billbergia iridifolia (Nees & Mart.) Lindley	Epip.	WT 14175		Caatinga, Atlantic Forest		
Billbergia saundersii Bull	Epip.	MC 687	AA 4849	Atlantic Forest		
Bromelia cf. *binotii* E.Morren ex Mez	Herb.	MC 739		Atlantic Forest		
Canistrum auratum Leme	Epip.		AA 4797	Atlantic Forest		
Canistrum montanum Leme	Epip.		PF 1762	Atlantic Forest		
Canistrum seidelianum W.Weber	Epip.		PF 1917	Atlantic Forest		
Guzmania lingulata (L.) Mez	Epip.	AA 4681		Atlantic Forest		
Hohenbergia sp.1	Epip.	WT 178 a		Atlantic Forest		
Hohenbergia brachycephala L.B. Sm.	Epip.	ML 1130		Atlantic Forest		
Lymania marantoides (L.B.Sm.) Read	Epip.		AA 4840	Atlantic Forest		
Neoregelia kerryi Leme	Epip.	MC 749	AA 4806	Atlantic Forest		
Neoregelia wilsoniana M.B. Foster	Epip.	MC 563		Atlantic Forest		
Nidularium innocentii Lem.	Epip.		AA 4530	Atlantic Forest		
Nidularium procerum Lindm.	Epip.		RB 493	Atlantic Forest		
Pitcairnia flammea Lindl.	Herb.		AA 4216	Cerrado, Atlantic Forest		
Portea filifera L.B.Sm.	Epip.	MC 681	AA 4825	Atlantic Forest		
Portea petropolitana (Wawra) Mez *var. noettigii* (Wawra) L.B.Sm.	Epip.	MC 580		Atlantic Forest		
Racinaea spiculosa (Griseb.) M.A.Spencer & L.B.Sm.	Epip. *	MC 758	AA 4817a	Amazonian, Atlantic Forest		
Ronnbergia silvana Leme	Epip.		PF 1764	Atlantic Forest		
Tillandsia gardneri Lindl.	Epip.	MC 398		Caatinga, Cerrado, Atlantic Forest		
Tillandsia sprengeliana Klotzsch ex Mez	Epip.	AA 4684	JP 505	Cerrado, Atlantic Forest		
Tillandsia stricta Sol.	Epip.	RB 460		Caatinga, Cerrado, Atlantic Forest		
Tillandsia usneoides (L.) L.	Epip.	MC 752		Caatinga, Cerrado, Atlantic Forest		
Vriesea sp. 1	Epip.	MC 882		Atlantic Forest		

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Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
Vriesea sp.2	Epip.		RB 511	Atlantic Forest		
Vriesea blackburniana Leme	Epip.	AA 6338	RB 494	Atlantic Forest		
Vriesea drepanocarpa (Baker) Mez	Epip.	MC 366		Atlantic Forest		
Vriesea duvaliana E.Morren	Epip.	AA 8165		Atlantic Forest		
Vriesea ensiformis (Vell.) Beer	Epip.		PF 1887	Atlantic Forest		
Vriesea flammea L.B.Sm.	Epip.		RB 497	Atlantic Forest		
Vriesea graciliscapa W.Weber	Epip.	MC 759		Atlantic Forest		
Vriesea procera (Mart. ex Schult. & Schult.f.) Wittm.	Epip.	ML 1132		Caatinga, Cerrado, Atlantic Forest		
Vriesea psittacina (Hook.) Lindl.	Epip.	RB 435	ML 1178	Atlantic Forest		VU anexo II
Vriesea rhodostachys L.B.Sm.	Epip.		JJ 4783	Atlantic Forest		
Vriesea ruschii L.B. Sm.	Epip.	RB 439	RB 501	Atlantic Forest		
Vriesea sandrae Leme	Epip.	ML 743		Atlantic Forest		
Vriesea simplex (Vell.) Beer	Epip.	MC 664	JP 777	Atlantic Forest		
BURMANNIACEAE						
Gymnosiphon divaricatus (Benth.) Benth. & Hook. f.	Herb.	ML 1288	ML 691	Amazonian, Cerrado, Atlantic Forest		
CACTACEAE						
Cereus sp.1	Shr.	MC 769				
Hatiora salicornioides (Haw.) Britton & Rose	Epip.		AA 4823	Atlantic Forest		
Lepismium cruciforme (Vell.) Miq.	Epip.	MC 723		Atlantic Forest		LC
Rhipsalis baccifera (J.M.Muell.) Stearn subsp. *hileiabaiana* N.P.Taylor & Barthlott	Epip. *	MC 495		Cerrado, Atlantic Forest		VU
Rhipsalis floccosa Salm-Dyck ex Pfeiff.	Epip.	MC 497		Caatinga, Cerrado, Atlantic Forest		LC
Rhipsalis oblonga Loefgr.	Epip.	RB 430	PF 1778	Atlantic Forest		NT
CAMPANULACEAE						
Centropogon cornutus (L.) Druce	Sub-shr.	MC 375	AA 4211	Amazonian, Caatinga, Cerrado, Atlantic Forest		
CANNABACEAE						
Celtis iguanaea (Jacq.) Sarg.	Shr.	WT 14162		Amazonian, Caatinga, Cerrado, Atlantic Forest, Pampa, Pantanal		
CANNACEAE						
Canna paniculata Ruiz & Pav.	Sub-shr.		AA 4236	Cerrado, Atlantic Forest		
CARDIOPTERIDACEAE						
Citronella megaphylla (Miers) R.A. Howard	Arb.	RP 121		Cerrado, Atlantic Forest		

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Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
CARICACEAE						
Jacaratia heptaphylla (Vell.) A.DC.	Arb.	MC 820	ML 350	Atlantic Forest		
CARYOCARACEAE						
Caryocar edule Casar.	Arb.		AA 4544	Atlantic Forest		
CELASTRACEAE						
Anthodon decussatum Ruiz & Pav.	Clim.	RB 377		Amazonian, Cerrado, Atlantic Forest		
Cheiloclinium cognatum (Miers) A.C.Sm.	Clim.	RB 420		Amazonian, Cerrado, Atlantic Forest, Pantanal		
Cheiloclinium serratum (Cambess.) A.C.Sm.	Clim.		RP 844	Amazonian, Cerrado, Atlantic Forest		
Maytenus brasiliensis Mart.	Arb.	MC 491	PF 1805	Atlantic Forest		
Peritassa hatschbachii Lombardi	Clim.	ML 1128		Atlantic Forest		
Pristimera nervosa (Miers) A.C. Sm.	Clim.	MC 558		Amazonian, Atlantic Forest	Bahia	
Salacia elliptica (Mart. ex Schult.) G.Don	Clim.		JP 498	Amazonian, Caatinga, Cerrado, Atlantic Forest, Pantanal		
Tontelea mauritioides (A.C.Sm.) A.C.Sm.	Clim.	MC 842		Amazonian, Atlantic Forest		
Tontelea miersii (Peyr.) A.C.Sm.	Clim.		JJ 4784	Atlantic Forest		
CHLORANTHACEAE						
Hedyosmum brasiliense Mart. ex Miq.	Shr.		AA 4791	Amazonian, Cerrado, Atlantic Forest		
CHRYSOBALANACEAE						
Hirtella santosii Prance	Arb.	MC 624	JJ 4791	Atlantic Forest		
Licania belemii Prance	Arb.	ML 736		Atlantic Forest		
Licania hoehnei Pilg.	Arb.	PF 2915		Cerrado, Atlantic Forest		
Licania hypoleuca Benth.	Arb.	ML 710		Amazonian, Atlantic Forest		
Licania octandra (Hoffmanns. ex Roem. & Schult.) Kuntze	Arb.	LM 4900		Amazonian, Caatinga, Cerrado, Atlantic Forest		
CLUSIACEAE						
Clusia cf. *criuva* Cambess.	Arb.		ML 323	Atlantic Forest		
Clusia cf. *dardanoi* G.Mariz & Maguire	Shr.	MC 767		Caatinga, Atlantic Forest		
Clusia melchiori Gleason	Arb.	ML 719	WT 14318	Caatinga, Cerrado, Atlantic Forest		
Clusia panapanari (Aubl.) Choisy	Epip.		MC 648	Amazonian, Caatinga, Atlantic Forest		
Garcinia gardneriana (Planch. & Triana) Zappi	Arb.	RB 522		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Garcinia macrophylla Mart.	Arb.	AA 4678		Amazonian, Cerrado, Atlantic Forest		
Tovomita sp. 1	Arb.	MC 602				
Tovomita mangle G.Mariz	Arb.		PF 1906	Atlantic Forest		

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Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
COMBRETACEAE						
Combretum mellifluum Eichler	Clim.	MC 672		Atlantic Forest		
COMMELINACEAE						
Callisia monandra (Sw.) Schult.f.	Herb.	MC 701		Caatinga, Atlantic Forest		
Commelina sp.1	Herb.		ML 1152	Atlantic Forest		
Dichorisandra sp. 1	Herb.	MC 605		Atlantic Forest		
Dichorisandra sp. nova	Herb.	MC 691		Atlantic Forest		
Dichorisandra sp.3	Herb.		RB 496	Atlantic Forest		
CONNARACEAE						
Connarus sp. 1	Clim.	JP 901		Atlantic Forest		
Connarus sp. 2	Clim.	MC 854		Atlantic Forest		
COSTACEAE						
Chamaecostus cuspidatus (Nees & Mart.) C. Specht & D. W. Stev.	Herb.	MC 493		Atlantic Forest		EN anexo I
Costus scaber Ruiz & Pav.	Sub-shr.		AA 4899	Amazonian, Atlantic Forest		
Costus spiralis (Jacq.) Roscoe	Herb.	MC 568		Amazonian, Cerrado, Atlantic Forest	Bahia	
CUCURBITACEAE						
Cayaponia sp. 1	Clim.	MC 357				
Cayaponia cf. *tayuya* (Vell.) Cogn.	Clim.	RB 375		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Cayaponia trifoliolata (Cogn.) Cogn.	Clim.		MC 654	Atlantic Forest		
Gurania acuminata Cogn.	Clim.		JP 788	Amazonian, Atlantic Forest		
Gurania bignoniacea (Poepp. & Endl.) C.Jeffrey	Clim.	AA 4685	AA 4219	Amazonian, Atlantic Forest		
Gurania speciosa (Poepp. & Endl.) Cogn.	Clim.		ML 1145	Amazonian, Atlantic Forest		
Melothria cucumis Vell.	Clim.	RP 108		Cerrado, Atlantic Forest		
CUNONIACEAE						
Lamanonia ternata Vell.	Arb.		AA 4830	Cerrado, Atlantic Forest		
CYCLANTHACEAE						
Asplundia gardneri (Hook.) Harling	Hemiep.	MC 531		Caatinga, Atlantic Forest		
Asplundia maximiliani Harling	Hemiep.	DC 2139		Atlantic Forest		
Evodianthus funifer (Poit.) Lindm.	Hemiep.	MC 528	FF 1492	Amazonian, Atlantic Forest		
Thoracocarpus bissectus (Vell.) Harling	Hemiep.		ML 303	Amazonian, Atlantic Forest		
CYPERACEAE						
Becquerelia cymosa Brongn.	Herb.	RB 446	AA 4532a	Amazonian, Cerrado, Atlantic Forest		

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Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
Cryptangium sp.1	Herb.		ML 660	Atlantic Forest		
Hypolytrum aff. *lucennoi* M.Alves & W.W.Thomas	Herb.		PF 1836	Atlantic Forest		
Hypolytrum schraderianum Nees	Herb.		AA 4532	Amazonian, Atlantic Forest		
Kyllinga sp.1	Herb.		ML 1163	Atlantic Forest		
Pleurostachys sp.1	Herb.	WT 14182		Atlantic Forest		
Pleurostachys sp.2	Herb.		AA 4888	Atlantic Forest		
Pleurostachys gaudichaudii Brongn.	Herb.	WT 14180	ML 1151	Atlantic Forest		
Pleurostachys aff. *orbignyana* Brongn.	Herb.	RB 544		Atlantic Forest		
Pleurostachys puberula Boeckeler	Herb.	MC 365		Amazonian, Atlantic Forest		
Rhynchospora sp. 1	Herb.	RB 425		Atlantic Forest		
Rhynchospora cryptantha C.B.Clarke	Herb.		WT 14326	Atlantic Forest		
Rhynchospora splendens Lindm.	Herb.	MC 356	WT 14332	Atlantic Forest		
Scleria sp.1	Herb.		AA 4235	Atlantic Forest		
Scleria latifolia Sw.	Herb.	MC 355		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Scleria panicoides Kunth	Herb.	ML 380		Cerrado, Atlantic Forest, Pampa		
Scleria scabra Willd.	Herb.	RB 396		Amazonian, Caatinga, Cerrado, Atlantic Forest, Pampa, Pantanal		
DICHAPETALACEAE						
Stephanopodium blanchetianum Baill.	Arb.	MC 794		Atlantic Forest		
DILLENIACEAE						
Davilla nitida (Vahl) Kubitzki	Clim.	RP 712		Amazonian, Cerrado, Atlantic Forest		
Doliocarpus sp. 1	Clim.	MC 871		Atlantic Forest		
DIOSCOREACEAE						
Dioscorea sp.1	Clim.		MC 638	Atlantic Forest		
Dioscorea macrothyrsa Uline	Clim.		MC 670	Atlantic Forest		
Dioscorea multiflora Mart. ex Griseb.	Clim.		JP 566	Amazonian, Cerrado, Atlantic Forest		
Dioscorea subhastata Vell.	Clim.	RB 561		Cerrado, Atlantic Forest		
EBENACEAE						
Diospyros sp. 1	Arb.	MC 589				
Diospyros apeibacarpos Raddi	Arb.		PF 1826	Atlantic Forest	Northeast	
Diospyros riedelii (Hiern) B.Walln.	Arb.	AA 4677		Atlantic Forest		
ELAEOCARPACEAE						
Sloanea guianensis (Aubl.) Benth.	Arb.	MC 867	PF 2637	Amazonian, Cerrado, Atlantic Forest		
Sloanea garckeana K. Schum.	Arb.	ML 703		Amazonian, Cerrado, Atlantic Forest		

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Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
ERYTHROXYLACEAE						
Erythroxylum citrifolium A.St.-Hil.	Arb.	MC 530	WT 14320	Amazonian, Cerrado, Atlantic Forest		
Erythroxylum columbinum Mart.	Arb.		AA 4879	Atlantic Forest		
Erythroxylum cuspidifolium Mart.	Arb.		AA 4834	Atlantic Forest		
Erythroxylum flaccidum Salzm. ex Peyr.	Shr.	MC 686		Caatinga, Cerrado, Atlantic Forest		
Erythroxylum aff. *macrocalyx* Mart.	Arb.	MC 559		Caatinga, Cerrado, Atlantic Forest		
Erythroxylum nobile O.E. Schulz	Arb.	MC 626		Atlantic Forest		
Erythroxylum aff. *pulchrum* A.St.Hil.	Arb.	MC 735		Caatinga, Atlantic Forest		
Erythroxylum squamatum Sw.	Arb.	MC 622		Amazonian, Caatinga, Cerrado, Atlantic Forest		
EUPHORBIACEAE						
Acalypha sp.1	Shr.	RB 382		Atlantic Forest		
Actinostemon appendiculatus Jabl.	Shr.	LM 4901		Atlantic Forest		
Alchornea triplinervia (Spreng.) Müll. Arg.	Arb.	ML 706		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Aparisthmium cordatum (A.Juss.) Baill.	Arb.		ML 295	Amazonian, Atlantic Forest		
Bernardia scabra Müll.Arg.	Shr.		WT 14291	Caatinga, Atlantic Forest		
Cnidosculus oligandrus (Müll.Arg.) Pax	Arb.	MC 745		Caatinga, Atlantic Forest		
Croton sp.1	Shr.	AA 4704		Atlantic Forest		
Croton floribundus Spreng.	Arb.	MC 766		Caatinga, Cerrado, Atlantic Forest		
Croton macrobothrys Baill.	Arb.	MC 879		Atlantic Forest		
Croton sincorensis Mart.	Shr.	MC 824		Caatinga, Atlantic Forest		
Dalechampia ficifolia Lam.	Clim.	MC 450	RB 484	Atlantic Forest		
Dalechampia ilheotica Wawra	Clim.		WT 14288	Atlantic Forest		
Mabea piriri Aubl.	Arb.		FF 1501	Amazonian, Cerrado, Atlantic Forest		
Microstachys aff. *hispida* (Mart.) Govaerts	Shr.	MC 595	RB 485	Caatinga, Cerrado, Atlantic Forest		
Pausandra morisiana (Casar.) Radlk.	Arb.	MC 823	PF 2627	Atlantic Forest		
Senefeldera verticillata (Vell.) Croizat	Arb.	MC 483		Atlantic Forest		
Tetrorchidium rubrivenium Poepp.	Arb.	PF 2910	JP 782	Amazonian, Caatinga, Atlantic Forest		
FABACEAE						
Abarema cochliacarpos (Gomes) Barneby & J.W. Grimes	Arb.	RB 380		Cerrado, Atlantic Forest		VU
Albizia pedicellaris (DC.) L. Rico	Arb.	JP 908		Amazonian, Cerrado, Atlantic Forest		
Anadenanthera peregrina var. *falcata* (Benth.) Altschul	Arb.	MC 407		Caatinga, Cerrado, Atlantic Forest		
Andira fraxinifolia Benth.	Arb.		PF 1543	Caatinga, Cerrado, Atlantic Forest		
Bauhinia sp. 1	Clim.	MC 729		Atlantic Forest		
Bauhinia integerrima Mart. ex Benth.	Arb.	JP 904	JP 765	Atlantic Forest		EN
Centrolobium robustum (Vell.) Mart. ex Benth.	Arb.	MC 746		Atlantic Forest		

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Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
Centrosema virginianum (L.) Benth.	Clim.	MC 455		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Copaifera trapezifolia Hayne	Arb.	ML 1280		Atlantic Forest		
Dalbergia nigra (Vell.) Allemão ex Benth.	Arb.	MC 811		Atlantic Forest		VU
Desmodium adscendens (Sw.) DC.	Sub-shr.	MC 781		Amazonian, Caatinga, Cerrado, Atlantic Forest, Pampa		
Exostyles venusta Schott	Arb.	MC 717		Atlantic Forest		
Inga blanchetiana Benth.	Arb.	PF 1612		Atlantic Forest		EN
Inga capitata Desv.	Arb.	ML 353	ML 1089	Amazonian, Atlantic Forest		
Inga conchifolia L.P. Queiroz	Arb.		PF 2648	Atlantic Forest		
Inga grazielae (Vinha) T.D.Penn.	Arb.	MC 600	ML 1097	Atlantic Forest		VU
Inga marginata Willd.	Arb.	MC 488	MC 424	Amazonian, Cerrado, Atlantic Forest		
Inga tenuis (Vell.) Mart.	Arb.	ML 1108	ML 669	Atlantic Forest		
Inga thibaudiana DC.	Arb.	MC 801		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Machaerium sp.1	Clim.	AA 8161		Atlantic Forest		
Machaerium salzmannii Benth.	Clim.	RP 706		Atlantic Forest		
Macrolobium latifolium Vogel	Arb.	PF 1639	PF 1820	Atlantic Forest		
Ormosia fastigiata Tul.	Arb.		ML 313	Cerrado, Atlantic Forest		
Peltogyne confertiflora (Mart. ex Hayne) Benth.	Arb.	RP 711		Caatinga, Cerrado, Atlantic Forest		
Phanera sp. 1	Clim.	MC 704		Atlantic Forest		
Phanera sp.2	Clim.	MC 839		Atlantic Forest		
Phanera smilacina (Schott) Vaz	Clim.	MC 728		Atlantic Forest		
Piptadenia adiantoides (Spreng.) J.F.Macbr.	Arb.	AA 8127		Caatinga, Cerrado, Atlantic Forest		
Plathymenia reticulata Benth.	Arb.	MC 864	AA s.n.	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Senegalia grandistipula (Benth.) Seigler & Ebinger	Shr.	MC 489	LD 431	Atlantic Forest		
Senegalia martiusiana (Steud.) Seigler & Ebinger	Arb.	PF 2907		Caatinga, Atlantic Forest		
Senna affinis (Benth.) H.S.Irwin & Barneby	Shr.	JP 896	AA 4091	Cerrado, Atlantic Forest		
Senna splendida (Vogel) H.S.Irwin & Barneby	Shr.	MC 716		Caatinga, Cerrado, Atlantic Forest		
Swartzia simplex (Sw.) Spreng. var. *continentalis* Urb.	Arb.		JP 494	Atlantic Forest		
GENTIANACEAE						
Chelonanthus purpurascens (Aubl.) Struwe	Herb.	MC 783		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Macrocarpaea atlantica J.R. Grant & V. Trunz	Shr.	MC 596	AA 4792	Atlantic Forest		
Macrocarpea orbiculata J.R.Grant & V.Trunz	Shr.		PF 2638	Atlantic Forest		
Voyria aphylla (Jacq.) Pers.	Herb.	RP 128		Amazonian, Cerrado, Atlantic Forest		
Voyria flavescens Griseb.	Herb.		AA 4237	Amazonian, Atlantic Forest		
Voyria obconica Progel	Herb.	MC 516	JJ 4769	Atlantic Forest		

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Table 1. Continued.

Family/Species	**Habit**	**SCO**	**SPL**	**Phytogeographic Domain**	**New Occurrence**	**Threat**
Voyria tenella Hook.	Herb.		RB 712	Amazonian, Cerrado, Atlantic Forest		
GESNERIACEAE						
Besleria flavovirens Nees & Mart.	Sub-shr.	MC 505	PF 1853	Amazonian, Atlantic Forest		
Codonanthe cordifolia Chautems	Epip.		AA 4526	Cerrado, Atlantic Forest		
Codonanthe gracilis (Mart.) Hanst.	Epip.	WT 14163		Atlantic Forest		
Codonanthe uleana Fritsch	Epip.	MC 620	PF 1919	Amazonian, Atlantic Forest		
Columnea sanguinea (Pers.) Hanst.	Epip.	WT 14173	AA 4203	Amazonian, Cerrado, Atlantic Forest		
Nematanthus albus Chautems	Epip.	LM 4896	AA 4907	Atlantic Forest		
Nematanthus corticola Schrad.	Epip.	MC 570	AA 4777	Atlantic Forest		
Nematanthus lanceolatus (Poir.) Chautems	Epip.	MC 778		Cerrado, Atlantic Forest		
Sinningia barbata (Nees & Mart.) G.Nicholson	Herb.		AA 4848	Caatinga, Atlantic Forest		
Sinningia brasiliensis (Regel & E.Schmidt) Wiehler & Chautems	Herb.	MC 571		Caatinga, Atlantic Forest		
Sinningia nordestina Chautems, Baracho & Siqueira-Filho	Herb.	DC 2141		Caatinga, Atlantic Forest		
HELICONIACEAE						
Heliconia sp.1	Herb.		AA 4245	Atlantic Forest		
Heliconia angusta Vell.	Herb.	JJ 4661	RP 855	Atlantic Forest		Anexo I
Heliconia richardiana Miq.	Herb.	WT 14144	PF 1538	Amazonian, Atlantic Forest		
Heliconia spathocircinata Aristeg.	Herb.	RB 555		Amazonian, Caatinga, Atlantic Forest, Pantanal		
HYPERICACEAE						
Vismia guianensis (Aubl.) Choisy	Arb.	JP 857	ML 687	Amazonian, Caatinga, Cerrado, Atlantic Forest		
IRIDACEAE						
Neomarica sp.1	Herb.		RB 499	Atlantic Forest		
LACISTEMATACEAE						
Lacistema robustum Schnizl.	Arb.		ML 1090	Cerrado, Atlantic Forest		LR lc
LAMIACEAE						
Aegiphila vitelliniflora Walp.	Clim.	JP 905		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Hyptis cf. *atrorubens* Poit.	Sub-shr.		AA 4239	Amazonian, Atlantic Forest		
LAURACEAE						
Aiouea laevis (Mart.) Kosterm.	Arb.	MC 841		Amazonian, Atlantic Forest		
Aniba intermedia (Meisn.) Mez	Arb.	MC 597		Atlantic Forest		

Continued on next page

Table 1. Continued.

Family/Species	**Habit**	**SCO**	**SPL**	**Phytogeographic Domain**	**New Occurrence**	**Threat**
Cryptocarya velloziana P.L.R.Moraes	Arb.	JP 802		Atlantic Forest		
Licaria bahiana Kurz	Arb.	LM 4910	PF 1781	Atlantic Forest		
Ocotea sp. 1	Arb.	LM 1139		Atlantic Forest		
Ocotea sp. 2	Arb.	JP 832		Atlantic Forest		
Ocotea aciphylla (Nees & Mart.) Mez	Arb.		PF 2645	Amazonian, Cerrado, Atlantic Forest		LR lc
Ocotea cernua (Nees) Mez	Arb.	MC 565	JJ 4781	Amazonian, Cerrado, Atlantic Forest		
Ocotea daphnifolia (Meisn.) Mez	Arb.	WT 14158	ML 668	Atlantic Forest		
Ocotea aff. *deflexa* Rohwer	Arb.	MC 432		Amazonian, Atlantic Forest		
Ocotea dispersa (Nees & Mart.) Mez	Arb.		PF 1774	Atlantic Forest		
Ocotea divaricata (Nees) Mez	Arb.	MC 376	ML 1102	Atlantic Forest		
Ocotea indecora (Schott) Mez	Arb.		LD 436	Atlantic Forest		
Ocotea cf. *insignis* Mez	Arb.	MC 581		Atlantic Forest		
Ocotea nitida (Meisn.) Rohwer	Arb.		ML 346	Cerrado, Atlantic Forest		
Ocotea notata (Nees & Mart.) Mez	Arb.	RB 457		Atlantic Forest		
Ocotea puberula (Rich.) Nees	Arb.	MC 498		Amazonian, Caatinga, Atlantic Forest		LR lc
Ocotea tabacifolia (Meisn.) Rohwer	Arb.	RB 538	AA 4233	Amazonian, Atlantic Forest		
Ocotea cf. *velloziana* (Meisn.) Mez	Arb.		RP 852	Caatinga, Cerrado, Atlantic Forest		
Persea americana Mill.	Arb.	JP 893	AA 4232	Atlantic Forest		
Rhodostemonodaphne sp. 1	Arb.	RB 448	PF 1792	Atlantic Forest		
LECYTHIDACEAE						
Cariniana estrellensis (Raddi) Kuntze	Arb.		JP 506	Amazonian, Cerrado, Atlantic Forest		
Lecythis lanceolata Poir.	Arb.		PF 1843	Atlantic Forest		LR cd
Lecythis pisonis Cambess.	Arb.	MC 765		Amazonian, Atlantic Forest		
LINACEAE						
Roucheria columbiana Hallier	Arb.	MC 875	ML 1159	Amazonian, Atlantic Forest		
LINDERNIACEAE						
Cubitanthus alatus (Cham. & Schltdl.) Barringer	Herb.	MC 446		Atlantic Forest		
LOASACEAE						
Aosa parviflora (Schrad. ex DC.) Weigend	Herb.		AA 4225	Atlantic Forest		
LOGANIACEAE						
Spigelia sp. 1	Herb.	RB 569		Atlantic Forest		
Spigelia laurina Cham. & Schltdl.	Sub-shr.	ML 1262		Atlantic Forest		
Strychnos sp.1	Clim.	AA 8146		Atlantic Forest		
LORANTHACEAE						
Phthirusa clandestina (Mart.) Mart.	Hemi-par.		PF 1525	Atlantic Forest		

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Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
Struthanthus sp.1	Hemi-par.	AA 8124	ML 316	Atlantic Forest		
Struthanthus polyrhizus (Mart.) Mart.	Hemi-par.	MC 722		Amazonian, Cerrado, Atlantic Forest		
Struthanthus salicifolius Mart.	Hemi-par.	MC 865		Cerrado, Atlantic Forest		
MALPIGHIACEAE						
Amorimia rigida (A.Juss.) W.R.Anderson	Shr.		AA 4102	Atlantic Forest		
Banisteriopsis sp.1	Clim.		AA 4104	Atlantic Forest		
Banisteriopsis membranifolia (A.Juss.) B.Gates	Clim.		PF 1539	Amazonian, Atlantic Forest		
Byrsonima sericea DC.	Arb.	RB 441		Caatinga, Cerrado, Atlantic Forest		
Byrsonima stipulacea A.Juss.	Arb.	MC 872		Amazonian, Cerrado, Atlantic Forest		
Diplopterys patula (B.Gates) W.R.Anderson & C.Cav.Davis	Clim.	MC 697	AA 4838	Atlantic Forest		
Heteropterys bullata Amorim	Clim.	WT 14193	RP 839	Atlantic Forest		VU anexo II
Heteropterys imperata Amorim	Clim.	ML 1137	PF 2632	Atlantic Forest		
Heteropterys macrostachya A.Juss.	Clim.	AA 8131		Amazonian, Caatinga, Atlantic Forest		
Heteropterys nitida (Lam.) DC.	Clim.		AA 4105	Cerrado, Atlantic Forest		
Hiraea sp. 1	Clim.	MC 734		Atlantic Forest		
Hiraea bullata W.R.Anderson	Clim.	MC 443	AA 4559	Atlantic Forest		
Niedenzuella acutifolia (Cav.) W.R. Anderson	Shr.	MC 555	AA 4524	Amazonian, Atlantic Forest		
Stigmaphyllon sp.1	Clim.		MC 422	Atlantic Forest		
Stigmaphyllon blanchetii C.E. Anderson	Clim.	ML 1109	PF 1920	Caatinga, Cerrado, Atlantic Forest		
Stigmaphyllon salzmannii A.Juss.	Clim.	MC 711		Atlantic Forest		
Tetrapterys phlomoides (Spreng.) Nied.	Clim.	MC 682	AA 4871	Amazonian, Caatinga, Cerrado, Atlantic Forest		
MALVACEAE						
Ceiba ventricosa (Nees & Mart.) Ravenna	Arb.	MC 690		Caatinga, Cerrado, Atlantic Forest		
Eriotheca globosa (Aubl.) A. Robyns	Arb.	MC 395	ML 657	Amazonian, Cerrado, Atlantic Forest		
Helicteres ovata Lam.	Shr.	MC 451		Caatinga, Cerrado, Atlantic Forest		
Hydrogaster trinervis Kuhlm.	Arb.	MC 718		Atlantic Forest		
Pachira glabra Pasq.	Arb.	MC 721	WT 14287	Caatinga, Cerrado, Atlantic Forest		
Pavonia castaneifolia A.St.-Hil. & Naudin	Herb.	MC 693		Atlantic Forest		
Pavonia fruticosa (Mill.) Fawc. & Rendle	Sub-shr.		AA 4882	Amazonian, Atlantic Forest		
Pavonia cf. *morii* Krapov.	Shr.	ML 716		Atlantic Forest		
Pseudobombax grandiflorum (Cav.) A.Robyns	Arb.	MC 726		Cerrado, Atlantic Forest		
Quararibea sp.1	Arb.	MC 826		Atlantic Forest		
Quararibea penduliflora (A.St.-Hil.) K.Schum.	Arb.	MC 572		Atlantic Forest		
Sterculia excelsa Mart.	Arb.	MC 676		Amazonian, Atlantic Forest		
Triumfetta semitriloba Jacq.	Sub-shr.	MC 805		Amazonian, Caatinga, Cerrado, Atlantic Forest		

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Table 1. Continued.

Family/Species	**Habit**	**SCO**	**SPL**	**Phytogeographic Domain**	**New Occurrence**	**Threat**
MARANTACEAE						
Calathea sp. 1	Herb.	MC 417		Atlantic Forest		
Calathea cylindrica (Roscoe) K.Schum.	Herb.	MC 469		Atlantic Forest		
Calathea rotundifolia Körn.	Herb.	ML 390		Atlantic Forest		
Calathea zebrina (Sims) Lindl.	Herb.	RB 546		Atlantic Forest		
Monotagma grallatum Hagberg	Herb.	RB 563	ML 1157	Atlantic Forest		
Stromanthe porteana Griseb.	Sub-shr.	PF 1616		Atlantic Forest		
Stromanthe tonckat (Aubl.) Eichler	Sub-shr.	DC 2144	ML 1156	Amazonian, Caatinga, Atlantic Forest		
MARCGRAVIACEAE						
Marcgravia polyantha Delpino	Hemiep.		AA 4250	Cerrado, Atlantic Forest	Northeast	
Schwartzia jucuensis Gir.-Cañas	Hemiep.		PF 1850	Atlantic Forest		
MELASTOMATACEAE						
Bertolonia sp.1	Epip.	RB 461	AA 4521	Atlantic Forest		
Bertolonia sp. 2 *	Herb. *	MC 477		Atlantic Forest		
Bertolonia bullata Baumgratz, Amorim & A.B.Jardim *	Epip. *		AA 4831	Atlantic Forest		
Bertolonia carmoi Baumgratz	Epip.	MC 389		Atlantic Forest		
Bertolonia marmorata (Naudin) Naudin	Herb.		AA 4861	Atlantic Forest		
Clidemia capilliflora (Naudin) Cogn.	Shr.	MC 359		Atlantic Forest		
Clidemia dentata D. Don	Shr.	PF 1614		Amazonian, Atlantic Forest		
Clidemia hirta (L.) D. Don	Sub-shr.	MC 575		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Conostegia icosandra (Sw.) Urb.	Arb.		JP 764	Atlantic Forest		
Graffenrieda intermedia Triana	Arb.	RP 127	ML 1103	Amazonian, Atlantic Forest		
Huberia consimilis Baumgratz	Arb.	RB 383		Caatinga, Cerrado, Atlantic Forest		
Leandra sp.1	Shr.	MC 608		Atlantic Forest		
Leandra aff. *carassana* (DC.) Cogn.	Arb.		AA 4819	Cerrado, Atlantic Forest		
Leandra clidemioides (Naudin) Wurdack	Shr.	RP 860	ML 682	Atlantic Forest		
Leandra cuneata (Mart.) Cogn.	Arb.		PF 1823	Atlantic Forest		
Leandra dasytricha (A. Gray) Cogn.	Arb.	RB 540	PF 1901	Atlantic Forest		
Leandra ionopogon (Mart.) Cogn.	Shr.	MC 591	AA 4789	Cerrado, Atlantic Forest		
Leandra laevigata (Triana) Cogn.	Shr.		WT 14297	Atlantic Forest		
Leandra melastomoides Raddi	Shr.	MC 601	AA 4539	Cerrado, Atlantic Forest		
Leandra rhamnifolia (Naudin) Cogn.	Sub-shr.	RB 571	RB 521	Amazonian, Atlantic Forest		
Miconia calvescens DC.	Arb.	MC 659	AA 4234	Amazonian, Cerrado, Atlantic Forest		
Miconia centrodesma Naudin	Arb.		AA 4803	Amazonian, Atlantic Forest		
Miconia chartacea Triana	Arb.	MC 353	WT 14305	Caatinga, Cerrado, Atlantic Forest		
Miconia dodecandra Cogn.	Arb.		AA 4214	Amazonian, Cerrado, Atlantic Forest		
Miconia dorsaliporosa R.Goldenb. & Reginato	Arb.	JP 851		Atlantic Forest		
Miconia holosericea (L.) DC.	Shr.	MC 860		Amazonian, Cerrado, Atlantic Forest		

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Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
Miconia octopetala Cogn.	Arb.	RB 405	ML 1105	Atlantic Forest		
Miconia prasina (Sw.) DC.	Arb.	RP 861		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Miconia aff. *rimalis* Naudin	Arb.	MC 731	ML 697	Caatinga, Cerrado, Atlantic Forest		
Miconia ruficalyx Gleason	Arb.	RP 120	PF 2639	Amazonian, Atlantic Forest		
Miconia tristis Spring	Shr.	PF 2936	ML 671	Cerrado, Atlantic Forest		
Ossaea angustifolia (DC.) Triana	Shr.	MC 632	WT 14302	Atlantic Forest		
Ossaea cabraliensis (Wurdack) D'El Rei Souza	Arb.	MC 583	WT 14301	Atlantic Forest		
Ossaea quadrisulca (Naudin) Wurdack	Shr.	MC 503	AA 4224	Atlantic Forest		
Ossaea sulbahiensis D'El Rei Souza	Shr.	ML 1282		Atlantic Forest		
Pleiochiton blepharodes (DC.) Reginato & R. Goldenb.	Epip.		AA 4774	Atlantic Forest		
Tibouchina arborea (Gardner) Cogn.	Arb.		ML 304	Atlantic Forest		
Tibouchina fissinervia (Schrank & Mart. ex DC.) Cogn.	Arb.	JP 846	AA 4787	Cerrado, Atlantic Forest		
MELIACEAE						
Cabralea canjerana (Vell.) Mart. subsp. *canjerana*	Arb.	JP 897	ML 1087	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Guarea blanchetii C.DC.	Arb.	ML 729	PF 1529	Atlantic Forest		
Guarea kunthiana A. Juss.	Arb.	PF 2931	MC 522	Amazonian, Cerrado, Atlantic Forest		
Trichilia lepidota Mart.	Arb.	JP 906	JP 773	Atlantic Forest		EN
Trichilia tetrapetala C.DC.	Arb.	MC 461	ML 330	Atlantic Forest		EN
MENISPERMACEAE						
Anomospermum reticulatum (Mart.) Eichler	Clim.		AA 4856	Amazonian, Atlantic Forest		
Chondodendron microphyllum (Eichl.) Mold.	Clim.	MC 471		Atlantic Forest		
Disciphania hernandia (Vell.) Barneby	Clim.	MC 874		Atlantic Forest		
MONIMIACEAE						
Mollinedia sp. 1	Shr.	ML 1118	PF 1818	Atlantic Forest		
Mollinedia sp. 2	Shr.	MC 507		Atlantic Forest		
Mollinedia oligantha Perkins	Arb.	ML 1122	JP 499	Atlantic Forest		
MORACEAE						
Clarisia ilicifolia (Spreng.) Lanj. & Rossberg	Arb.	MC 543		Amazonian, Atlantic Forest		
Dorstenia bahiensis Klotzsch ex Fisch. & C.A.Mey.	Herb.		AA 4238	Atlantic Forest		
Dorstenia hirta Desv.	Herb.	AA 4707	WT 14295	Atlantic Forest		
Dorstenia setosa Moric.	Herb.	AA 4708		Atlantic Forest		

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Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
Ficus arpazusa Casar.	Arb.	PF 2913		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Ficus bahiensis C.C. Berg & Carauta	Arb.	ML 1281		Caatinga, Cerrado, Atlantic Forest		
Ficus citrifolia Mill.	Arb.	MC 460		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Ficus cyclophylla (Miq.) Miq.	Arb.	AA 8157		Atlantic Forest		
Ficus hirsuta Schott	Arb.	JP 862		Caatinga, Atlantic Forest		LR nt
Ficus insipida Willd.	Arb.	ML 365		Amazonian, Cerrado, Atlantic Forest		
Ficus nymphaeifolia Mill.	Arb.	MC 770		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Ficus trigona L.f.	Arb.	MC 743	RC 1046	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Helicostylis tomentosa (Poepp. & Endl.) Rusby	Arb.		JP 767	Amazonian, Caatinga, Atlantic Forest		
Sorocea hilarii Gaudich.	Arb.	JP 853		Cerrado, Atlantic Forest		
Sorocea racemosa Gaudich.	Arb.	MC 750	AA 4560	Atlantic Forest		
MYRISTICACEAE						
Virola bicuhyba (Schott ex Spreng.) Warb.	Arb.	MC 877		Atlantic Forest		
Virola officinalis Warb.	Arb.	RB 537		Atlantic Forest		
MYRTACEAE						
Myrtac. sp.1	Arb.	MC 878		Atlantic Forest		
Blepharocalyx salicifolius (Kunth) O.Berg	Arb.		ML 696	Caatinga, Cerrado, Atlantic Forest, Pampa		
Calyptranthes pulchella DC.	Arb.		WT 14336	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Eugenia sp. 1	Arb.	ML 1124		Atlantic Forest		
Eugenia sp. 2	Arb.	MC 556		Atlantic Forest		
Eugenia adenantha O. Berg.	Arb.	MC 593		Atlantic Forest		
Eugenia cerasiflora Miq.	Arb.	MC 557		Caatinga, Cerrado, Atlantic Forest		
Eugenia excelsa O.Berg	Arb.	ML 715		Amazonian, Atlantic Forest		
Eugenia cf. *florida* DC.	Arb.		ML 310	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Eugenia itapemirimensis Cambess.	Arb.	PF 2911	PF 1814	Atlantic Forest		
Eugenia ligustrina (Sw.) Willd.	Arb.	RP 119		Amazonian, Caatinga, Cerrado, Atlantic Forest	Bahia	
Eugenia schottiana O. Berg.	Arb.	MC 628		Caatinga, Atlantic Forest		
Eugenia tinguyensis Cambess.	Arb.	LM 4917	ML 1091	Atlantic Forest		
Gomidesia sp. 1	Arb.	RP 705	WT 14321	Atlantic Forest		
Marlierea sp. 1	Arb.	DC 2131		Atlantic Forest		

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Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
Marlierea cf. *affinis* (O.Berg) D. Legrand	Arb.	ML 360		Atlantic Forest		
Marlierea cf. *obversa* D. Legrand	Arb.	ML 391		Atlantic Forest		
Marlierea cf. *racemosa* (Vell.) Kiaersk.	Arb.		AA 4213	Atlantic Forest		
Marlierea cf. *verticillaris* O.Berg	Arb.	MC 485		Atlantic Forest		
Myrceugenia pilotantha (Kiaersk.) Landrum	Arb.	RB 548		Atlantic Forest		VU
Myrcia cf. *bicolor* Kiaersk.	Arb.	RP 719		Atlantic Forest		
Myrcia lascada Sobral	Arb.		ML 658	Atlantic Forest		
Myrcia multiflora (Lam.) DC.	Arb.	MC 669		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Myrcia pendula Sobral	Arb.	ML 1232		Atlantic Forest		
Myrcia pubescens DC.	Arb.	RB 550	RP 686	Caatinga, Cerrado, Atlantic Forest		
Myrcia racemosa (O.Berg) Kiaersk.	Arb.	JP 807		Cerrado, Atlantic Forest		
Myrcia spectabilis DC.	Arb.	ML 366		Atlantic Forest		
Myrcia tenuivenosa Kiaersk.			JJ 4794	Atlantic Forest		
Pimenta pseudocaryophyllus (Gomes) Landrum	Arb.	JP 819		Atlantic Forest	Northeast	
NYCTAGINACEAE						
Guapira sp.1	Arb.	AA 4697	ML 336	Atlantic Forest		
Guapira sp.2	Arb.	JP 891	PF 1851	Atlantic Forest		
Guapira cf. *obtusata* (Jacq.) Little	Arb.	WT 14168	AA 4535	Caatinga, Cerrado, Atlantic Forest		
Guapira opposita (Vell.) Reitz	Arb.	RB 536	ML 327	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Neea floribunda Poepp. & Endl.	Arb.	AA 4690		Amazonian, Atlantic Forest		
Neea laxa Poepp. & Endl.	Arb.	JP 821	ML 1085	Amazonian, Atlantic Forest		
OCHNACEAE						
Ouratea sp.1	Shr.		AA 4202	Atlantic Forest		
Sauvagesia vellozii (Vell. ex A.St.-Hil.) Sastre	Sub-shr.		PF 1812	Atlantic Forest		
OLACACEAE						
Tetrastylidium grandifolium (Baill.) Sleumer	Arb.	JP 808		Atlantic Forest		
OLEACEAE						
Chionanthus micranthus (Mart.) Lozano & Fuertes	Shr.		JJ 4780	Atlantic Forest		
ONAGRACEAE						
Fuchsia regia (Vell.) Munz	Epip.	RB 385		Cerrado, Atlantic Forest		
ORCHIDACEAE						
Acianthera oligantha (Barb.Rodr.) F.Barros	Epip.	AF 2631		Atlantic Forest	Northeast	

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Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
Acianthera saundersiana (Rchb.f.) Pridgeon & M.W.Chase	Epip.	JP 894		Caatinga, Cerrado, Atlantic Forest		
Alatiglossum ciliatum (Lindl.) Baptista	Herb.	MC 419		Atlantic Forest		
Alatiglossum longipes (Lindl.) Baptista	Epip.	MC 478		Atlantic Forest	Northeast	
Anathallis sclerophylla (Lindl.) Pridgeon & M.W.Chase	Epip.	MC 678	AA 4083	Caatinga, Cerrado, Atlantic Forest		
Aspidogyne argentea (Vell.) Garay	Herb.	JP 917	PF 1834	Cerrado, Atlantic Forest		
Aspidogyne foliosa (Poepp. & Endl.) Garay	Herb.		ML 342	Amazonian, Atlantic Forest		
Baptistonia silvana (V.P.Castro & Campacci) V.P.Castro & Chiron	Epip.	ML 1121		Atlantic Forest		
Bifrenaria calcarata Barb.Rodr.	Epip.	RP 86		Atlantic Forest		
Brasilaelia grandis (Lindl. & Paxton) Gutfreund	Epip.		PF 1769	Atlantic Forest		
Brassia arachnoidea Barb.Rodr.	Epip.	MC 404		Amazonian, Atlantic Forest	Northeast	
Bulbophyllum cf. *exaltatum* Lindl.	Epip.	MC 714		Caatinga, Cerrado, Atlantic Forest		
Bulbophyllum napellii Lindl.	Epip.	MC 369		Cerrado, Atlantic Forest		
Camaridium carinatum (Barb.Rodr.) Hoehne	Epip.	ML 1275	PF 1576	Atlantic Forest		
Camaridium cf. *micranthum* M.A.Blanco	Epip.	AF 2625		Amazonian, Atlantic Forest	Northeast	
Campylocentrum cf. *linearifolium* Cogn.	Epip.	RP 113		Caatinga, Cerrado, Atlantic Forest		
Campylocentrum robustum Cogn.	Epip.	PF 2750		Amazonian, Cerrado, Atlantic Forest	Northeast	
Catasetum cf. *hookeri* Lindl.	Epip.	AA 8123		Amazonian, Caatinga, Atlantic Forest		
Cattleya cf. *elongata* Barb. Rodr.	Epip.		MC 421	Caatinga, Cerrado, Atlantic Forest	Atlantic Forest	
Cattleya warneri T.Moore	Herb.	MC 445		Atlantic Forest		VU
Coppensia flexuosa (Sims) Campacci	Epip.	ML 1135	PF 1810	Atlantic Forest		
Coppensia hookeri (Rolfe) F.Barros & L.Guimarães	Epip.	AF 2644		Atlantic Forest		
Coryanthes sp.1	Epip.		AF 2601	Atlantic Forest		
Cyrtopodium flavum Link & Otto ex Rchb.f.	Herb. *	MC 472		Cerrado, Atlantic Forest		
Dichaea cogniauxiana Schltr.	Epip.	AF 2636	AA 4537	Cerrado, Atlantic Forest		
Elleanthus brasiliensis (Lindl.) Rchb.f.	Herb.	JP 874		Atlantic Forest		
Elleanthus crinipes Rchb.f.	Epip.		ML 1164	Cerrado, Atlantic Forest		
Elleanthus linifolius C. Presl	Epip.	RP 102	ML 1161	Amazonian, Atlantic Forest		
Encyclia patens Hook.	Epip.		MC 428	Cerrado, Atlantic Forest		
Epidendrum sp. 1	Epip.	AF 2628		Atlantic Forest		
Epidendrum densiflorum Lindl.	Epip. *	MC 684		Amazonian, Cerrado, Atlantic Forest		
Epidendrum flexuosum G.Mey.	Epip.		AF 2600	Amazonian, Cerrado, Atlantic Forest		
Epidendrum paranaense Barb.Rodr.	Epip.	RP 95	JP 583	Caatinga, Cerrado, Atlantic Forest		
Epidendrum proligerum Barb.Rodr.	Epip.		ML 674	Atlantic Forest		
Epidendrum ramosum Jacq.	Epip.		AA 4808	Cerrado, Atlantic Forest		
Epidendrum rigidum Jacq.	Herb.	MC 496		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Epidendrum saxatile Lindl.	Herb.		PF 1572	Caatinga, Cerrado, Atlantic Forest		

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Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
Epidendrum secundum Jacq.	Epip.	AF 2638		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Gomesa handroi (Hoehne) Pabst	Epip.		WT 14310	Atlantic Forest	Northeast	
Gomesa recurva Barb.Rodr.	Epip.	MC 585	AF 2613	Cerrado, Atlantic Forest		
Heterotaxis brasiliensis (Brieger & Illg) F.Barros	Epip. *	ML 1276	ML 664	Atlantic Forest		
Houlletia brocklehurstiana Lindl.	Epip.	MC 641		Atlantic Forest		
Huntleya meleagris Lindl.	Epip.		AA 4877	Atlantic Forest		
Isochilus linearis (Ruiz & Pav.) R.Br.	Epip.	AF 2627		Cerrado, Atlantic Forest		
Jacquiniella globosa (Jacq.) Schltr.	Epip.	MC 771	ML 1167	Amazonian, Atlantic Forest		
Liparis nervosa (Thumb.) Lindl.	Herb.	JP 887		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Lockhartia lunifera (Lindl.) Rchb.f.	Epip.	MC 533		Amazonian, Atlantic Forest		
Malaxis excavata (Lindl.) Kuntze	Herb.	ML 726	AA 4073	Cerrado, Atlantic Forest		
Maxillaria leucaimata Barb. Rodr.	Epip.	RP 98	PF 1573	Amazonian, Atlantic Forest		
Maxillaria ochroleuca Lodd. ex Lindl.	Epip.		ML 688	Amazonian, Cerrado, Atlantic Forest		
Maxillaria cf. *rodriguesii* Cogn.	Epip.	RP 103		Atlantic Forest	Northeast	
Maxillariella robusta (Barb.Rodr.) M.A.Blanco & Carnevali	Epip.	AA 4706		Atlantic Forest	Northeast	
Microchilus arietinus (Rchb.f. & Warm.) Ormerod	Herb.	ML 352		Cerrado, Atlantic Forest	Northeast	
Microchilus lamprophyllus (Rchb.f. & Warm.) Ormerod	Herb.	AF 2624	ML 690	Atlantic Forest		
Myoxanthus punctatus (Barb. Rodr.) Luer	Epip.	MC 569		Atlantic Forest	Northeast	
Nitidobulbon nasutum (Rchb.f.) Ojeda & Carnevali	Epip.	RP 101	AA 4541	Amazonian, Atlantic Forest		
Octomeria crassifolia Lindl.	Epip.	AF 2643	PF 1559	Atlantic Forest		
Octomeria tricolor Rchb.f.	Epip.	RP 93	JJ 4768	Atlantic Forest		
Oeceoclades maculata (Lindl.) Lindl.	Herb.	RP 87		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Ornithidium rigidum (Barb.Rodr.) M.A.Blanco & Ojeda	Epip.	ML 1274		Amazonian, Atlantic Forest	Northeast	
Pabstiella carinifera (Barb.Rodr.) Luer	Epip.	LD 332		Atlantic Forest	Northeast	
Pabstiella ramphastorhyncha (Barb. Rodr.) L. Kollmann	Epip.	RP 106		Atlantic Forest		
Platystele sp.1	Epip.		AA 4839	Atlantic Forest		
Pleurothallis sp.1	Epip.		AA 4810	Atlantic Forest		
Pleurothallis ruscifolia (Jacq.) R.Br.	Epip.	RP 88		Amazonian, Atlantic Forest		
Polycycnis silvana F.Barros	Epip.		AA 4090	Atlantic Forest		
Polystachya concreta (Jacq.) Garay & Sweet	Epip.	MC 763		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Polystachya estrellensis Rchb.f.	Epip.	MC 394	AA 4230	Amazonian, Caatinga, Cerrado, Atlantic Forest		

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Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
Prescottia stachyodes (Sw.) Lindl.	Herb.	RP 89	JP 586	Amazonian, Caatinga, Atlantic Forest		
Promenaea silvana F.Barros & Cath.	Epip. *	MC 532		Atlantic Forest		
Prosthechea sp.1	Epip.		AA 4207	Atlantic Forest		
Prosthechea bueraremensis (Campacci) Campacci	Epip.	ML 1133		Atlantic Forest		
Prosthechea calamaria (Lindl.) W.E.Higgins	Epip.	RP 100		Atlantic Forest	Northeast	
Prosthechea fragrans (Sw.) W.E.Higgins	Epip.		ML 1104	Amazonian, Atlantic Forest		
Prosthechea pachysepala (Klotzsch) Chiron & V.P.Castro	Epip.		PF 1567	Cerrado, Atlantic Forest		
Prosthechea pygmaea (Hook.) W.E.Higgins	Epip.	ML 1272		Atlantic Forest		
Psilochilus modestus Barb.Rodr.	Herb.		AA 4788	Amazonian, Atlantic Forest		
Rhetinantha notylioglossa (Rchb.f.) M.A.Blanco	Epip.	AF 2632		Amazonian, Atlantic Forest		
Scaphyglottis modesta (Rchb.f.) Schltr.	Epip.	RP 99	AF 2603	Amazonian, Caatinga, Atlantic Forest		
Scuticaria hadwenii (Lindl.) Planch.	Epip.	RP 94		Atlantic Forest		
Sobralia sessilis Lindl.	Epip.	ML 1264		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Stelis sp. 1	Epip.	ML 1263		Atlantic Forest		
Stelis intermedia Poepp. & Endl.	Epip.		ML 348	Atlantic Forest	Northeast	
Stelis megantha Barb. Rodr.	Epip.		PF 1553	Atlantic Forest		
Stelis papaquerensis Rchb.f.	Epip.	AA 8139		Atlantic Forest	Bahia	
Stigmatosema polyaden (Vell.) Garay	Herb.	WT 14165		Cerrado, Atlantic Forest	Northeast	
Vanilla cf. *bahiana* Hoehne	Epip.	AF 2642		Caatinga, Cerrado, Atlantic Forest		
Vanilla cf. *bicolor* Lindl.	Epip.	ML 1277		Amazonian, Atlantic Forest	Northeast and Atlantic Forest	
Xylobium colleyi (Batem. ex Lindl.) Rolfe	Epip.	ML 1269		Amazonian, Atlantic Forest		
Xylobium variegatum (Ruiz & Pav.) Mansf.	Epip.	JP 877	ML 1165	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Zygopetalum sp. 1	Herb.	ML 1268		Atlantic Forest		
PASSIFLORACEAE						
Passiflora contracta Vitta	Clim.	MC 673	ML 677	Caatinga, Atlantic Forest		
Passiflora nitida Kunth	Clim.	PF 2924		Amazonian, Caatinga, Cerrado, Atlantic Forest	Atlantic Forest	
PENTAPHYLLACEAE						
Ternstroemia alnifolia Wawra	Arb.		WT 14339	Caatinga, Cerrado, Atlantic Forest		
PERACEAE						
Pogonophora schomburgkiana Miers ex Benth.	Shr.	MC 623		Amazonian, Caatinga, Cerrado, Atlantic Forest		
PHYLLANTHACEAE						
Hieronyma oblonga (Tul.) Müll.Arg.	Arb.	JP 801	AA 4827	Amazonian, Atlantic Forest		

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Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
Margaritaria nobilis L.f.	Arb.	RB 541	JP 776	Amazonian, Caatinga, Atlantic Forest		
Phyllanthus gradyi M.J.Silva & M.F.Sales	Arb.		AA 4842	Atlantic Forest		
Phyllanthus subemarginatus Müll. Arg.	Sub-shr.	RP 109	AA 4860	Caatinga, Cerrado, Atlantic Forest		
PHYTOLACCACEAE						
Phytolacca thyrsiflora Fenzl. ex J.A.Schmidt	Shr.		WT 14338	Amazonian, Caatinga, Cerrado, Atlantic Forest, Pampa		
PICRAMNIACEAE						
Picramnia ciliata Mart.	Arb.	WT 14190	AA 4223	Cerrado, Atlantic Forest		
Picramnia glazioviana Engl.	Arb.	JP 885	ML 672	Atlantic Forest		
PIPERACEAE						
Peperomia sp.1	Epip.	RB 421	DM 572	Atlantic Forest		
Peperomia sp. Nova	Herb. *	RB 419	DM 571	Atlantic Forest		
Peperomia alata Ruiz & Pav.	Epip. *	RB 564		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Peperomia blanda (Jacq.) Kunth	Epip. *	ML 1265		Amazonian, Cerrado, Atlantic Forest	Bahia	
Peperomia corcovadensis Gardner	Epip. *	AA 4689	PF 2630	Atlantic Forest	Northeast	
Peperomia emarginella (Sw.) C.DC.	Epip.	MC 536	MJ 890	Atlantic Forest		
Peperomia hernandiaefolia (Vahl) A.Dietr.	Epip.		AA 4783	Amazonian, Atlantic Forest		
Peperomia macrostachya (Vahl) A.Dietr.	Epip.	JP 890	PF 1892	Amazonian, Atlantic Forest		
Peperomia magnoliifolia (Jacq.) A. Dietr.	Epip. *	AA 4712	ML 317	Amazonian, Atlantic Forest		
Peperomia obtusifolia (L.) A. Dietr.	Epip.	ML 714		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Peperomia pernambucensis Miq.	Epip.		PF 1797	Atlantic Forest		
Peperomia tetraphylla (G.Forst.) Hook. & Arn.	Epip.	MC 371	PF 2625	Caatinga, Cerrado, Atlantic Forest		
Peperomia urocarpa Fisch. & C.A. Mey.	Epip. *	AA 4694		Amazonian, Cerrado, Atlantic Forest		
Piper amplum Kunth	Shr.	AA 4711	MJ 880	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Piper arboreum Aubl.	Shr.	AA 4709	MC 436	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Piper bowiei Yunck.	Shr.		MJ 879	Atlantic Forest	Northeast	
Piper caldense C.DC.	Shr.		MC 524	Caatinga, Cerrado, Atlantic Forest		
Piper cernuum Vell.	Arb.	MC 590		Amazonian, Cerrado, Atlantic Forest		
Piper dilatatum Rich.	Shr.		MJ 885	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Piper eucalyptophyllum C.DC.	Shr.	MC 459	MJ 878	Atlantic Forest		
Piper hispidum Sw.	Shr.	AA 4713	MJ 887	Amazonian, Cerrado, Atlantic Forest		
Piper klotzschianum (Kunth) C. DC.	Shr.	WT 14145		Cerrado, Atlantic Forest		
Piper malacophyllum (C.Presl) C.DC.	Shr.	MC 856		Amazonian, Cerrado, Atlantic Forest	Northeast	

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Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
Piper mollicomum Kunth	Shr.		MJ 884	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Piper mosenii C.DC.	Shr.	AA 4710	MJ 876	Atlantic Forest	Northeast	
Piper robustipedunculum Yunck.	Shr.	DM 573		Atlantic Forest		
Piper sprengelianum C.DC.	Shr.	DM 582	MJ 881	Cerrado, Atlantic Forest		
Piper subglabrifolium C.DC.	Shr.	DM 577		Amazonian, Atlantic Forest	Northeast and Atlantic Forest	
Piper umbellatum L.	Shr.	MC 525	MJ 882	Amazonian, Cerrado, Atlantic Forest		
Piper vellosoi Yunck.	Shr.	WT 178b		Cerrado, Atlantic Forest		
POACEAE						
Alvimia lancifolia Soderstr. & Londoño	Arb.		PO 1224	Atlantic Forest		
Andropogon bicornis L.	Herb.	RB 374		Amazonian, Caatinga, Cerrado, Atlantic Forest, Pampa, Pantanal		
Arberella bahiensis Soderstr. & Zuloaga	Herb.		AA 4843	Atlantic Forest		
Atractantha aureolanata Judz.	Arb.	MC 835		Atlantic Forest		
Chusquea sp. 1	Arb.	RP 708	PO 1223	Atlantic Forest		
Chusquea aff. *attenuata* (Döll) L.G.Clark	Arb.		PO 1220	Atlantic Forest		
Chusquea oxylepis (Hack.) Ekman	Arb.		PO 1222	Atlantic Forest		
Dichanthelium sp.1	Herb.		PO 1219	Atlantic Forest		
Eremocaulon sp. 1	Arb.	ML 1251	PO 1226	Atlantic Forest		
Guadua calderoniana Londoño & Judz.	Arb.	AA 8153		Atlantic Forest		
Ichnanthus sp. 1	Herb.	MC 368	RB 505	Atlantic Forest		
Ichnanthus hirtus (Raddi) Chase	Herb.	ML 1260		Caatinga, Cerrado, Atlantic Forest		
Ichnanthus leiocarpus (Spreng.) Kunth	Herb.	RB 384	PO 1215	Caatinga, Cerrado, Atlantic Forest		
Ichnanthus nemoralis (Schrad. ex Schult.) Hitchc. & Chase	Herb.	MC 761		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Ichnanthus pallens (Sw.) Munro ex Benth.	Herb.	ML 1261	PO 1212	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Ichnanthus tenuis (J.Presl & C.Presl) Hitchc. & Chase	Herb.		PO 1210	Amazonian, Caatinga, Cerrado, Atlantic Forest	Bahia	
Lasiacis ligulata Hitchc. & Chase	Shr.	MC 715	AA 4220	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Merostachys sp. 1	Arb.	MC 848	PO 1221	Atlantic Forest		
Merostachys sp. 2	Arb.	WT 14155		Atlantic Forest		
Merostachys leptophylla Send.	Arb.	MC 760		Atlantic Forest		
Merostachys cf. *sparsiflora* Rupr.	Arb.	AA 4688	PF 2651	Atlantic Forest		
Ocellochloa cf. *rudis* (Nees) Zuloaga & Morrone	Herb.		RB 510	Atlantic Forest	Northeast	
Olyra latifolia L.	Herb.	ML 1229		Amazonian, Caatinga, Cerrado, Atlantic Forest		

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Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
Panicum sp.1	Herb.	MC 385		Atlantic Forest		
Panicum sp.2	Herb.		RB 478	Atlantic Forest		
Panicum pilosum Sw.	Herb.		PO 1207	Amazonian, Caatinga, Cerrado, Atlantic Forest, Pampa, Pantanal		
Parodiolyra micrantha (Kunth) Davidse & Zuloaga	Herb.	MC 412		Amazonian, Caatinga, Atlantic Forest		
Parodiolyra ramosissima (Trin.) Soderstr. & Zuloaga	Herb.	ML 1107		Atlantic Forest		
Paspalum conjugatum P.J.Bergius	Herb.		PO 1211	Amazonian, Caatinga, Cerrado, Atlantic Forest, Pampa, Pantanal		
Paspalum corcovadense Raddi	Herb.		PO 1209	Cerrado, Atlantic Forest		
Paspalum decumbens Sw.	Herb.	ML 1258	PO 1213	Amazonian, Cerrado, Atlantic Forest		
Paspalum pilosum Lam.	Herb.		PO 1217	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Pharus lapullaceus Aubl.	Herb.	RB 523	PO 1214	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Pseudechinolaena polystachya (Kunth) Stapf	Herb.	MC 688		Cerrado, Atlantic Forest		
Schizachyrium condensatum (Kunth) Nees	Herb.	ML 723		Cerrado, Atlantic Forest, Pampa		
Setaria sp.1	Herb.		PO 1208	Atlantic Forest		
Streptochaeta spicata Schrad. ex Nees	Herb.	ML 1287		Amazonian, Caatinga, Cerrado, Atlantic Forest		
PODOSTEMACEAE						
Mourera aspera (Bong.) Tul.	Herb.	MC 396		Cerrado, Atlantic Forest	Northeast	
POLYGALACEAE						
Polygala laureola A. St.-Hil.	Sub-shr.	MC 796	JP 797	Atlantic Forest		
POLYGONACEAE						
Coccoloba sp. 1	Clim.	MC 612		Atlantic Forest		
Coccoloba declinata (Vell.) Mart.	Clim.	ML 733		Amazonian, Caatinga, Cerrado, Atlantic Forest		
PRIMULACEAE						
Cybianthus sp. 1	Shr.	AA 4696		Atlantic Forest		
Cybianthus amplus (Mez) G. Agostini	Arb.	MC 544	RP 850	Amazonian, Atlantic Forest		
Cybianthus aff. *detergens* Mart.	Arb.	ML 1123		Amazonian, Cerrado, Atlantic Forest		
Cybianthus peruvianus (A.DC.) Miq.	Arb.	RP 715	WT 14341	Atlantic Forest		
Myrsine sp.1	Arb.	MC 627		Atlantic Forest		
Myrsine guianensis (Aubl.) Kuntze	Arb.		JP 579	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Myrsine leuconeura Mart.	Arb.		JP 563	Cerrado, Atlantic Forest	Atlantic Forest	
Myrsine venosa A.DC.	Arb.	MC 797	ML 349	Cerrado, Atlantic Forest		

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Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
PROTEACEAE						
Panopsis multiflora (Schott) Ducke	Arb.		RP 847	Atlantic Forest	Northeast	
QUIINACEAE						
Lacunaria crenata (Tul.) A.C.Sm. subsp. *decastyla* (Radlk.)	Arb.	ML 1117	PF 1535	Atlantic Forest		
RHAMNACEAE						
Rhamnus sphaerosperma Sw.	Arb.	RB 458		Cerrado, Atlantic Forest		
ROSACEAE						
Rubus sp.1	Clim.		MC 433	Atlantic Forest		
RUBIACEAE						
Amaioua sp.1	Arb.		WT 14342	Atlantic Forest		
Bathysa sp.1	Arb.		PF 1914	Atlantic Forest		
Bathysa cuspidata (A. St. Hil.) Hook. f. ex K.Schum.	Arb.	WT 14188		Cerrado, Atlantic Forest		
Bathysa mendoncaei K.Schum.	Arb.		PF 2634	Atlantic Forest		
Carapichea lucida J.G. Jardim & Zappi	Shr.	ML 1238	ML 683	Atlantic Forest		
Chiococca alba (L.) Hitchc.	Clim.	JP 816		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Coccocypselum aureum (Spreng.) Cham. & Schltdl.	Herb.	MC 680	MC 324	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Coccocypselum cordifolium Nees & Mart.	Herb.		JP 790	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Coccocypselum geophiloides Wawra	Herb.		JP 789	Atlantic Forest		
Coccocypselum hasslerianum Chodat	Herb.		AA 4227	Caatinga, Cerrado, Atlantic Forest		
Coccocypselum lanceolatum (Ruiz & Pav.) Pers.	Herb.	JP 799		Caatinga, Cerrado, Atlantic Forest		
Cordiera sp. 1	Shr.	LM 4914	ML 1096	Atlantic Forest		
Coussarea contracta (Walp.) Müll.Arg.	Arb.	MC 416	AA 4836	Caatinga, Cerrado, Atlantic Forest		
Coussarea graciliflora (Mart.) Müll.Arg.	Shr.		ML 661	Atlantic Forest		
Coussarea ilheotica Müll. Arg.	Arb.	AA 4705		Atlantic Forest		
Denscantia cymosa (Spreng.) E.L. Cabral & Bacigalupo	Clim.	RP 122		Atlantic Forest		
Emmeorhyza umbellata (Spreng.) K. Schum.	Clim.	RP 116		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Faramea sp. 1	Shr.	ML 1119	PF 1825	Atlantic Forest		
Faramea sp. 2	Arb.	MC 629		Atlantic Forest		
Faramea martiana Müll.Arg.	Arb.	MC 391		Atlantic Forest		

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Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
Faramea multiflora A.Rich.	Shr.		AA 4828	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Ferdinandusa edmundoi Sucre	Arb.	LM 4906		Amazonian, Cerrado, Atlantic Forest		
Hillia parasitica Jacq.	Epip.	DC 2134	ML 1101	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Hillia ulei K.Krause	Epip.	PF 1622		Amazonian, Atlantic Forest	Northeast	
Ixora muelleri Bremek.	Arb.	MC 347	AA 4833	Atlantic Forest		
Malanea sp.1	Shr.	MC 830		Atlantic Forest		
Malanea boliviana Standl.	Clim.		PF 1844	Atlantic Forest		
Margaritopsis astrellantha (Wernhan) L.Anderson	Shr.		PF 1544	Amazonian, Atlantic Forest		
Notopleura bahiensis C.M. Taylor	Epip.	RB 445	AA 4212	Atlantic Forest		
Notopleura tapajozensis (Standl.) Bremek.	Arb.	RB 424	AA 4815	Amazonian, Atlantic Forest		
Palicourea blanchetiana Schltdl.	Shr.	MC 465	AA 4210	Amazonian, Caatinga, Atlantic Forest		
Palicourea guianensis Aubl.	Arb.	MC 616	WT 14319	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Palicourea aff. *rigida* Kunth	Shr.		RB 520	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Posoqueria latifolia (Rudge) Schult. subsp. *latifolia*	Shr.	WT 14189		Amazonian, Cerrado, Atlantic Forest		
Psychotria sp.1	Shr.	MC 529		Atlantic Forest		
Psychotria sp.2	Arb.	AA 8147	AA 4846	Atlantic Forest		
Psychotria sp.3	Arb.	AA 8133		Atlantic Forest		
Psychotria colorata (Willd. ex Schult.) Müll.Arg.	Arb.	AA 8149	JJ 4788	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Psychotria cupularis (Müll.Arg.) Standl.	Shr.	RB 454	AA 4215	Amazonian, Atlantic Forest	Bahia	
Psychotria deflexa DC.	Shr.	AA 4702	PF 1889	Amazonian, Cerrado, Atlantic Forest		
Psychotria hoffmannseggiana (Willd. ex Schult.) Müll. Arg.	Shr.	RB 463	PF 2640	Amazonian, Cerrado, Atlantic Forest		
Psychotria leiocarpa Cham. & Schltdl.	Arb.	JP 920	PF 1787	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Psychotria longipes Müll.Arg.	Shr.	ML 370	PF 2641	Amazonian, Atlantic Forest		
Psychotria lupulina Benth.	Shr.		JJ 4790	Amazonian, Cerrado, Atlantic Forest		
Psychotria mapourioides DC.	Arb.	MC 829	AA 4864	Amazonian, Cerrado, Atlantic Forest	Northeast and Atlantic Forest	
Psychotria minutiflora Müll.Arg.	Shr.	JP 850	PF 1897	Caatinga, Atlantic Forest		
Psychotria myriantha Müll. Arg.	Shr.	ML 713		Cerrado, Atlantic Forest		
Psychotria platypoda DC.	Shr.		WT 14300	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Psychotria phyllocalymmoides Müll. Arg.	Shr.	PF 2934		Atlantic Forest		
Psychotria schlechtendaliana (Müll.Arg.) Müll.Arg.	Shr.	DC 2130		Caatinga, Atlantic Forest		
Psychotria aff. *stachyoides* Benth.	Shr.	MC 607	AA 4534	Caatinga, Cerrado, Atlantic Forest		

Continued on next page

Table 1. Continued.

Family/Species	**Habit**	**SCO**	**SPL**	**Phytogeographic Domain**	**New Occurrence**	**Threat**
Psychotria vellosiana Benth.	Arb.	RB 467		Caatinga, Atlantic Forest		
Randia armata (Sw.) DC.	Arb.	MC 541	AA 4829	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Richardia sp.1	Herb.	AA 8148		Atlantic Forest		
Ronabea latifolia Aubl.	Shr.	MC 578	PF 1530	Amazonian, Atlantic Forest		
Rudgea sp. 1	Shr.	ML 1245		Atlantic Forest		
Rudgea aff. *interrupta* Benth.	Arb.		PF 1768	Atlantic Forest		
Rudgea cf. *involucrata* Müll. Arg.	Shr.	MC 453		Caatinga, Atlantic Forest		
Rudgea aff. *nodosa* (Cham.) Benth.	Shr.	PF 1640		Cerrado, Atlantic Forest	Northeast	
Rudgea pachyphylla Müll.Arg.	Arb.		ML 308	Atlantic Forest	Northeast	
Rudgea reticulata Benth.	Arb.		PF 1759	Atlantic Forest		
Sabicea sp.1	Sub-shr.		AA 4228	Atlantic Forest		
Schradera polycephala DC.	Hemiep.	RB 535	WT 14330	Amazonian, Atlantic Forest		
RUTACEAE						
Conchocarpus macrophyllus J.C. Mikan	Shr.	MC 509		Atlantic Forest		
Esenbeckia leiocarpa Engl.	Arb.	RB 400		Cerrado, Atlantic Forest		VU
Galipea laxiflora Engl.	Arb.	JP 880		Atlantic Forest		
Neoraputia alba (Nees & Mart.) Emmerich ex Kallunki	Arb.	MC 730		Atlantic Forest		
Pilocarpus grandiflorus Engl.	Arb.	MC 463		Atlantic Forest		
Pilocarpus riedelianus Engl.	Shr.	PF 2925		Atlantic Forest		
Zanthoxylum acuminatum (Sw.) Sw.	Arb.	ML 356		Amazonian, Cerrado, Atlantic Forest		
SABIACEAE						
Meliosma sp.1	Arb.		JJ 4789	Atlantic Forest		
Meliosma sellowii Urb.	Arb.	ML 740	ML 667	Cerrado, Atlantic Forest		
SALICACEAE						
Banara serrata (Vell.) Warb.	Arb.		WT 14290	Amazonian, Atlantic Forest		
Casearia sp. 1	Arb.	MC 671		Atlantic Forest		
Casearia sp. 2	Arb.	LM 4924		Atlantic Forest		
Casearia arborea (Rich.) Urb.	Arb.	AA 4676	JP 783	Amazonian, Cerrado, Atlantic Forest		
Casearia bahiensis Sleumer	Arb.	MC 457		Atlantic Forest		
Casearia commersoniana Cambess.	Arb.	MC 392	PF 1780	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Casearia decandra Jacq.	Arb.	MC 838		Amazonian, Cerrado, Atlantic Forest		
Prockia crucis P.Browne ex L.	Shr.	MC 567		Amazonian, Caatinga, Cerrado, Atlantic Forest		
SANTALACEAE						
Phoradendron sp.1	Hemi-par.	JP 828		Atlantic Forest		
Phoradendron affine (Pohl ex DC.) Engl. & Krause	Hemi-par.	MC 740		Amazonian, Caatinga, Cerrado, Atlantic Forest, Pampa, Pantanal		

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Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
Phoradendron chrysocladon A. Gray	Hemi-par.	PF 2912		Caatinga, Cerrado, Atlantic Forest		
Phoradendron crassifolium (Pohl ex DC.) Eichler	Hemi-par.	MC 609	ML 302	Amazonian, Caatinga, Cerrado, Atlantic Forest, Pampa, Pantanal		
Phoradendron nigricans Rizzini	Hemi-par.	ML 711		Caatinga, Cerrado, Atlantic Forest		
Phoradendron piperoides (Kunth) Trel.	Hemi-par.	JP 831		Amazonian, Caatinga, Cerrado, Atlantic Forest, Pampa, Pantanal		
SAPINDACEAE						
Allophylus sp. 1	Arb.	MC 448		Atlantic Forest		
Allophylus leucophloeus Radlk.	Arb.	ML 1246		Atlantic Forest	Northeast	
Allophylus petiolulatus Radlk.	Arb.	MC 613		Atlantic Forest		
Allophylus sericeus (Cambess.) Radlk.	Arb.		PF 1913	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Cupania sp.1	Arb.		PF 2647	Atlantic Forest		
Cupania rugosa Radlk.	Arb.	RP 713		Caatinga, Atlantic Forest		
Matayba cf. *grandis* Radlk.	Arb.		RP 698	Atlantic Forest	Northeast	
Matayba intermedia Radlk.	Arb.		ML 1086	Atlantic Forest	Northeast	
Paullinia carpopoda Cambess.	Clim.	MC 876	RP 701	Cerrado, Atlantic Forest		
Paullinia revoluta Radlk.	Clim.	RP 856		Atlantic Forest		
Paullinia rubiginosa Cambess.	Clim.		ML 1173	Amazonian, Atlantic Forest		
Paullinia trigonia Vell.	Clim.	RP 710		Amazonian, Caatinga, Atlantic Forest		
Paullinia weinmanniaefolia Mart.	Clim.	RB 534		Atlantic Forest		
Serjania sp. 1	Clim.	MC 806		Atlantic Forest		
Serjania clematidifolia Cambess.	Clim.	ML 1114		Amazonian, Cerrado, Atlantic Forest		
Serjania salzmanniana Schltdl.	Clim.		RB 506	Amazonian, Cerrado, Atlantic Forest		
Talisia aff. *macrophylla* Radlk.	Arb.	MC 502		Amazonian, Atlantic Forest		
Thinouia sp. 1	Clim.	JP 909		Atlantic Forest		
SAPOTACEAE						
Chrysophyllum gonocarpum (Mart. & Eichler ex Miq.) Engl.	Arb.	MC 458	LD 438	Amazonian, Cerrado, Atlantic Forest		
Chrysophyllum splendens Spreng.	Arb.		ML 670	Atlantic Forest		VU
Chrysophyllum subspinosum Monach.	Arb.	MC 467		Atlantic Forest		EN
Micropholis gardneriana (A.DC.) Pierre	Arb.		FF 1471	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Micropholis guyanensis (A.DC.) Pierre	Arb.		AA 4837	Amazonian, Cerrado, Atlantic Forest		
Pradosia lactescens (Vell.) Radlk.	Arb.	MC 630	JP 503	Atlantic Forest		
SCHELEGELIACEAE						
Schlegelia parviflora (Oerst.) Monach.	Clim.	RB 404	AA 4543	Amazonian, Atlantic Forest		
SIMAROUBACEAE						
Simaba cf. *subcymosa* A.St.-Hil. & Tul.	Arb.	MC 658		Atlantic Forest	Northeast	

Continued on next page

Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
Simarouba amara Aubl.	Arb.	AA 8158		Amazonian, Caatinga, Cerrado, Atlantic Forest		
SIPARUNACEAE						
Siparuna reginae (Tul.) A.DC.	Arb.	AA 4679		Amazonian, Cerrado, Atlantic Forest		
SMILACACEAE						
Smilax sp.1	Clim.	AA 8160		Atlantic Forest		
Smilax sp.2	Clim.		ML 1100	Atlantic Forest		
Smilax staminea Griseb.	Clim.	RB 406	PF 1791	Cerrado, Atlantic Forest		
SOLANACEAE						
Solanac. sp.1	Clim.	MC 776		Atlantic Forest		
Acnistus arborescens (L.) Schltdl.	Arb.		JP 570	Atlantic Forest		
Aureliana fasciculata (Vell.) Sendtn.	Arb.	WT 14187	WT 14286	Amazonian, Atlantic Forest		
Brunfelsia cf. *clandestina* Plowman	Shr.	PF 2927		Atlantic Forest		
Cestrum cf. *retrofractum* Dunal	Shr.	MC 550		Atlantic Forest, Pantanal		
Cestrum salzmanni Dunal	Arb.		JP 796	Atlantic Forest		
Cestrum schlechtendalii G.Don	Shr.		MC 527	Amazonian, Cerrado, Atlantic Forest		
Dyssochroma viridiflorum (Sims) Miers	Epip.	MC 706		Atlantic Forest		
Solanum acerifolium Dunal	Shr.	ML 1279		Amazonian, Caatinga, Cerrado, Atlantic Forest		
Solanum americanum Mill.	Shr.	RP 110		Amazonian, Caatinga, Cerrado, Atlantic Forest, Pampa, Pantanal		
Solanum asterophorum Mart.	Shr.	MC 857		Atlantic Forest		
Solanum bahianum S. Knapp	Shr.	ML 382	MC 523	Atlantic Forest		CR anexo I
Solanum caavurana Vell.	Shr.	JP 858	MC 656	Caatinga, Cerrado, Atlantic Forest		
Solanum jussieui Dunal	Shr.	LM 4898		Atlantic Forest	Northeast	
Solanum polytrichum Moric.	Shr.	RB 565		Atlantic Forest		
Solanum reflexiflorum Moric. ex Dunal	Shr.	MC 442	ML 338	Atlantic Forest		
Solanum restingae S. Knapp	Shr.	MC 370		Atlantic Forest		EN anexo II
Solanum aff. *schizandrum* Sendtn.	Clim.	RB 543		Atlantic Forest		
Solanum swartzianum Roem. & Schult.	Shr.	RP 123	AA 4082	Cerrado, Atlantic Forest		
Solanum sycocarpum Mart. & Sendtn.	Arb.		PF 1817	Atlantic Forest		EN
STYRACACEAE						
Styrax acuminatus Pohl	Arb.	MC 494		Atlantic Forest	Northeast	
SYMPLOCACEAE						
Symplocos sp.1	Arb.		AA 4824	Atlantic Forest		
Symplocos estrellensis Casar.	Shr.		AA 4799	Atlantic Forest		

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Table 1. Continued.

Family/Species	Habit	SCO	SPL	Phytogeographic Domain	New Occurrence	Threat
THYMELAEACEAE						
Daphnopsis sp. 1	Shr.	JP 830		Atlantic Forest		
TRIGONIACEAE						
Trigonia nivea Cambess.	Clim.	MC 665		Amazonian, Cerrado, Atlantic Forest		
URTICACEAE						
Cecropia hololeuca Miq.	Arb.	MC 861		Cerrado, Atlantic Forest		
Cecropia pachystachya Trécul	Arb.	MC 817	RC 1047	Amazonian, Caatinga, Cerrado, Atlantic Forest, Pantanal		
Pilea sp. 1	Herb.	RB 568		Atlantic Forest		
Pilea rhizobola Miq.	Herb.	MC 482	AA 4826	Atlantic Forest	Northeast	
Pourouma guianensis Aubl.	Arb.	MC 513	JP 781	Amazonian, Atlantic Forest		
Pourouma velutina Mart. ex Miq.	Arb.	MC 808		Amazonian, Atlantic Forest		
Urera caracasana (Jacq.) Griseb.	Arb.	MC 807		Amazonian, Caatinga, Cerrado, Atlantic Forest		
VELLOZIACEAE						
Barbacenia sp. 1	Herb.	DC 2150		Atlantic Forest		
VERBENACEAE						
Lantana sp.1	Shr.		AA 4239	Atlantic Forest		
Lantana camara L.	Shr.		AA 4908	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Lantana morii Moldenke	Shr.	PF 2920		Atlantic Forest		
Lantana undulata Schrank	Shr.	AA 8121		Atlantic Forest		
Stachytarpheta sp. 1	Herb.	MC 694		Atlantic Forest		
Vitex sp. 1	Arb.	MC 869		Atlantic Forest		
VIOLACEAE						
Noisettia orchidiflora (Rudge) Ging.	Herb.	MC 631	RB 507	Amazonian, Atlantic Forest		
Rinorea guianensis Aubl.	Arb.		PF 2633	Amazonian, Atlantic Forest		
VITACEAE						
Cissus erosa Rich.	Clim.	RP 720	RB 473	Amazonian, Caatinga, Cerrado, Atlantic Forest		
Cissus nobilis Kuhlm.	Clim.	MC 587		Amazonian, Atlantic Forest		
Cissus paucinervia Lombardi	Clim.	MC 414		Atlantic Forest		
VOCHYSIACEAE						
Qualea sp. 1	Arb.	AA 4714		Atlantic Forest		
Qualea sp. 2	Arb.		PF 1528	Atlantic Forest		
ZINGIBERACEAE						
Renealmia petasites Gagnep.	Herb.	ML 375	ML 312	Atlantic Forest	Northeast	

Figure 3. Endemic species

A and B: *Portea filifera* (Bromeliaceae), an endemic species of southern Bahia. C: *Chamaecostus cuspidatus* (Costaceae), an endemic species of the Atlantic Forest. D: *Bertolonia bullata* (Melastomataceae), an endemic species of southern Bahia. E: *Dorstenia hirta* (Moraceae), an endemic species of the Atlantic Forest. F: *Notopleura tapajozensis* (Rubiaceae), a disjunct species between the Amazonian and Atlantic forests. Photos A, B, D,E and F were taken by André Amorim. Photo C was taken by Macielle Coelho.

accounting for 59.4% of the liana species recorded. The Orchidaceae family consisted of the highest number of epiphytic species (74 species), followed by Bromeliaceae (47 species), Araceae (25 species), and Piperaceae (12 species), accounting for 82.7% of the epiphytic species recorded. The Myrtaceae family had the highest number of arboreal species (25 species), followed by Fabaceae (23 species), Rubiaceae (22 species), Lauraceae (21 species), Melastomataceae (18 species), Annonaceae (10 species), and Euphorbiaceae and Sapindaceae (9 species each), accounting for 34.6% of the arboreal species sampled.

In addition to the seven angiosperm species recently described following the first field trips to SPL and SCO, 12 other species have been identified by nine specialists till date. Some of these species are in the description phase, including one species each of *Philodendron* (Araceae), *Vriesea* (Bromeliaceae), *Dichorisandra* (Commelinaceae), *Bertolonia* (Melastomataceae), *Ichnanthus* (Poaceae), *Myrsine* (Primulaceae), *Faramea* and *Psychotria* (Rubiaceae), *Cupania* (Sapindaceae), and *Symplocos* (Symplocaceae) and two species of *Peperomia* (Piperaceae).

Discussion

From a floristic perspective, the abundance and percentage of endemic Atlantic Forest species found in the two areas surveyed (SCO and SPL) are corroborated in previous studies indicating that this environment is one of the richest ecosystems in Brazil with high levels of endemism (Mori et al. 1981, Gentry 1992, Martini et al. 2007, Murray-Smith et al. 2008, Amorim et al. 2009, Forzza et al. 2012). Southern Bahia is considered one of the three regions of endemism in the Atlantic Forest and one of the six regions with high levels of endemic plants threatened with extinction (Murray-Smith et al. 2008). However, research and conservation measures focused on this region are still inadequate (Carnaval and Moritz 2008, Amorim et al. 2009). The percentage of endemism among the species in southern Bahia and northern Espírito Santo found in this study (11.2%) was similar to that obtained by Amorim et al. (2009) in the Montane Forest (7.4%) but lower than that obtained in areas of lowland ombrophilous forests

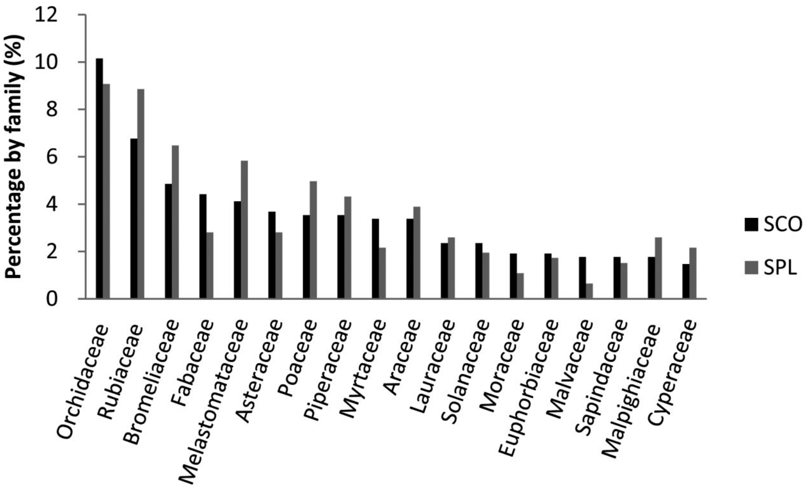

Figure 4. The most abundant angiosperm families in the vestigial forests of Serra do Corcovado (SCO) and Serra da Pedra Lascada (SPL) located in southern Bahia, Brazil

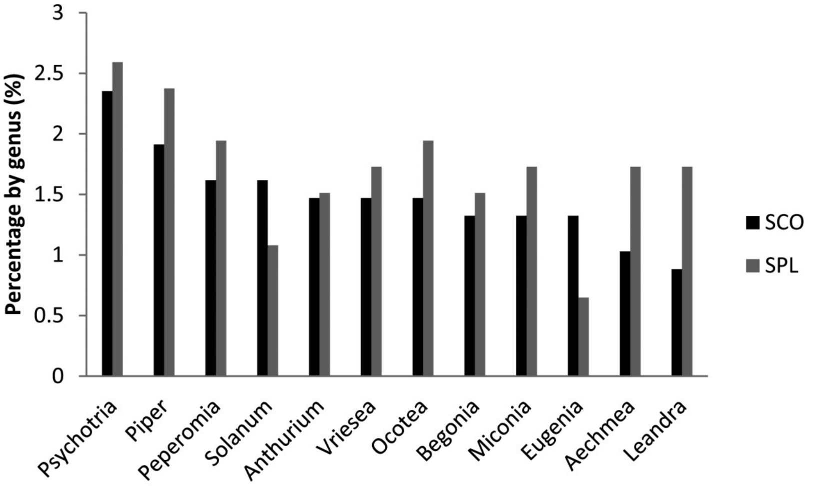

Figure 5. The most abundant angiosperm genera in the vestigial forests of Serra do Corcovado (SCO) and Serra da Pedra Lascada (SPL) located in southern Bahia, Brazil

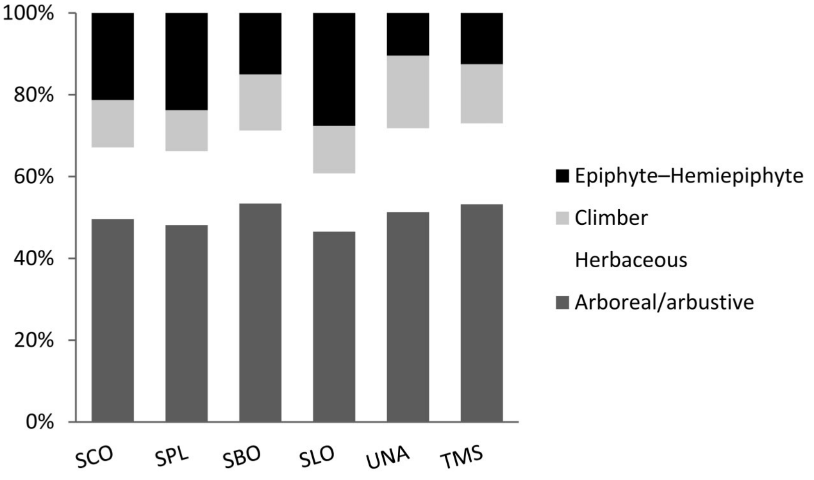

Figure 6. Life forms found in distinct areas of the Atlantic Forest in southern Bahia: Serra do Corcovado (SCO), Serra da Pedra Lascada (SPL), Serra Bonita (SBO), Serra das Lontras (SLO), Una Biological Reserve (UNA), and Serra do Teimoso Natural Reserve [Patrimônio Natural Serra do Teimoso (TMS)]

(18.9%–28.1% of the total flora) (Thomas et al. 1998, Amorim et al. 2008). However, the endemism in the Montane Forest appears to be more local, with species recorded only in these elevation zones, as exemplified by the recent addition of species to genera such as *Bertolonia*, *Dichorisandra*, *Macrocarpaea*, *Quesnelia*, and others.

In the two study areas, *Psychotria*, *Piper*, *Ocotea*, *Vriesea*, and *Peperomia* were the most abundant genera in terms of the number of species; these were also the most representative genera in previous study conducted in similar areas, with the exception of *Vriesea* (Amorim et al. 2009), which is epiphytic. In addition, the genera represented by a single species

Table 2. Comparison of taxonomic diversity and life forms from four montane areas of southern Bahia and other areas of Atlantic Forest. SCO = Corcovado Mountain, SPL = Pedra Lascada Mountain, SBO = Serra Bonita Mountain, SLO = Lontras Mountain, UNA = Una Biological Reserve, TMS = Teimoso Mountain. Epi./Hemiepiph. = Epiphytes and hemiepiphytes, Climb. = Climbers, Herb. = Herbaceous, Árb./Shr. = Trees and shrubs. (Adapted from Amorim et al. 2009 with updates numbers).

Locality	N. spp.	N. gen.	N. fam.	Arb./Shr. (%)	Herb. (%)	Climb. (%)	Epi./Hemiepiph. (%)
SCO	680	367	100	49	17,3	11,5	21
SPL	463	269	88	48	18	10	23,7
SBO	905	451	126	52,4	17,5	13,5	14,7
SLO	910	421	122	45,7	14	11,4	27,1
UNA	947	435	108	51,3	20,5	17,8	10,4
TMS	667	363	100	53,2	19,8	14,5	12,5

accounted for 29.4% of the total, which was close to the percentage (23.6%) obtained by Amorim et al. (2009).

In terms of the number of species, the families Orchidaceae, Rubiaceae, Bromeliaceae, and Poaceae were abundant not only in SCO and SPL but also in other areas of the Atlantic Forest (Pabst and Dungs 1975, Soderstrom et al. 1988, Giulietti et al. 2005, Martinelli et al. 2008, Amorim et al. 2009). Furthermore, Melastomataceae is another family with a high number of species in the areas surveyed and constitutes an important Atlantic Forest group, considering the species abundance (Oliveira-Filho and Fontes 2000, Rocha and Amorim 2012).

The abundance of Asteraceae, Melastomataceae, and Solanaceae tends to increase with altitude in the Atlantic Forest (Oliveira-Filho and Fontes 2000). According to Amorim et al. (2009), these families are among the most abundant families in the mountainous areas of southern Bahia, including SCO and SPL reported in the present study. In contrast, the abundance of Chrysobalanaceae, Rutaceae, and Sapotaceae tends to decrease with an increase in the altitude (Oliveira-Filho and Fontes 2000). In the present study, the latter three families contained five, seven, and six species, respectively, and were among the least abundant families. On the other hand, in the study of Amorim et al. (2005), a high abundance of Rutaceae was detected in a montane region.

One of the main differences in floristic documentation between the present study and previous studies is related to the families Burseraceae and Combretaceae. These families have been reported to be generally highly abundant in the lowlands of southern Bahia (Amorim et al. 2005). In contrast, we did not identify the family Burseraceae and found a low representativeness of the family Combretaceae in the present study.

With regard to the life forms documented, more than 50% of the species recorded in the two areas were nonarboreal (64.8% in SCO and 66.3 in SPL). This is in accordance with previous findings that in tropical forests, a high abundance of angiosperms is expected for nonwoody species (Gentry and Dodson 1987, Gentry 1988, Webster 1995), particularly in the Montane Forest. In addition, these values are very similar to those found in PARNA Serra das Lontras and in RPPN Serra Bonita and, to a lesser extent, in RPPN Serra do Teimoso and REBIO de Una (Amorim et al. 2009). However, the latter two regions represent very different physiognomies than SCO and SPL: RPPN Serra do Teimoso has a strong seasonal influence, whereas REBIO de Una is situated in a submontane area near the coast.

With regard to the Atlantic Forest regions located in southeast Brazil, our results were very similar to those of Lima and Guedes-Bruni (1997) in Macaé de Cima and, to a lesser extent, to the inventory of the Juréia Mountains (Mamede et al. 2001), indicating that this pattern of life forms is similar to that observed in the Atlantic Forest. Subtle differences in the life forms can be observed, for example, the greater abundance of climbing species in SCO than in SPL and the greater abundance of epiphytic species in PARNA Serra das Lontras in contast to the greater abundance of herbaceous species in REBIO de Una and RPPN Serra do Teimoso. However, the homogeneity in the patterns of life forms is evident in these distinct locations, as described by Amorim et al. (2009) in a floristic study conducted in three montane areas in southern Bahia.

According to the Lista de Espécies da Flora do Brasil (2012) [List of Species of the Brazilian Flora (2012)], three species were not found in the Atlantic Forest: *Cattleya elongata* (Orchidaceae), *M. leuconeura* (Primulaceae), and *Passiflora nitida* (Passifloraceae). Of all the species sampled, 47 are new occurrences in northeast Brazil, four are new occurrences in southern Bahia, and eight are new occurrences in Bahia. Of the 47 new occurrences, *Vanilla* cf. *bicolor* (Orchidaceae) and *Piper subglabrifolium* (Piperaceae) were known only in the State of Amazonas in northern Brazil. In addition, it should be emphasized that 32 species found in SCO and SPL have been classified into various categories of threat of extinction, including *Bactris pickelli* (Arecaceae), *Rhipsalis baccifera* subsp. *hileiabaiana* (Cactaceae), *Abarema cochliacarpos* and *Inga grazielae* (Fabaceae), *Heteropterys bullata* (Malpighiaceae), and *C. warneri* (Orchidaceae), all of which are in the vulnerable category (MMA 2008, Biodiversitas 2009).

The presence of disjunct taxa between the Amazonian and Atlantic forests (6.8%, represented by 78 species) reinforces the idea of possible floristic connections between southern Bahia and the Amazonian Forest during the Quaternary era (Prance 1979, Oliveira-Filho and Ratter 1995, Carnaval and Moritz 2008). Although the percentage of species typically found in the Amazonian Forest is lower in the Montane Forest than in lowland areas, the disjunct distribution between taxa of the Atlantic and Amazonian forests has been previously reported (Andrade-Lima 1953, Prance 1979, Mori et al. 1981, Gentry 1982, Rizzini 1997, Amorim et al. 2008, 2009). The presence of common species among Bahia, Espírito Santo, and Rio de Janeiro (40 species; 3.5%) indicates another pattern in taxa distribution, which is in agreement with the study of Oliveira-Filho et al. (2005), which suggests the occurrence of a continuous gradient in the ombrophilous forests, from Rio de Janeiro to the south of Bahia.

The percentage of species not yet described (1.3%) was similar to that reported in studies by Amorim et al. (2005) (1.8%) and Amorim et al. (2009) (3.5%). These figures when added to the recently published species collected in SCO and SPL, such as *A. viridipetala* A.F.Costa and Amorim (Bromeliaceae), *M. atlantica* J.R.Grant and V.Trunz and *M. orbiculata* J.R.Grant and V.Trunz (Gentianaceae), *B. bullata* Baumgratz, Amorim, and A.B.Jardim and *M. dorsaliporosa* R.Goldenb and Reginato (Melastomataceae), *Myrcia lascada* Sobral (Myrtaceae), and *Carrapichea lucida* J.G.Jardim and Zappi (Rubiaceae), together with the records of other species previously unknown in southern Bahia (7.9%) indicate the lack of floristic studies in this region (Amorim et al. 2009). In addition to the rare and unknown angiosperm species, the presence of species of ferns and lycophytes also deserves attention, particularly in SCO, where the *Diplazium fimbriatum* (Athyriaceae) (Mynssen and Matos 2012) type originates and where *Adiantum diphyllum* (Pteridaceae), a rare and endemic species of Bahia, was detected during the initial field trips to the area (Sundue and Prado 2005).

Therefore, floristic surveys that contribute to the description of new species and help delimit the distribution of occurrence of taxa constitute rich sources of information for the studies on biodiversity and conservation because these surveys will enable the identification of hotspots that should be prioritized in future conservation projects, at both the state and national levels. Till date, there has been no effective action for the establishment of legal protection units in SCO and SPL, which is a cause for concern, considering the abundance of vascular plants and the high number of new and endemic species documented, in addition to the large number of threatened species. Morever, the results of the present study revealed the ecological importance of the vestigial Montane Forest in southern Bahia and the need for further surveys in these areas. We believe that the data presented here will be useful in developing future conservation strategies in these areas, while serving as the fountation for future ecological, phylogenetic, and taxonomic studies, thereby complementing studies on local biodiversity, which are necessary for the preservation of these ecosystems.

Acknowledgments

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References

AMORIM, A.M., JARDIM, J.G., CLIFTON, B.C., FIASCHI, P., THOMAS, W.W., CARVALHO, A.M.V. 2005. The vascular plants of a forest fragment in southern Bahia, Brazil. Sida 21(3): 1726–1752.

AMORIM, A.M., THOMAS, W.W., CARVALHO, A.M.V. & JARDIM, J.G. 2008. Floristics of the Una Biological Reserve, Bahia, Brasil. In: The Atlantic Coastal Forest of Northeastern Brazil (W Thomas, ed.). Mem. New York Bot. Gard. 100:67-146.

AMORIM, A.M., JARDIM, J.G., LOPES, M.M.M., FIASCHI, P., BORGES, R.A.X., PERDIZ, R.O. & THOMAS, W.W. 2009. Angiospermas em remanescentes de Floresta Montana no sul da Bahia, Brasil. Biota Neotrop. 9(3): 313-348 http://www.biotaneotropica.org.br/v9n3/pt/abstract?article+bn02909032009 (último acesso em 26/02/2013), doi: http://dx.doi.org/10.1590/S1676-06032009000300028

ANDRADE-LIMA, D. 1953. Notas sobre a dispersão de algumas espécies vegetais no Brasil. Anais da Sociedade de Biologia de Pernambuco 11(1):25-49.

APG III. 2009. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. Bot. Jour. Linn. Soc. 161 (20): 105-121.

BIODIVERSITAS. 2009. http://www.biodiversitas.org.br/floraBr/destaque_flora.asp (último acesso em 19/12/2012).

CARNAVAL, A.C. & MORITZ, C. 2008. Historical climate modelling predicts patterns of current biodiversity in the Brazilian Atlantic forest. J. Biogeogr. 35: 1187–1201, doi: http://dx.doi.org/10.1111/j.1365-2699.2007.01870.x

FIDALGO, O. & BONONI, V.L.R. 1989. Técnicas de coleta, preservação e herborização de material botânico. Secretaria de Agricultura e Abastecimento. Instituto de Botânica. São Paulo. 62p.

FORZZA, R.C., BAUMGRATZ, J.F.A., BICUDO, C.E.M., CANHOS, D.A.L., CARVALHO JR., A A., COELHO, N.M.A., COSTA, A.F., COSTA, D.P., HOPKINS, M.G., LEITMAN, P.M., LOHMANN, L.G., LUGHADHA, E.N., MAIA, L.C., MARTINELLI, G., MENEZES, M., MORIM, M.P., PEIXOTO, A.L., PIRANI, J.R., PRADO, J., QUEIROZ, L.P., SOUZA, S., SOUZA, V.C., STEHMANN, J.R., SYLVESTRE, L.S., WALTER, B.M.T. & ZAPPI, D.C. 2012. New Brazilian floristic list highlights conservation challenges. Bioscience, 62(1): 39-45, doi: http://dx.doi.org/10.1525/bio.2012.62.1.8

FUNK, V.A. 2006. Floras: a model for biodiversity studies or a thing of the past? Taxon, 55(3): 581-588, doi: http://dx.doi.org/10.2307/25065635

GENTRY, A.H. 1982. Neotropical floristic diversity: phytogeographical connections between Central and South America, Pleistocene climatic fluctuations, or an accident of the Andean orogeny? Ann. Miss. Bot. Gard. 69(3):557-593, doi: http://dx.doi.org/10.2307/2399084

GENTRY, A.H. 1988. Changes in plant community diversity and floristic composition on environmental and geographical gradients. Ann. Miss. Bot. Gard. 75(1):1-34, doi: http://dx.doi.org/10.2307/2399464

GENTRY, A.H. 1992. Tropical forest biodiversity: distributional patterns and their conservational significance. Oikos 63:19-28, doi: http://dx.doi.org/10.2307/3545512

GENTRY, A.H. & DODSON, C.H. 1987. Diversity and biogeography of neotropical vascular epiphytes. Ann. Miss. Bot. Gard. 74(2):205-233, doi: http://dx.doi.org/10.2307/2399395

GIULIETTI, A.M., HARLEY, R.M., QUEIROZ, L.P. & WANDERLEY M.G.L., VAN DEN BERG, C. 2005. Biodiversity and conservation of plants in Brazil. Conserv. Biol. 19(3):632-639, doi: http://dx.doi.org/10.1111/j.1523-1739.2005.00704.x

GOUVÊA, J.B.S., MATTOS SILVA, L.A. & HORI, M. 1976. Fitogeografia. In: Diagnostico socioeconômico da região cacaueira. (Comissão Executiva do Plano da Lavoura Cacaueira e Instituto Interamericano de Ciências Agrícolas, ed.). Ilhéus, Bahia. 7:1-7.

LIEBERMAN, D., LIEBERMAN, M., PERALTA, R. & HARTSHORN, G.S. 1996. Tropical forest and composition on large-scale altitudinal gradient in Costa Rica. J. Trop. Ecol. 84: 137-152, doi: http://dx.doi.org/10.2307/2261350

LIMA, H.C. & GUEDES-BRUNI, R.R. 1997. Diversidade de plantas vasculares na Reserva Ecológica de Macaé de Cima. In: Serra de Macaé de Cima: diversidade florística e conservação em Atlantic Forest (H.C. Lima & R.R. Guedes-bruni, Orgs.). Jardim Botânico do Rio de Janeiro, Rio de Janeiro, 346p.

LISTA DE ESPÉCIES DA FLORA DO BRASIL. http://floradobrasil.jbrj.gov.br/2012 (último acesso em 28/02/2013).

LOMOLINO, M.V. 2001. Elevation gradients of species-density: historical and prospective views. Global Ecol. Biogeogr. 10:3-13, doi: http://dx.doi.org/10.1046/j.1466-822x.2001.00229.x

MMA. 2008. www.mma.gov.br/estruturas/ascom.../83_19092008034949.pdf (último acesso em 26/02/2013).

MAMEDE, M.C.H., CORDEIRO, I. & ROSSI, L. 2001. Flora vascular da Serra da Juréia, Município de Iguape, São Paulo, Brasil. Bol. Inst. Bot. 15:63-124.

MARTINELLI, G., MAGALHÃES, C.V., GONZALEZ, M., LEITMAN, P.M., PIRATININGA, A., COSTA, A.F. & FORZZA, R.C. 2008. Bromeliaceae da Atlantic Forest Brasileira: Lista de espécies, distribuição e conservação. Rodriguesia 59(1): 209-258.

MARTINI, A.M.Z., FIASCHI, P., AMORIM, A.M. & PAIXÃO, J.P. 2007. A hot-point within a hot-spot: a high diversity site in Brazil's Atlantic Forest. Biodivers. Conserv. 16(11):3111-3128, doi: http://dx.doi.org/10.1007/s10531-007-9166-6

MYNSSEN, C.M. & MATOS, F.B. 2012. *Diplazium fimbriatum* (Athyriaceae), a New species from Brazil. Am. Fern J. 102(2):167–173, doi: http://dx.doi.org/10.1640/0002-8444-102.2.167

MORI, S.A., BOOM, B.M. & PRANCE, G.T. 1981. Distribution patterns and conservation of eastern Brazilian coastal forest tree species. Brittonia 33:233–245, doi: http://dx.doi.org/10.2307/2806330

MURRAY-SMITH, C., BRUMMITT, N.A., OLIVEIRA-FILHO, A.T., BACHMAN, S.P., NIC LUGHADHA, E.M., MOAT, J., LUCAS, E.J. 2008. Plant diversity hotspots in the Atlantic coastal forests of Brazil. Conserv. Biol. 23: 151-163, doi: http://dx.doi.org/10.1111/j.1523-1739.2008.01075.x

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, doi: http://dx.doi.org/10.1111/j.1744-7429.2000.tb00619.x

OLIVEIRA-FILHO, A.T., TAMEIRÃO-NETO, E., CARVALHO, W.A.C., WERNECK, M., BRINA, A.E., VIDAL, C.V., REZENDE, S.C. & PEREIRA, J.A.A. 2005. Análise florística do compartimento arbóreo de áreas de Floresta Atlântica *sensu lato* na região das bacias do leste (Bahia, Minas Gerais, Espírito Santo e Rio de Janeiro). Rodriguesia 56(87): 185-235.

OLIVEIRA-FILHO, A.T. & RATTER, J.A. 1995. A study of the origin of central Brazilian forests by the analysis of plant species distribution patterns. Edinb. J. Bot. 52(2):141-194, doi: http://dx.doi.org/10.1017/S0960428600000949

PABST, G.F.J. & DUNGS, F. 1975. Orchidaceae Brasilienses vol. I. Hildesheim, Brucke-Verlag Kurt Schmersow.

PEEL, M.C., FINLAYSON, B.L., & MCMAHON, T.A. 2007. Updated world map of the Koppen-Geiger climate classification. Hydrol. Earth Syst. Sc. 11:1633–1644, doi: http://dx.doi.org/10.5194/hess-11-1633-2007

PENDRY, C.A. & PROCTOR, J. 1996. The causes of altitudinal zonation of rain forests on Bukit Belalong, Brunei. J. Ecol. 84: 407-418, doi: http://dx.doi.org/10.2307/2261202

PINTO, L.P.S., COSTA, J.P.O., FONSECA, G.A.B. & COSTA, C.M.R., 1996, Atlantic Forest: ciência, conservação e políticas. Workshop científico sobre a Atlantic Forest. Secretaria do Meio Ambiente do Estado de São Paulo (Documentos Ambientais), São Paulo.

POREMBSKI, S., MARTINELLI, G., OHLEMÜLLER, R. & BARTHLOTT, W. 1998. Diversity and ecology of saxicolous vegetation mats on inselbergs in the Brazilian Atlantic rainforest. Divers Distrib 4: 107-119, doi: http://dx.doi.org/10.1046/j.1365-2699.1998.00013.x

PRANCE, G.T. 1979. The taxonomy and phytogeography of the Chrysobalanaceae of the Atlantic coastal forests of Brazil. Rev. Bras. Bot. 2(1):19-39.

RIZZINI, C.T. 1997. Tratado de Fitogeografia do Brasil. Âmbito Cultural, Rio de Janeiro.

ROCHA, D.S.B. & AMORIM, A.M. 2012. Heterogeneidade altitudinal na Floresta Atlântica setentrional: um estudo de caso no sul da Bahia, Brasil. Acta Bot. Bras. 26(2): 309-327.

SILVA, J.M.C. & CASTELETI, C.H. 2005. Estado da biodiversidade da Atlantic Forest brasileira. In: Atlantic Forest: Biodiversidade, ameaças e perspectivas (C. Galindo-Leal & I.G. Câmara, eds.). Fundação SOS Atlantic Forest, Belo Horizonte. 472p.

SODERSTROM, T R., JUDZIEWICZ, E.J.L. & CLARK, L.G. 1988. Distribution patterns in neotropical bamboos. In: Proceedings of the neotropical biotic distribution pattern workshop. (P.E. Vanzolini & W.R. Heyer, eds.) Academia Brasileira de Ciências, Rio de Janeiro, p.120-156.

STEHMANN, J.R, FORZZA, R.C., SALINO, A., SOBRAL, M., COSTA, D.P. & KAMINO, L.H.Y. 2009. Plantas da Floresta Atlântica. Jardim Botânico do Rio de Janeiro, Rio de Janeiro. 516p.

SUNDUE, M.A. & PRADO, J. 2005. *Adiantum diphyllum*, a rare and endemic species of Bahia State, Brazil and its close relatives. Brittonia 57(2):123-128, doi: http://dx.doi.org/10.1663/0007-196X(2005)057[0123:ADARAE]2.0.CO;2

THE PLANT LIST. http://www.theplantlist.org. (último acesso em 28/02/2013).

THOMAS W.W., CARVALHO, A.M.V., AMORIM, A.M.A., GARRISON, J. & ARBELÁEZ, A.L. 1998. Plant endemism in two forests in southern Bahia, Brasil. Biodivers. Conserv. 7: 311-322, doi: http://dx.doi.org/10.1023/A:1008825627656

THOMAS, W.W., JARDIM, J.G., FIASCHI, P. & AMORIM, A.M. 2003. Lista preliminar das angiospermas localmente endêmicas do sul da Bahia e norte do Espírito Santo, Brasil. In: Corredor de Biodiversidade da Atlantic Forest do Sul da Bahia. (P.I. Prado, E.C. Landau, R.T. Moura, L.P.S. Pinto, G.A.B. Fonseca & K. Alger, orgs.) IESB, CI, CABS, UFMG, UNICAMP, Ilhéus. Publicação em CD-ROM.

THOMAS, W.W. & BARBOSA, M.R.V. 2008. Natural vegetation types in the Atlantic Coastal Forest of Northeastern Brazil. In: The Atlantic Coastal Forests of Northeastern Brazil (W.W. Thomas, ed.). Mem. New York Bot. Gard. 100:6-20.

THOMAS, W.W., JARDIM, J.G., FIASCHI, P., MARIANO-NETO, E. & AMORIM, A.M. 2009. Composição florística e estrutura do componente arbóreo de uma área transicional de Floresta Atlântica no sul da Bahia, Brasil. Rev. Bras. Bot. 32(1): 65-78, doi: http://dx.doi.org/10.1590/S0100-84042009000100007

VELOSO, HP. 1992. Sistema fitogeográfico. In: Manual técnico da vegetação brasileira (IBGE ed.). Fundação Instituto Brasileiro de Geografia e Estatística, Manuais Técnicos em Geociências, Rio de Janeiro. n. 1, 38p.

WEBSTER, G.L. 1995. The panorama of neotropical cloud forests. In: Biodiversity and conservation of Neotropical Montane Forests. (S.P. Churchill, H. Balslev, E. Forero & J.L. Luteyn, eds.) The New York Botanical Garden, New York, p.53-77.

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short communication

"*Swallowing it all*" – Extreme ingestion capability of juvenile reef fish

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Abstract: During a predation event a juvenile grouper, rock hind *Epinephelus adscensionis*, fed upon the redlip blenny *Ophioblennius trinitatis*. It is important to highlight that both individuals had pretty much the same size during the predation event (around 5 cm); however, the grouper ingested the whole prey.
Keywords: *Feeding behavior, Piscivory, Reef Fish, Atlantic Ocean.*

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Resumo: Durante um evento de predação um indivíduo juvenil de *Epinephelus adscensionis* (peixe-gato) alimentou-se de *Ophioblennius trinitatis* (macaquinho). É importante destacar que ambos os peixes apresentavam praticamente o mesmo tamanho (aproximadamente 5 cm); no entanto, a garoupa engoliu a presa inteira.
Palavras-chave: *Comportamento alimentar, Piscivoria, Peixes recifais, Oceano Atlântico.*

Introduction

A reduced number of animals have the ingestion capability to swallow a whole prey, in just one trial, during their juvenile life phase (Hampton 2014). This behaviour needs to be associated with a series of morphological and anatomical features such as gape size, stomach dilatation, quantity and quality of digestive enzymes (Richard & Wainwright 1995). Despite the fact that this behaviour can be considered rare for juveniles, it has already been recorded for reptiles, birds and fishes (Rodriguez-Robles 2002).

Piscivorous reef fishes are defined as the ones that feed most on live fishes. This trophic guild is proportionally better represented in high latitudes due to a decrease in the abundance of other groups such as herbivores and planktivores (Ferreira et al. 2004). Moreover, their life cycle characteristics (*e.g.* long life span, ontogenetic migrations) and reproduction (*e.g.* sex inversion) make them highly vulnerable to even low levels of exploitation (Sadovy 2001).

Epinephelus adscensionis, rock hind, is a solitary grouper (Family Epinephelidae) that inhabits rocky reefs in the Western Atlantic Ocean (Nelson 2006). It is characterized by a medium body size grouper (maximum 50.0 cm total length) with bases of soft dorsal and anal fins covered with scales and thick skin. Also, 2 or 3 dark saddles along base of dorsal fin and another on top of caudal peduncle and red spots on head, body and fins, spots becoming larger ventrally (Smith 1997; Nelson 2006).

Ontogenetic diet changes have been already recorded for piscivorous fish and also for the *Epinephelus* genus (Machado et al. 2008), such as for another reef fishes trophic guilds (Pereira & Ferreira 2013). These diet changes according to ontogeny are normally useful to minimize energetic coast, predation risk and diet overlap; in contrast, increase species growth rates.

Material and Methods

The predation event recorded herein was observed in Northeast Brazil macroalgal beds adjacent to coral reefs (Tamandaré municipality – 8°44′26″ S and 35°05′11″ W) during the summer of 2011. These macroalgae beds are mainly composed by *Sargassum polyceratium*, *Dictyopteris delicatula* and *Canistrocarpus cervicornis* and are recognised nursery and feeding grounds for different reef fishes (Chaves et al. 2013). The observation was performed by snorkelling during the morning (09:00 – 11:00) in depth average of 2 m.

Results and Discussion

During the observation, a juvenile grouper, rock hind *Epinephelus adscensionis*, fed upon the redlip blenny *Ophioblennius trinitatis* (endemic Brazilian cryptobenthic species). The ingestion process was observed and took approximately 5 minutes from the first strike until the final tail ingestion. Before the attack, the prey was observed swimming close to the predator without any sign of debilitation what emphasise the predator hunting skills. The rock hind, *Epinephelus adscensionis*, was camouflaged around an algae bottom and attacked the redlip blenny *Ophioblennius trinitatis* in an extremely fast movement once it approached. It is important to highlight that both individuals had pretty much the same size during the predation event (around 5 cm);

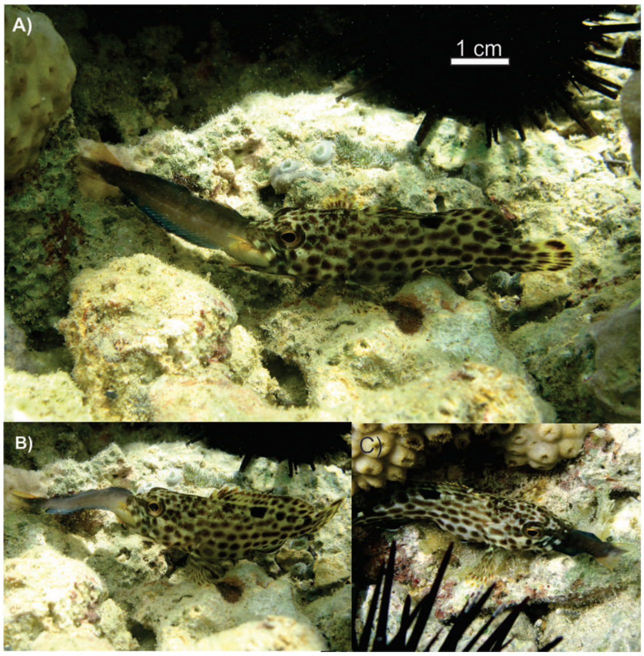

Figure 1. Predation event recorded on Northeast Brazil macroalgal beds when a juvenile grouper (around 5.0 cm), *Epinephelus adscensionis*, ingested the whole redlip blenny (around 4.5 cm), *Ophioblennius trinitatis* in just one trial. The feeding behaviour started from the head (Figure 1A) continuous towards the body (Figure 1B) and then the grouper swallowed the whole fish (Figure 1 C). Size scales are presented in the figure.

however, the juvenile grouper ingested the whole prey. The feeding behaviour started from the head (Figure 1A) continuous towards the body (Figure 1B) and then the grouper swallowed the whole fish (Figure 1 C).

Epinephelus adscensionis individuals are characterized as an ambush predator, displaying a “sit and wait” feeding behaviour. This behaviour is normally associated with low mobility and high camouflage capability. Therefore, the predation event observed herein supports this behaviour for the *Epinephelus* genus also during juvenile life phase when the rock hind ingested the whole redlip blenny in just one trial.

The rock hind diet is composed mainly by crabs (66.70%) and fishes (20.1%); and they can also include young sea turtles in their diet (Randall 1967, Coelho 2012). Nevertheless, the diet of *E. adscensionis* during juvenile life phase is still unclear, despite the fact that crabs are normally found on their stomachs (Randall 1967).

Ontogenetic changes in habitat use are also known for *E. adscensionis*. Juveniles are more abundant associated with macroalgal beds (Chaves et al. 2013); in contrast adults are common in deeper waters connected with coral reefs (author personal observation). Therefore, these habitat use modification according to ontogeny can also be relevant for *E. adscensionis* and other reef fishes, reducing their predation risk and also increasing feeding rates (Brown et al. 2002).

The plasticity of the feeding event reported herein highlight ontogenetic diet changes on piscivorous reef fishes as well as already observed for the *Epinephelus* genus (López & Orvay 2005, Machado et al. 2008, Coelho 2012). Furthermore, the extreme ingestion capability of juvenile piscivorous reef fish needs to be better investigated regarding its anatomical and morphological characteristics.

References

BROWN, G.E., GERSHANECK, D.L., PLATA, D.L. & GOLUB, J.L. 2002. Ontogenetic changes in response to heterospecific alarm cues by juvenile bass are phenotypically plastic. Behaviour. 139:913-927. doi: http://dx.doi.org/10.1163/156853902320387891

CHAVES, L.C.T., PEREIRA, P.H.C. & FEITOSA, J.L.L. 2013. Coral reef fish association with macroalgal beds on a tropical reef system in Northeastern Brazil. Mar. Freshwater Res. 64:1101–1111. doi: http://dx.doi.org/10.1071/MF13054

COELHO, F.N. 2012. Ecologia trófica e distribuição espacial de peixes predadores na ilha da trindade. Tese de doutorado, Universidade Federal do Espírito Santo.

FERREIRA, C.E.L., FLOETER, S.R., GASPARINE, J.L., JOYEUX, J.C. & FERREIRA, B.P. 2004 Trophic structure patterns of Brazilian reef fishes: a latitudinal comparison. J. Biogeogr. 31:1093-1106. doi: http://dx.doi.org/10.1111/j.1365-2699.2004.01044.x

HAMPTON, P. 2014. Allometry of skull morphology, gape size and ingestion performance in the banded watersnake (*Nerodia fasciata*) feeding on two types of prey. J. Exp. Biol. 217:472-478. doi: http://dx.doi.org/10.1242/jeb.092924

LÓPEZ, V.G., & Orvay, F.C. 2005. Food habits of groupers *Epinephelus marginatus* (Lowe, 1834) and *Epinephelus costae* (Steindachner, 1878) in the Mediterranean Coast of Spain. Hidrobiológica. 15:27–34.

MACHADO, L.F., DARON, F. A. M. L., BERTONCINI, A. A., HOSTIM-SILVA, M., & BARREIROS, J. P. 2008. Feeding ecology and trophic ontogeny in *Epinephelus marginatus* (Perciformes: Serranidae) from south Brazil. Cybium. 32:33–41.

NELSON, J. S. 2006. Fishes of the world. New York, John Wiley & Sons.

PEREIRA, P.H.C. & FERREIRA, B.P. 2013. Effects of life phase and schooling patterns on the foraging behaviour of coral-reef fishes from the genus *Haemulon*. J. Fish Biol. 82:1226-1238. doi: http://dx.doi.org/10.1111/jfb.12054

RANDALL, J.E. 1967. Food habits of reef fishes in the West Indies. Stud Trop Oceanogr 5:665.

RICHARD, B. A. & WAINWRIGHT, P. C. 1995. Scaling the feeding mechanism of largemouth bass (*Micropterus salmoides*): kinematics of prey capture. J. Exp. Biol. 198:419-433.

RODRIGUEZ-ROBLES, J.Á. 2002. Feeding ecology of North American gopher snakes (Pituophis catenifer, Colubridae). Biol. J. Linn. Soc. 77:165–183. doi: http://dx.doi.org/10.1046/j.1095-8312.2002.00098.x

SADOVY, Y. 2001. The threat of fishing to highly fecund fishes. J. Fish Biol. 59:90–108. doi: http://dx.doi.org/10.1111/j.1095-8649.2001.tb01381.x

SMITH, C. L. 1997. National Audubon Society field guide to tropical marine fishes of the Caribbean, the Gulf of Mexico, Florida, the Bahamas, and Bermuda. Alfred A. Knopf, Inc., New York.

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inventory

Ichthyofauna of the Parnaíba river Basin, Northeastern Brazil

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Abstract: The Parnaíba River is the largest hydrographic basin with its limits entirely within the northeastern region of Brazil. It is one of the few perennial rivers in the Brazilian Northeastern Region, running predominantly in the area of Caatinga on the eastern portion (with intermittent drainages associated to this type of environment), and partly extending into the Cerrado region on the western portion. The objective of this study was to describe the diversity of freshwater fishes of the Parnaíba River basin by conducting a comprehensive ichthyofauna inventory of the basin. The sampling design of this study was based on the placement of (1) Fixed Sites for seasonal collection (dry and wet season, two years) in the three portions of the main course of the Parnaíba River, and (2) "Aquarap" protocol collections which covered the entire basin. The collection effort consisted of 244 sampling sites surveyed along the entire basin between the years 2004 and 2011. Fish were collected with the use of seines, cast nets, gill nets and dip nets; only the first two fishing gears were used in Fixed Sites. As a result, 146 species of freshwater fish were recorded in the Parnaíba River basin, distributed in 103 genera, 36 families and 11 orders. The registered endemism reached a total of 54 species.

Keywords: *Parnaíba River, Ichthyofauna, Northeastern Brazil, Neotropical Region.*

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Resumo: O rio Parnaíba é o maior rio cuja bacia hidrográfica está inteiramente situada na região Nordeste do Brasil. É um dos poucos rios perenes do Nordeste e encontra-se sob domínio predominante de Caatinga (com drenagens intermitentes associadas a este tipo de ambiente), uma parte estendendo-se em região de Cerrado. Este estudo descreveu a diversidade da ictiofauna de água doce da bacia do rio Parnaíba através da realização de um amplo inventário. O desenho amostral baseou-se no estabelecimento de (1) Pontos Fixos de coleta sazonal (seca e cheia, dois anos de coleta) nas três porções do curso principal do rio Parnaíba, e (2) coletas do tipo "AquaRap", que cobriram toda a bacia. O esforço de coleta somou 244 pontos visitados ao longo da bacia entre os anos de 2004 e 2011. Os peixes foram coletados com o uso de redes de arrasto, tarrafas, esperas e puçás; apenas os dois primeiros tipos de apetrechos foram utilizados nos Pontos Fixos. Como resultado, foram registradas 146 espécies de peixes de água doce na bacia do rio Parnaíba, distribuídas em 103 gêneros, 36 famílias e 11 ordens; o endemismo registrado foi de 54 espécies.

Palavras-chave: *Rio Parnaíba, Ictiofauna, Nordeste brasileiro, região Neotropical..*

Introduction

Most basins in Northeastern Brazil are under the influence of the Caatinga. This biome is characterized by low rainfall, high evaporation rate and hence intermittent rivers, except for the main course of the São Francisco and Parnaíba rivers, which are perennials (Rosa et al. 2003). The Parnaíba River, object of this study, is the largest river in Northeastern Brazil among those whose drainage extends completely into this region, running on the north-western portion of the Caatinga, and is part of the Maranhão-Piauí ecoregion. Only a small part of its drainage is associated with the Cerrado area (Rosa et al. 2003).

The volume of information related to the fish fauna of the Parnaíba River basin is limited, although its exploration has begun in the nineteenth century, with Johan von Spix and Karl von Martius (Ramos 2012). This basin was included in the "Thayer Expedition", lead by Louis Agassiz. The collection at the Parnaíba basin, however, was done by Orestes St. John. After studying Parnaiba's specimens Agassiz focused on the similarities between the ichthyofauna of this basin and that of the Amazon basin, being the first author to state that the

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Parnaíba basin, under the geological and zoological viewpoints seems to be part of the Amazon basin (Agassiz & Agassiz, 1875). Géry (1969) agreed with the preceding authors in considering the Parnaíba basin as part of the "Amazon faunistic region", and Paiva (1978) followed this statement adding that its ichthyofauna was impoverished. Rosa et al. (2003) refuted this last statement, referring to a higher number of species and endemism, and also highlighted that the Parnaíba river basin shares some similar species with the Amazonian basin. Vari (1989) cited some examples of the close relationship between the ichthyofauna of these two basins, such as the genus *Psectrogaster*, whose species occurring at the Parnaíba River is the sister-taxon of a species occurring at the Amazon basin.

Fowler (1941, 1954), Menezes (1955), Roberts (1968), Paiva (1973), Fontanele & Farias (1979), Barbosa (1981) and Soares (1987) compiled lists of freshwater fish species of the Parnaíba River; and fisheries at the Parnaíba River were addressed during the 60's and 70's by Menezes (1964, 1973) and Paiva (1973, 1976). These papers provided lists of the freshwater fish species occurring in the basin in which 50-80 species were cited. These lists were biased on citing mostly middle to large-sized species (i.e., those targeted by the fishermen) and are now also largely outdated with respect to the taxonomy (Ramos 2012). In the last decade were described nine new species of freshwater fish of the Parnaíba River basin. This scenario shows that the Parnaíba River basin is still poorly known ichthyologically. A more in-depth analysis currently in preparation by the authors point that the level of endemism of the Parnaíba River basin is even higher than the present estimate indicates. Other recent studies have demonstrated a low level of knowledge on the taxonomy of the Parnaíba River ichthyofauna. For example, Staeck & Shindler (2006) described *Geophagus parnaibae* based on specimens traditionally identified as *G. surinamensis*; Piorski et al. (2008) described *Platydoras brachylecis* based on specimens identified as *P. costatus*. The aim of this study was to describe the diversity of freshwater fishes of the Parnaíba River basin through an extensive inventory.

Material and Methods

1. *Study area*

The main course of the Parnaíba River (Figure 1) has a south-north direction, with large meanders along its course. The low water period spans from June to October, the raining season from November to May; and large floods occur in January and February (SEMAR-PI; SRH/MMA. 2008). The main river course has a length of 1400 km, with the entire basin covering an area of 344.112 km^2 (3.9% of Brazilian territory) and draining nearly the entire Piauí State (99% of the territory), part of Maranhão (19%) and Ceará (10%) States. The main channel extends between Maranhão and Piauí States, defining the border between them in its entire length. The Parnaíba River basin includes 143 tributaries on the Piauí side, and 74 on the Maranhão side; part of tributaries on the east margin have their headwaters in Ceará State. The main tributaries of the

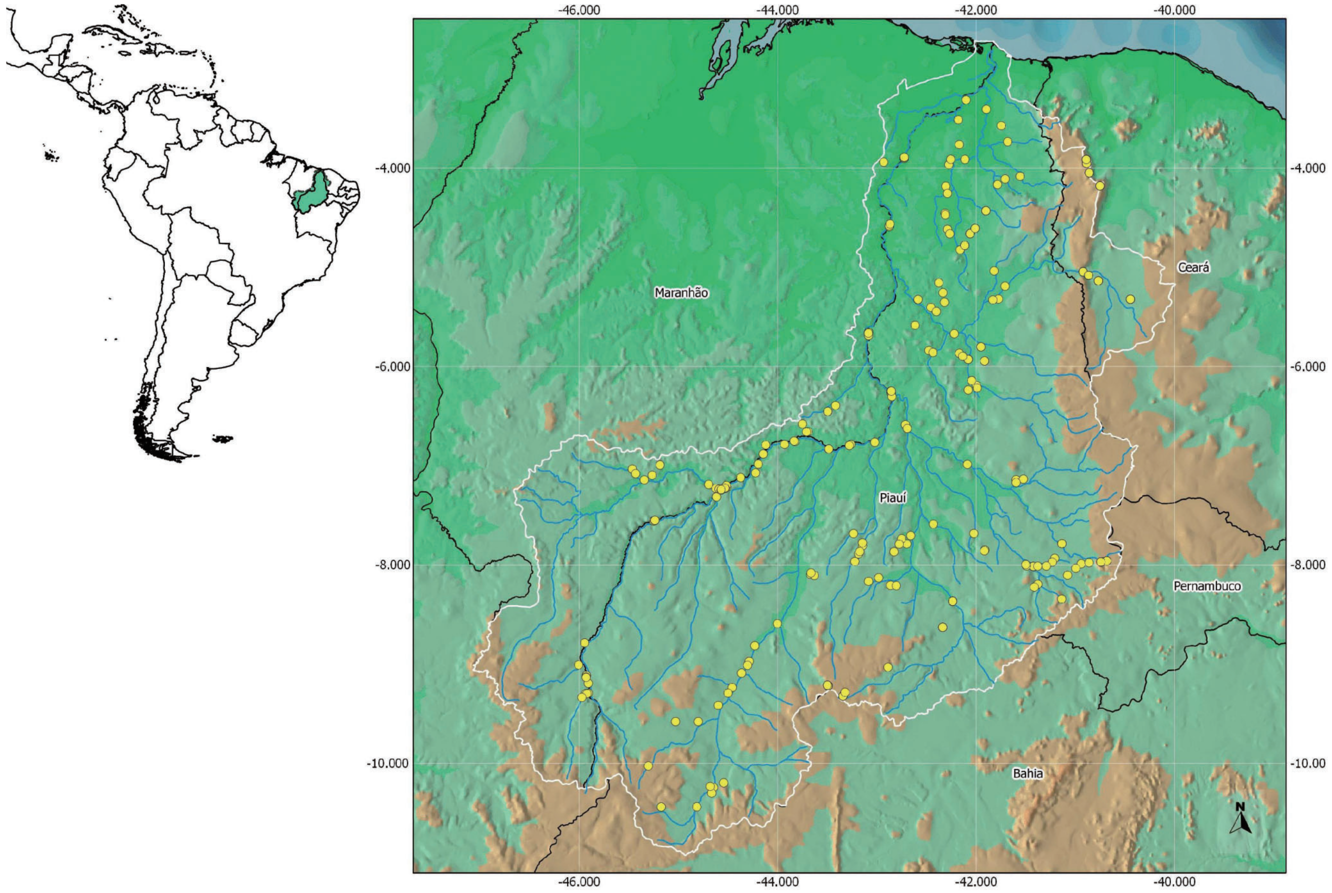

Figure 1. Map of the Parnaíba River basin showing the geographical location of the study's sampling sites (see Sample Design). The marks on the map may represent more than one collection site.

Parnaíba river are: the Balsas River (Maranhão side); Poti and Portinho Rivers (Piauí side, with headwaters in Ceará State); Caninde, Piauí, Gurguéia, and Longá Rivers running exclusively in Piauí State. The Parnaíba River has a perennial regime, despite of intermittent tributaries, and represents the transition zone between the Caatinga's semi-arid land in the east area of the basin, and the more humid climate of Cerrado, in the west (Rosa et al. 2003, Ramos 2012).

2. *Sampling Design*

The sampling design of this study was based on the establishment of (1) Fixed Sites for seasonal collection (nine groups of three sites, totalizing 27 collection sites, dry and wet season, from 2009 to 2011), restricted to the main course of the river through its three sections: high, medium and low regions; and (2) AquaRap collections performed between 2004 and 2011, which covered the entire basin. The collection effort conducted in this study consisted in 244 sampling sites along the entire river basin (Figure 1). As a freshwater fish study, it has excluded the area of the basin under marine influence. Additionally, reliable data from the literature were also considered for the compilation of the present list.

3. *Collection and identification of specimens*

Fishes were collected with seines (seines 20m long, 2.5m high, mesh size 10mm; seines 4m long, 2m height, mesh size 5mm), castnets (2m height, mesh size 15mm), gillnets of various mesh sizes (15, 25, 35, 45 and 55mm), and dip nets (mesh size 5 and 10mm). The ichthyological material obtained in the samples was fixed in the field into a 10% formalin solution neutralized with sodium tetraborate. Some specimens were photographed alive in order to obtain records of natural coloration. Specimens were treated according to the rules of scientific curation following Malabarba & Reis (1987). Sorting and identification of specimens were carried out at the Laboratório de Sistemática e Morfologia de Peixes of Universidade Federal da Paraíba. This ichthyological material was deposited into the Ichthyological Collection of the Departamento de Sistemática e Ecologia of the same university.

Meristic and morphometric data were taken according to Hubbs & Lagler (2006). The systematic list follows Nelson (2006).

Results and Discussion

1. *Ichthyofauna*

This study recorded 146 species of freshwater fish in the Parnaíba River basin, belonging to 103 genera, 36 families and 11 orders (Table 1). The number of 146 species recorded in the present work exceeds by more than 40 the assumption of the richness of the Parnaíba River freshwater fish fauna by Abell et al. (2008), who proposed between 67 and 101 species, this being the largest number of supposed species found in the basin, among the propositions reported in the literature.

The order of fish with the greatest number of species occurring in the Parnaíba River basin was Characiformes, with 59 species, representing 40% of the recorded species. The species of the order Characiformes are distributed in 40 genera and 12 families. The second more representative order was Siluriformes, with 48 species in 30 genera and 8 families, representing 33% of the species (Figure 2). The families with the

Table 1. List of species of freshwater fish of the Parnaíba River basin analyzed on this study: (E) Endemic Species; (I) Introduced species; (L) record from the literature (not confirmed by this study – literature source: [1] Reis et al., 2003; [2] Rosa et al. (2003); [3] Buckup et al., 2007); (NR) New Record.)

- **ORDER MYLIOBATIFORMES**
  - **Family Potamotrygonidae**
    - *Potamotrygon signata* Garman, 1913(E)
    - *Potamotrygon orbignyi* (Castelnau, 1855)(NR)
- **ORDER OSTEOGLOSSIFORMES**
  - **Family Osteoglossidae**
    - *Arapaima gigas* (Cuvier, 1829)(I)
- **ORDER CLUPEIFORMES**
  - **Family Pristigasteridae**
    - *Pellona flavipinnis* (Valenciennes, 1836)
  - **Family Engraulidae**
    - *Anchovia surinamensis* (Bleeker, 1865)
    - *Anchoviella guianensis* (Eigenmann, 1912)(NR)
    - *Anchoviella lepidentostole* (Fowler, 1911)(NR)
    - *Pterengraulis atherinoides* Schultz, 1949
    - *Lycengraulis batesii* (Günther, 1868)
- **ORDER CHARACIFORMES**
  - **Family Parodontidae**
    - *Apareiodon* sp.
    - *Apareiodon davisi* Fowler, 1941(NR)
    - *Apareiodon machrisi* (Travassos, 1957)
  - **Family Curimatidae**
    - *Curimatella immaculata* (Fernández-Yépez, 1948)(NR)
    - *Curimata macrops* (Eigenmann & Eigenmann, 1889)(E)
    - *Psectrogaster rhomboides* Eigenmann & Eigenmann, 1889
    - *Steindachnerina notonota* (Miranda Ribeiro, 1937)
  - **Family Prochilodontidae**
    - *Prochilodus lacustris* Steindachner, 1907(E)
  - **Family Anostomidae**
    - *Leporinus friderici* (Bloch, 1794)
    - *Leporinus obtusidens* Valenciennes, 1836(NR)
    - *Leporinus piau* Lutken, 1875
    - *Leporinus reinhardti* Lütken, 1875(NR)
    - *Schizodon knerii* (Steindachner, 1875)(NR)
    - *Schizodon rostratus* (Borodin, 1931)(E)
    - *Schizodon dissimilis* (Garman, 1890)(E)
  - **Family Chilodontidae**
    - *Caenotropus labyrinthicus* (Kner, 1858)
  - **Famíilia Crenuchidae**
    - *Characidium* cf. *bahiense* Almeida, 1971(NR)
    - *Characidium bimaculatum* Fowler, 1941
    - *Characidium zebra* Eigenmann, 1909(NR)
    - *Characidium* sp.1
    - *Characidium* sp.2
  - **Family Hemiodontidae**
    - *Hemiodus parnaguae* Eigenmann & Henn, 1916(E)
  - **Family Characidae**
    - *Astyanax* aff. *bimaculatus* (Linnaeus 1758)
    - *Astyanax* aff. *fasciatus* (Cuvier 1819)
    - *Bryconops* cf. *melanurus* (Bloch, 1794)
    - *Bryconamericus* sp.
    - *Ctenobrycon hauxwellianus* (Cope, 1870)(L2)
    - *Creagrutus*(NR) sp.
    - *Hemigrammus marginatus* Ellis, 1911(NR)

Continued on next page

Table 1. Continued.

Hemigrammus sp.
Hyphessobrycon sp. 1
Hyphessobrycon sp. 2
Gymnocorymbus thayeri Eigenmann, 1908(L2)
Jupiaba polylepis (Günther, 1864)(NR)
Knodus victoriae (Steindachner, 1907)(E)
Moenkhausia sp.
Moenkhausia lepidura (Kner, 1858) (L2)
Moenkhausia sanctaefilomenae (Steindachner, 1907)
Psellogrammus kennedyi (Eigenmann, 1903)(NR)
Phenacogaster calverti (Fowler, 1941)
Roeboides margareteae Lucena, 2003(E)
Roeboides sazimai Lucena, 2007(E)
Brachychalcinus parnaibae Reis, 1989(E)
Poptella compressa (Günther, 1864)
Tetragonopterus argenteus Cuvier, 1816
Compsura heterura Eigenmann, 1915
Serrapinnus heterodon (Eigenmann, 1915)
Serrapinnus piaba (Lütken, 1875)
Serrapinnus sp.
Family Serrasalmidae
Colossoma macropomum (Cuvier, 1816)(I)
Metynnis lippincottianus (Cope, 1870)
Myleus asterias (Müller & Troschel, 1844)
Mylossoma aureum (Agassiz, 1829)(L2)
Pygocentrus nattereri Kner, 1858
Serrasalmus rhombeus Lütken, 1875
Family Triportheidae
Triportheus signatus (Garman 1890)
Family Acestrorhynchidae
Acestrorhynchus falcatus (Bloch, 1794)
Family Erythrinidae
Hoplerythrinus unitaeniatus (Spix & Agassiz, 1829)
Hoplias malabaricus (Bloch, 1794)
ORDER SILURIFORMES
Family Trichomycteridae
Ituglanis(NR)sp.
Family Callichthyidae
Callichthys callichthys (Linnaeus, 1758)
Hoplosternum littorale (Hancock, 1828)
Aspidoras raimundi (Steindachner, 1907)(E)
Corydoras julii Steindachner, 1906
Corydoras treitlii Steindachner, 1906(E)
Corydoras vittatus Nijssen, 1971
Family Loricariidae
Otocinclus hasemani Steindachner, 1915
Parotocinclus cearensis Garavello, 1977(NR)
Parotocinclus haroldoi Garavello, 1988(E)
Parotocinclus sp.
Limatulichthys griseus Eigenmann, 1909(L1,3)
Loricaria parnahybae Steindachner, 1907
Loricaria sp.
Loricariichthys derbyi Fowler, 1915
Rineloricaria(NR) sp.
Ancistrus damasceni (Steindachner, 1907)(E)
Ancistrus sp.1
Ancistrus sp.2
Hypostomus johnii (Steindachner, 1877)(E)

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Table 1. Continued.

Hypostomus sp. 1
Hypostomus sp. 2
Hypostomus sp. 3
Hypostomus sp. 4
Pterygoplichthys parnaibae (Weber, 1991)(E)
Family Aspredinidae
Aspredo aspredo (Linnaeus, 1758)
Family Heptapteridae
Imparfinis(NR)sp.
Pimelodella parnahybae Fowler, 1941(E)
Pimelodella cf. *steindachneri* Eigenmann, 1917
Phenacorhamdia(NR)sp.
Rhamdia quelen (Quoy & Gaimard, 1824)
Family Doradidae
Hassar affinis (Steindachner, 1881)(E)
Platydoras brachylecis Piorski, Garavello, Arce H. & Sabaj Pérez, 2008
Family Auchenipteridae
Ageneiosus inermis (Linnaeus, 1766)
Ageneiosus sp.
Auchenipterus menezesi Ferraris & Vari, 1999(E)
Trachelyopterus galeatus (Linnaeus, 1766)
Family Pimelodidae
Brachyplatystoma filamentosum (Lichtenstein, 1819)
Brachyplatystoma vaillantii (Valenciennes, 1840)
Hemisorubim platyrhynchos (Valenciennes, 1840)
Hypophthalmus cf. *edentatus* Spix & Agassiz, 1829(NR)
Pimelodus blochii Valenciennes, 1840
Pimelodus maculatus La Cepède, 1803
Pimelodus ornatus Kner, 1858
Pimelodus sp. 1
Pimelodus sp. 2
Pseudoplatystoma fasciatum (Linnaeus, 1766)
Sorubim lima (Bloch & Schneider, 1801)
ORDER GYMNOTIFORMES
Family Gymnotidae
Gymnotus carapo Linnaeus, 1758
Family Hypopomidae
Brachypopomus(NR) sp.
Family Rhamphichthyidae
Rhamphichthys marmoratus Castelnau 1855(NR)
Family Sternopygidae
Eigenmannia macrops (Boulenger 1897)(NR)
Eigenmannia virescens (Valenciennes, 1842)
Sternopygus macrurus (Bloch & Schneider, 1801)
Family Apteronotidae
Apteronotus sp.
ORDER BELONIFORMES
Family Belonidae
Pseudotylosurus microps (Günther, 1866)
ORDER CYPRINODONTIFORMES
Family Rivulidae
Cynolebias parnaibensis Costa, Ramos, Alexandre & Ramos, 2010(E)
Hypsolebias coamazonicus Costa, Amorim & Bragança, 2013(E.)
Pituna schindleri Costa, 2007(E)
Melanorivulus parnaibensis (Costa, 2003)(E)

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Table 1. Continued.

Family Poeciliidae
Pamphorichthys hollandi (Henn, 1916)
Poecilia reticulata Peters, 1859$^{(I)}$
Poecilia sarrafae Bragança & Costa, 2011$^{(E)}$
Poecilia vivipara Bloch & Schneider 1801$^{(NR)}$
ORDER SYNBRANCHIFORMES
Family Synbranchidae
- *Synbranchus marmoratus* Bloch, 1795

ORDER PERCIFORMES
Family Sciaenidae
Plagioscion squamosissimus (Heckel, 1840)
Family Cichlidae
- *Aequidens tetramerus* (Heckel, 1840)
- *Apistogramma piauiensis* Kullander, 1980$^{(E)}$
- *Astronotus ocellatus* (Agassiz, 1831)$^{(I)}$
- *Cichla monoculus* Spix & Agassiz, 1831$^{(I)}$
- *Cichlasoma orientale* Kullander, 1983$^{(NR)}$
- *Cichlasoma sanctifranciscense* Kullander, 1983

Crenicichla menezesi Ploeg 1991
Geophagus parnaibae Staeck & Schindler, 2006$^{(E)}$
Tilapia rendalli (Boulenger, 1896)$^{(I)}$
Oreochromis niloticus (Linnaeus 1758)$^{(I)}$
Satanoperca jurupari (Heckel, 1840)$^{(NR)}$
ORDER PLEURONECTIFORMES
Family Achiridae
Trinectes cf. *paulistanus* (Miranda Ribeiro, 1915)$^{(NR)}$

highest number of species was Characidae, with 27 species, representing 18% of the species, followed by Loricariidae, with 18 species (12%), Cichlidae and Pimelodidae, with 11 (8%) species each (Figure 3). This result is in agreement with previous studies conducted on Northeastern region of Brazil (Rosa et al., 2003, Ramos et al. 2005), but also when considered the whole Brazil (Buckup et al. 2007) or the Neotropical region (Reis et al. 2003). The presence of Pimelodidae among the four families with the largest number of species in the Parnaíba River basin follows the recorded pattern for the Caatinga, as stated by Rosa et al. (2003). This family is not registered within those with the largest number of species in the List of freshwater fish of Brazil (Buckup et al. 2007) and that of Neotropical region (Reis et al. 2003), corroborating this pattern as characteristic of the Caatinga biome. Fifteen families were represented with only one species.

Among the 146 species recorded in this study, 27 are new records for the basin, five are recorded only by the literature (not collected in this study), seven are introduced species, and other 27 are undescribed species. The 27 new records in the Parnaíba basin, cited above, may include undescribed species, but more study is necessary before sorting out which species are truly undescribed and which are already known. This is the case, for example, of the specimens preliminarily identified as *Characidium* cf. *bahiense*, referred to species whose occurrence is restricted to coastal rivers of Bahia State, and situated east of the São Francisco basin.

2. *Endemism*

Eigenmann (1910) has listed only 19 species of freshwater fish in the Parnaíba River; Menezes (1955) recorded 93 species.

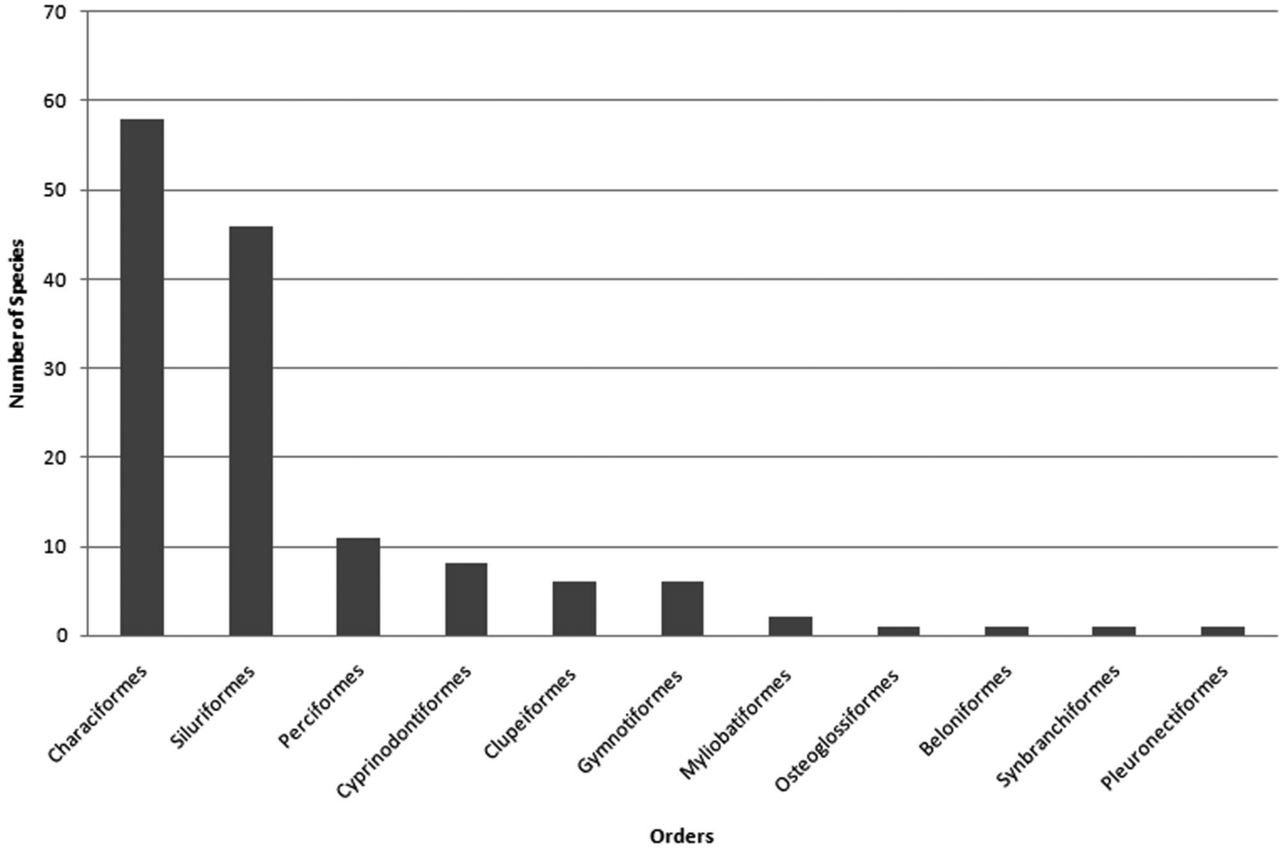

Figure 2. Number of species recorded by order in the Parnaíba River basin between 2004 and 2011.

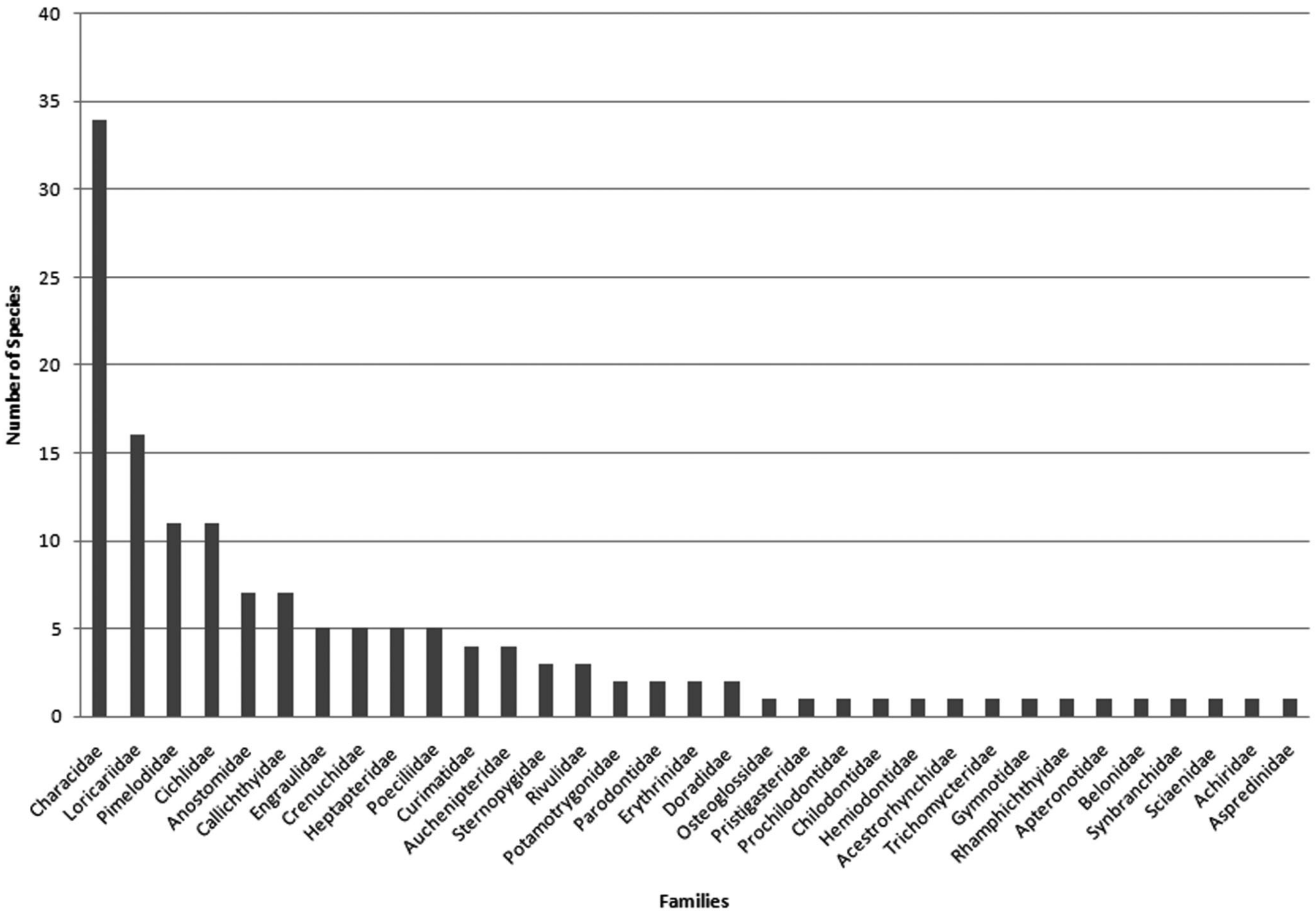

Figure 3. Number of species recorded per family in the Parnaíba River basin between 2004 and 2011.

According to Roberts (1968) and Paiva (1978) the fish fauna of the Parnaíba River would consist of 80 to 100 species, but with low level of endemism. Rosa et al. (2003) counted 86 species for the Maranhão-Piauí Region (which includes the Parnaíba basin) with 15 possible endemic species (17.5% of the fish fauna). Hubert & Renno (2006) considered the Parnaíba River basin as one of the 11 basins diagnosed as areas of endemism in South America, when analyzing the biogeographic history of the freshwater fishes of this region. According to the above cited authors the Parnaíba River basin would have a fish fauna consisting of 24 species, 8 endemic. Abell et al. (2008) consider the Parnaíba River basin as one of the 44 ecoregions of tropical South America and estimate the species richness of the basin between 67 and 101 and from 12 to 19 the number of endemic species (around 15 to 21%). Albert & Reis (2011) state that the species richness of the Parnaíba River would be around 95 species, 20 endemic. However, Pinna & Wosiacki (2003), stressed that the Parnaíba basin is poorly sampled and that the low level of endemism recorded in this basin at that time would be related to the restricted number of samples, especially in the upper portion of the basin.

The authors above mentioned, who worked during the second half of the 20th century and in the 21st century, registered between 67-101 species in the Parnaíba River basin, a number notably beneath that recorded in this study, 146 species. Over the past decade, new species endemic to the Parnaíba basin have been described: *Roeboides margareteae* Lucena 2003, *Melanorivulus parnaibensis* (Costa 2003), *Geophagus parnaibae* Staeck & Schindler 2006, *Pituna schindleri* Costa 2007, *Roeboides sazimai* Lucena 2007, *Platydoras brachylecis* Piorski, Garavello, Arce H. & Sabaj Pérez, 2008, *Cynolebias parnaibensis* Costa, Ramos, Alexandre & Ramos, 2010, *Poecilia sarrafae* Bragança & Costa 2011 e *Hypsolebias coamazonicus* Costa, Amorim & Bragança, 2013. Adding these taxa to those 27 undescribed taxa detected in the present study, the record of endemism in Parnaíba River basin is increased by 36 species. The endemism data referred by Rosa et al. (2003) and distribution by Reis et al. (2003) and Buckup et al. (2007), together with those registered in the present study increase the number of freshwater fish species endemic to the Parnaíba basin to 54 species, 34 more than the highest number of endemic species previously proposed as occurring in the Parnaíba basin (20 species, Albert & Reis, 2011). The 54 endemic species represent 38.9% of the 139 native species diagnosed in the present work. Again, it is necessary to emphasize that the headwaters of this basin were not yet thoroughly sampled.

3. *Final Remarks*

The present study is the most comprehensive survey from the Parnaíba River to date and considerably increased our knowledge about its freshwater fish fauna. However, some gaps in the knowledge of this fish fauna still remain. First, the headwaters of the basin still need to be adequately surveyed. Also, more studies are necessary to understand the relationships of the species occurring in the Parnaíba River with species from other river systems, which depend on a better assessment of the taxonomy of several fish groups. The present study is an initial step towards a full account on the fish diversity of this biogeographically important river basin.

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References

ABELL, R.,THIEME, M.L.,REVENGA, C.,BRYER, M.,KOTTELAT, M.,BOGUTSKAYA, N.,COAD, B.,MANDRAK, N.,CONTRERAS BALDERAS, S., BUSSING, W.,STIASSNY, M.L. J.,SKELTON, P.,ALLEN, G.R.,UNMACK, P.,NASEKA, A.,NG, R.,SINDORF, N.,ROBERTSON, J.,ARMIJO, E.,HIGGINS, J.V.,HEIBEL, T.J.,WIKRAMANAYAKE, E.,OLSON, D.,LÓPEZ, H. L.,REIS, R. E.,LUNDBERG, J.G.,SABAJ PÉREZ, M. H., & PETRY, P. 2008. Freshwater ecoregions of the world: a new map of Biogeographic units for freshwater biodiversity conservation. Bioscience. 58(5):403-414. doi: http://dx.doi.org/10.1641/B580507

AGASSIZ, L. & AGASSIZ. E.C. 1975. Viagem ao Brasil: 1865-1866. Tradução de João Etienne Filho. Ed. da Universidade de São Paulo, São Paulo.

ALBERT, J.S. & REIS, R.E.2011. Historical Biogeography of Neotropical Freshwater Fishes.University of California Press. London. England, p.1- 406.

BARBOSA, J.M. 1981. Sobre a Ictiofauna da bacia do rio Parnaíba. Boletim do Centro de Ciências da Natureza/UFPI, v. 2, n. 2, p. 78-82.

BRAGANÇA, P.H.N. & COSTA, W.J.E.M. 2011. *Poecilia sarrafae*, a new poeciliid species from Parnaíba and Mearim river basins, northeastern Brazil (Cyprinodontiformes: Cyprinodontoidei). Ichthyological Exploration of Freshwaters, v. 21, p. 369-376.

BUCKUP, P.A., MENEZES, N.A. &GHAZZI, M.S. 2007.Catálogo das Espécies de Peixes de Água Doce do Brasil. Rio de Janeiro: Museu Nacional. p.1-195.

COSTA, W.J.E.M. 2003. A new species of the genus *Rivulus* Poey, 1860 from the Parnaiba river basin, northeastern Brazil (Teleostei, Cyprinodontiformes, Rivulidae). Boletim do Museu Nacional, Rio de Janeiro, 511:1-7.

COSTA, W.J.E.M. 2007.Taxonomy of the plesiolebiasine killifish genera *Pituna*, *Plesiolebias* and *Maratecoara* (Teleostei: Cyprinodontiformes: Rivulidae), with descriptions of nine new species., Zootaxa (1410), pp. 1-41:13-16

COSTA, W.J.E.M., RAMOS, T.P.A., ALEXANDRE, L.C. &RAMOS, R.T.C.2010. *Cynolebias parnaibensis*, a new seasonal killifish from the Caatinga, Parnaíba river basin, northeastern Brazil, with notes on sound producing courtship behavior (Cyprinodontiformes: Rivulidae). Neotropical Ichthyology, v. 8, p. 283-288. doi: http://dx.doi.org/10.1590/S1679-62252010000200006

EIGENMANN, C.H. 1910. Catalogue of the fresh water fishes of tropical and south temperate America. Rep. Princeton Univ. Exped. Patagonia., Princeton, 3(2):375-511.

FONTENELE, O. & FARIAS, J.O. 1979. Efeitos da barragem Boa Esperança (Guadalupe, Piauí) sobre a Ictiofauna do rio Parnaíba. Bol. Tec, DNOCS, Fortaleza, 37(1):23-29.

FOWLER, H.W. 1941.A collection of fresh-water fishes obtained in eastern Brazil by Dr. Rodolpho von Ihering. Proceedings of The Academy of Natural Sciencies of Philadelphia. V. 93, p.123.199.

FOWLER, H.W. 1954. Os peixes de água doce do Brasil. Arq. Zool. Estado São Paulo. São Paulo. v.6, 4a, p.1-400.

HUBBS, C.L. & LAGLER, K.F. 2006.Fishes of the Great Lakes region. Ann Arbor: University of Michigan Press. p.1-213.

HUBERT, N. & RENNO, J.F. 2006. Historical biogeography of South American freshwater fishes. J. Biogeogr., v. 33, p. 1414-1436. doi: http://dx.doi.org/10.1111/j.1365-2699.2006.01518.x

LUCENA, C.A.S. 2003. Revisão taxonômica e relações filogenéticas das espécies de *Roeboides* grupo-*microlepis* (Ostariophysi Characiformes, Characidae). Ilheringia, Série Zoologia. 93(3):283-308. doi: http://dx.doi.org/10.1590/S0073-47212003000300008

LUCENA, C.A.S. 2007. Revisão taxonômica das espécies do gênero *Roeboides* grupo-*affinis* (Ostariophysi, Characiformes, Characidae). Iheringia. Série Zoologia, v. 97, p. 117-136. doi: http://dx.doi.org/10.1590/S0073-47212007000200001

MALABARBA, L.R. & REIS, R.E. 1987. Manual de técnicas para a preparação de coleções zoológicas. Sociedade Brasileira de Zoologia, Campinas, v. 36, p. 1-14.

MENEZES, R.S. 1955. Lista de peixes de água doce do Piauí. *In:* PORTO, C. E. - Roteiro do Piauí. Ministério da Educação e Cultura. Ilus., Rio de Janeiro, 188 p.

MENEZES, R.S. 1964. A Pesca e os Peixes da Bacia do rio Parnaíba, Piauí. Chacaras e Quintais. São Paulo, 110(5):747-752.

MENEZES, R.S. 1973. Recursos pesqueiros da bacia do rio Parnaíba (Maranhão – Piauí). Bol. Tec. DNOCS. Fortaleza, 31(1):51-94.

NELSON, J.S.Fishes of the world. 4 ed. Edmonton, Canadá: John Wiley & Sons, Inc, 2006. 622p.

PAIVA, M.P. 1973. Recursos pesqueiros e pesca na bacia do rio Parnaíba (Brasil). Bol. Cear. Agron. Fortaleza, 14: p.49-82.

PAIVA, M.P. 1976. A pesca na represa de boa Esperança. Revista Brasileira de Energia Elétrica, Rio de Janeiro, (33): p.49-56.

PAIVA, M.P. 1978. A ictiofauna das Grandes Represas Brasileiras. Revista DAE116: p. 49-57.

PINNA, M.C.C. de, & WOSIACKI.W. 2003. Family Trichomycteridae (Pencil or parasitic catfishes).*In*: Check List of the Freshwater Fishes of South and Central America, R. E. REIS, S. O. KULLANDER, e C. J. FERRARIS, Jr. (eds.), Porto Alegre: Edipucrs. Porto Alegre, p. 270–290.

PIORSKI, N.M., GARAVELLO, J.C., ARCE, H.M., & PÉREZ, M.H.S. 2008. *Platydoras brachylecis*, a new species of thorny catfish (Siluriformes: Doradidae) from northeastern Brazil. Neotropical Ichthyology, 6(3):481-494. doi: http://dx.doi.org/10.1590/S1679-62252008000300021

RAMOS, R.T.C., RAMOS, T.P.A., ROSA, R.S., BELTRÃO, G.B.M. & GROTH, F. 2005. Diversidade de Peixes (Ictiofauna) da bacia do rio Curimataú, Paraíba. *In*: ARAUJO, F.S., RODAL, M.J.N. &BARBOSA, M.R.V. Análise das variações da biodiversidade do bioma caatinga: suporte das estratégias regionais de conservação. Brasília: Ministério do Meio Ambiente, p. 291-318.

RAMOS, T.P.A. 2012. Ictiofauna de Água Doce da Bacia do Rio Parnaíba. Tese de Doutorado. Universidade Federal da Paraíba, João Pessoa.

REIS, R.E., KULLANDER, S.O., FERRARIS, J. & CARL, J. 2003. Check List of the freshwater fishes of South and Central America. Porto Alegre: EDIPUCRS. P.1-729.

ROBERTS, T.R. 1968. The fishes of the Rio Parnaíba. Fortaleza, p.10.

ROSA, R.S., MENEZES, N.A., BRITSKI, H.A., COSTA, W.J.E.M. & GROTH, F. 2003. Diversidade, padrões de distribuição e conservação dos peixes da Caatinga. *In*: LEAL, I.R., TABARELLI, M. &SILVA, J.M.C. Ecologia e Conservação da Caatinga. Recife: Editora Universitária da UFPE. p.135-162.

SEMAR-PI; SRH/MMA. 2008 - Secretária do Meio Ambiente e Recursos Hídricos do Piauí. Secretária de Recursos Hídricos do Ministério do Meio Ambiente Caderno Regional – Região Hidrográfica Parnaíba. Resumo Executivo. Piauí. 110 p.

SOARES, R.R. 1987. Dados preliminares sobre a composição da ictiofauna da bacia do rio Parnaíba. *In*: Anais da Sociedade Nordestina1: p.167-171.

STAECK, W. & SCHINDLER, I. 2006.*Geophagus parnaibae* sp. n. a new species of cichlid fish (Teleostei; Perciformes; Cichlidae) from the rio Parnaíba basin, Brazil. ZoologischeAbhandlungen Museum fürTierkunde Dresden. 55, p. 69-75.

VARI, R.P. 1989. Systematics of the Neotropical Characiform Genus *Psectrogaster* Eigenmann and Eigenmann (Pisces, Characiformes).Smithsonian Contributions to Zoology, 481: p.1-41. doi: http://dx.doi.org/10.5479/si.00810282.474

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Editorial

The conceptual framework of the Intergovernmental Platform on Biodiversity and Ecosystem Services/IPBES

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1. Human life would not be possible without biodiversity and ecosystems. The intervention in nature by human societies to meet their needs, however, has modified the composition, structure and functions of ecosystems and has caused detrimental changes that seriously threaten the long term sustainability of societies around the world. In many cases, biodiversity loss and poverty are trapped in a mutually reinforcing vicious circle. Overall, the efforts made on conservation and on the sustainable use of biodiversity and ecosystems have not kept pace with increasing human pressures. A stronger response by Governments, public organizations, communities, the private sector, households and individuals thus requires an improved understanding of such pressures and concerted action to change them.

2. The goal of the Intergovernmental Platform on Biodiversity and Ecosystem Services is to "strengthen the science-policy interface for biodiversity and ecosystem services for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development". To achieve this goal, the Platform has four functions: to catalyse the generation of new knowledge; to produce assessments of existing knowledge; to support policy formulation and implementation; and to build capacities relevant to achieving its goal. These interconnected functions are realized in the Platform work programme. A conceptual framework for biodiversity and ecosystems services is required to support the analytical work of the Platform, to guide the development, implementation and evolution of its work programme, and to catalyse a positive transformation in the elements and interlinkages that are the causes of detrimental changes in biodiversity and ecosystems and subsequent loss of their benefits to present and future generations.

3. The conceptual framework (diagram presented in the cover of this issue) is a highly simplified model of the complex interactions between the natural world and human societies. The model identifies the main elements, together with their interactions, that are most relevant to the Platform's goal and should therefore be the focus for assessments and knowledge generation to inform policy and the required capacity building. The Platform recognizes and considers different knowledge systems, including indigenous and local knowledge systems, which can be complementary to science-based models and can reinforce the delivery of the functions of the Platform. In this sense, the conceptual framework is a tool for the achievement of a shared working understanding across different disciplines, knowledge systems and stakeholders that are expected to be active participants in the Platform. A full alignment between the categories of different knowledge systems or even disciplines is probably unattainable. The Platform's conceptual framework is intended, however, to be a basic common ground, general and inclusive, for coordinated action towards the achievement of the ultimate goal of the Platform. Within these broad and transcultural categories, different Platform activities may identify more specific subcategories associated with knowledge systems and disciplines relevant to the task at hand, without losing view of their placement within the general conceptual framework.

4. The Platform's conceptual framework includes six interlinked elements constituting a social ecological system that operates at various scales in time and space: nature; nature's benefits to people; anthropogenic assets; institutions and governance systems and other indirect drivers of change; direct drivers of change; and good quality of life.

5. "Nature" in the context of the Platform refers to the natural world with an emphasis on biodiversity. Within the context of science, it includes categories such as biodiversity, ecosystems, ecosystem functioning, evolution, the biosphere, humankind's shared evolutionary heritage, and biocultural diversity. Within the context of other knowledge systems, it includes categories such as Mother Earth and systems of life. Other components of nature, such as deep aquifers, mineral and fossil reserves, wind, solar, geothermal and wave power, are not the focus of the Platform. Nature contributes to societies through the provision of benefits to people (instrumental and relational values, see below) and has its own intrinsic values, that is, the value inherent to nature, independent of human experience and evaluation and thus beyond the scope of anthropocentric valuation approaches.

6. "Anthropogenic assets" refers to built-up infrastructure, health facilities, knowledge (including indigenous and local knowledge systems and technical or scientific knowledge, as well as formal and non formal education), technology (both physical objects and procedures), and financial assets, among others. Anthropogenic assets have been highlighted to emphasize that a good life is achieved by a co production of benefits between nature and societies.

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7. "Nature's benefits to people" refers to all the benefits that humanity obtains from nature. Ecosystem goods and services, considered separately or in bundles, are included in this category. Within other knowledge systems, nature's gifts and similar concepts refer to the benefits of nature from which people derive a good quality of life. Aspects of nature that can be negative to people, such as pests, pathogens or predators, are also included in this broad category. All nature's benefits have anthropocentric value, including instrumental values – the direct and indirect contributions of ecosystem services to a good quality of life, which can be conceived in terms of preference satisfaction, and relational values, which contribute to desirable relationships, such as those among people and between people and nature, as in the notion of "living in harmony with nature".

8. Anthropocentric values can be expressed in diverse ways. They can be material or non-material, can be experienced in a non-consumptive way, or consumed; and they can be expressed from spiritual inspiration to market value. They also include existential value (the satisfaction obtained from knowing that nature continues to be there) and future-oriented values. The latter include bequest value – in other words, the preservation of nature for future generations – or the option values of biodiversity as a reservoir of yet-to-be discovered uses from known and still unknown species and biological processes, or as a constant source, through evolutionary processes, of novel biological solutions to the challenges of a changing environment. Nature provides a number of benefits to people directly without the intervention of society, for example the production of oxygen and the regulation of the Earth's temperature by photosynthetic organisms; the regulation of the quantity and quality of water resources by vegetation; coastal protection by coral reefs and mangroves; and the direct provision of food or medicines by wild animals, plants and microorganisms.

9. Many benefits, however, depend on or can be enhanced by the joint contribution of nature and anthropogenic assets. For example, some agricultural goods such as food or fibre crops depend on ecosystem processes such as soil formation, nutrient cycling, or primary production as well as on social intervention such as farm labour, knowledge of genetic variety selection and farming techniques, machinery, storage facilities and transportation.

10. Trade-offs between the beneficial and detrimental effects of organisms and ecosystems are not unusual and they need to be understood within the context of the bundles of multiple effects provided by them within specific contexts. For example, wetland ecosystems provide water purification and flood regulation but they can also be a source of vector-borne disease. In addition, the relative contribution of nature and anthropogenic assets to a good quality of life varies according to the context. For example, the level at which water filtration by the vegetation and soils of watersheds contributes to quality of life in the form of improved health or reduced treatment costs is based in part on the availability of water filtration by other means, for example treating water in a built facility. If there are no alternatives to watershed filtration by vegetation, then it will contribute strongly to good lives. If there are cost-effective and affordable alternatives, water filtration by vegetation may contribute less.

11. "Drivers of change" refers to all those external factors that affect nature, anthropogenic assets, nature's benefits to people and a good quality of life. They include institutions and governance systems and other indirect drivers and direct drivers (both natural and anthropogenic).

12. "Institutions and governance systems and other indirect drivers" are the ways in which societies organize themselves, and the resulting influences on other components. They are the underlying causes of environmental change that are exogenous to the ecosystem in question. Because of their central role, influencing all aspects of human relationships with nature, these are key levers for decision-making. Institutions encompass all formal and informal interactions among stakeholders and social structures that determine how decisions are taken and implemented, how power is exercised, and how responsibilities are distributed. Institutions determine, to various degrees, the access to, and the control, allocation and distribution of components of nature and anthropogenic assets and their benefits to people. Examples of institutions are systems of property and access rights to land (e.g., public, common-pool, private), legislative arrangements, treaties, informal social norms and rules, including those emerging from indigenous and local knowledge systems, and international regimes such as agreements against stratospheric ozone depletion or the protection of endangered species of wild fauna and flora. Economic policies, including macroeconomic, fiscal, monetary or agricultural policies, play a significant role in influencing people's decisions and behaviour and the way in which they relate to nature in the pursuit of benefits. Many drivers of human behaviour and preferences, however, which reflect different perspectives on a good quality of life, work largely outside the market system.

13. "Direct drivers", both natural and anthropogenic, affect nature directly. "Natural drivers" are those that are not the result of human activities and are beyond human control. These include earthquakes, volcanic eruptions and tsunamis, extreme weather or ocean-related events such as prolonged drought or cold periods, tropical cyclones and floods, the El Niño/La Niña Southern Oscillation and extreme tidal events. The direct anthropogenic drivers are those that are the result of human decisions, namely, of institutions and governance systems and other indirect drivers. Anthropogenic drivers include habitat conversion, e.g., degradation of land and aquatic habitats, deforestation and afforestation, exploitation of wild populations, climate change, pollution of soil, water and air and species introductions. Some of these drivers, such as pollution, can have negative impacts on nature; others, as in the case of habitat restoration, or the introduction of a natural enemy to combat invasive species, can have positive effects.

14. “Good quality of life” is the achievement of a fulfilled human life, a notion which varies strongly across different societies and groups within societies. It is a context-dependent state of individuals and human groups, comprising access to food, water, energy and livelihood security, and also health, good social relationships and equity, security, cultural identity, and freedom of choice and action. From virtually all standpoints, a good quality of life is multidimensional, having material as well as immaterial and spiritual components. What a good quality of life entails, however, is highly dependent on place, time and culture, with different societies espousing different views of their relationships with nature and placing different levels of importance on collective versus individual rights, the material versus the spiritual domain, intrinsic versus instrumental values, and the present time versus the past or the future. The concept of human well-being used in many western societies and its variants, together with those of living in harmony with nature and living well in balance and harmony with Mother Earth, are examples of different perspectives on a good quality of life.

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article

Geographic distribution patterns of Leguminosae and their relevance for the conservation of the Itacolomi State Park, Minas Gerais, Brazil

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Abstract: This study identified patterns of geographic distribution of 102 Leguminosae taxa within the Park, based on literature data and herbarium specimens. Among the taxa, 38 grow exclusively in *Campos Rupestres* (rocky fields) and 49 in the Semideciduous Forest. Eleven patterns of geographic distribution were identified, of which the West-East- Central South America pattern was the most representative, with 27 taxa. Of the 102 sampled taxa of Leguminosae, five are endemic to the Espinhaço Range and ten are included in lists of endangered species of the flora of Brazil and Minas Gerais. Information on these taxa is crucial to provide conservation practices for conserving the vegetation formations of the PEIT.

Keywords: Atlantic Forest, Espinhaço Range, Fabaceae, rocky fields, Semideciduous Forest

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Resumo: Neste estudo foram identificados os padrões de distribuição geográfica dos 102 táxons de Leguminosae ocorrentes no PEIT, com base nos dados obtidos na literatura e em material de herbário, sendo 38 exclusivos dos Campos Rupestres e 49 das Florestas Estacionais. Foram reconhecidos 11 padrões de distribuição geográfica, dos quais o padrão América do Sul Ocidental- Centro-Oriental foi o mais representativo com 27 táxons. Dos 102 táxons amostrados de Leguminosae, cinco são endêmicos da Cadeia do Espinhaço e 10 constam nas listas de espécies ameaçadas da flora brasileira ou da Flora de Minas Gerais, sendo consideradas importantes para fornecer subsídios na conservação das formações vegetacionais do PEIT.

Palavras-chave: Cadeia do Espinhaço, campos rupestres, Fabaceae, Florestas Estacionais, Mata Atlântica

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Introduction

Leguminosae is the third largest family of flowering plants, comprising 727 genera and 19.325 species (Lewis et al. 2005). The high ecological plasticity of the family allows its distribution in highly diverse habitats and this peculiar feature is determinant for its great diversity in neotropical vegetation types (Lima 2000). In Brazil, the family is represented by 212 genera and 2717 species (Lima et al. 2010a), distributed in almost all vegetation types (Barroso et al. 1991). Moreover, it has been identified as one of the most representative of flowering species in the *Campos Rupestres* (rocky fields), in the *Cerrado* (Brazilian savannas) and Tropical Forests (Giulietti & Pirani 1988, Mendonça et al. 1998, Ribeiro 1998, Pirani et al. 2003, Dutra et al. 2008a), highlighting its importance for the flora of Brazil.

In floristic surveys of biomes of the state of Minas Gerais, Leguminosae has also been considered one of the most representative flowering plant families, as reported for *Caatinga* (*e.g.* Brandão & Gavilanes 1994), *Cerrado* (*e.g.* Brandão & Gavilanes 1997), *Campos Rupestres* (Dutra et al. 2008a) and areas of Atlantic Forest (Oliveira-Filho et al. 1994). Information as this about the diversity of species, together with data on the presence of endemic, threatened and rare species, has been used to determine priority conservation areas in the State and to delimit areas which require the creation and implementation of Conservation Units (Drummond et al. 2005).

The Itacolomi State Park (PEIT) is located in the southern part of the Espinhaço Range, in the so-called *Quadrilátero Ferrífero* (Peron 1989), in a vegetation transition zone between the Atlantic Forest and the *Cerrado*, representing an important migratory corridor and consisting of gallery forests between the two formations (Oliveira-Filho & Ratter 1995).

The vegetation of the Espinhaço Range includes a series of altitudinal strata, with *Campos Rupestres* and cloud forests in the highest strata, *Cerrado* and Semideciduous Forests in the intermediary strata and a varied combination of vegetation types of the adjacent lowlands (Harley 1995). The geological antiquity, geographical position and climate fluctuations that occurred during the Quaternary and allowed a vertical migration of the flora from the lower regions, as well as the physiognomy variety are the main factors related to the high biodiversity of the Espinhaço Range (Giulietti et al . 2002, Gontijo 2008). The high species richness, high landscape diversity and high degree of endemism led to the recognition of the Espinhaço Range as one of the priority areas for conservation, with special biological importance, hence the area of the PEIT has great biological relevance (Drummond et al. 2005).

The aim of this study was to analyze the endemism and habitat preference of the Itacolomy State Park flora using the Leguminosae family as a model to characterize geographic distribution patterns of specific and/or infraspecific taxa. The patterns that emerged from the analysis were used to answer the following questions: (i) What is the influence of the surrounding vegetation on the flora of the PEIT? (ii) What are the implications of the findings for the conservation of the flora of the park?

Methods

The PEIT is located in the municipalities of Ouro Preto and Mariana, State of Minas Gerais, (between 20º22’30”and 20º30’00” S and 43°32’30”and 43º22’30” W) (Fig. 1), comprising the entire Itacolomi Range (Peron 1989). The Park encompasses an area of approximately 7000 ha. The relief is characterized by steep slopes and altitudes between 700 and 1772 m (Messias et al. 1997).

The regional climate is typically tropical, Cwa and Cwb, according to Koeppen’s classification, with two well-defined seasons: a dry season, from May to September, and a rainy season, from October to April. The annual rainfall is on average 2018 mm (Messias et al. 1997, Nalini Junior et al. 2006). Fog is frequent and the average annual temperature is 21 ºC (maximum 33 ºC, minimum 4 °C) (Messias et al. 1997).

The soils were formed by the weathering of parent material, mostly of quartzite and mica-schists of the Minas Supergroup, with latosols, where the topography is hilly, and lithosols where the relief is jagged (Messias et al. 1997).

The vegetation consists of Semideciduous Forest and *Campos Rupestres* (Messias & Sousa 2006, Fig. 2), varying with the soil, water availability, altitude and topography.

The Campos Rupestres practically cover the entire Park at elevations above 1000 m. They are characterized by the diversity of substrates formed by the exposure of various types of rocks, shallow, lithic, sandy, acidic and nutrient-poor soils with limited water and intense sun exposure (Giulietti & Pirani 1988, Meguro et al. 1994, Giulietti et al. 1997). The vegetation is formed by a well-developed herbaceous- shrub stratum and has a heterogeneous flora composed of many endemic species (Harley 1995, Mendonça et al. 1998).

The Semideciduous Forests that grow in highly seasonal parts of the tropics, with a severe and prolonged dry season, have mean annual precipitation below 1600 mm and 5–6 months of the year with less than 100 mm rainfall (Gentry 1995). Most species of these forests are deciduous, with 20-50% of the trees losing their leaves in the dry season (IBGE 2012). The Semideciduous Forest of the PEIT can be classified, by the altitudinal gradient, as submontane (300-700 m), lower highlands (700-1100m) and upper highlands (above 1100m) (Oliveira-Filho 2009).

The list of taxa used in this study was obtained from the floristic survey of the Leguminosae within the PEIT (Lima et al. 2007, Dutra et al. 2008b, 2008c, 2009, Lima et al. 2010c). The habit descriptions were according to Guedes-Bruni et al. (2002).

The mapping of the geographical distribution was based on the occurrence records of herbarium collections (BHCB, OUPR, RB, VIC) and specialized literature. The distribution patterns were adapted from Giulietti & Pirani (1988), Lima et al. (1997), Lima (2000) and Morim (2006): [1] Wide geographical distribution, which corresponds to the taxa that occur in Africa, Asia, Australasia, North America, Central America and South America; [2] South America, Central America and North America, taxa whose distribution is restricted to the Americas, from the United

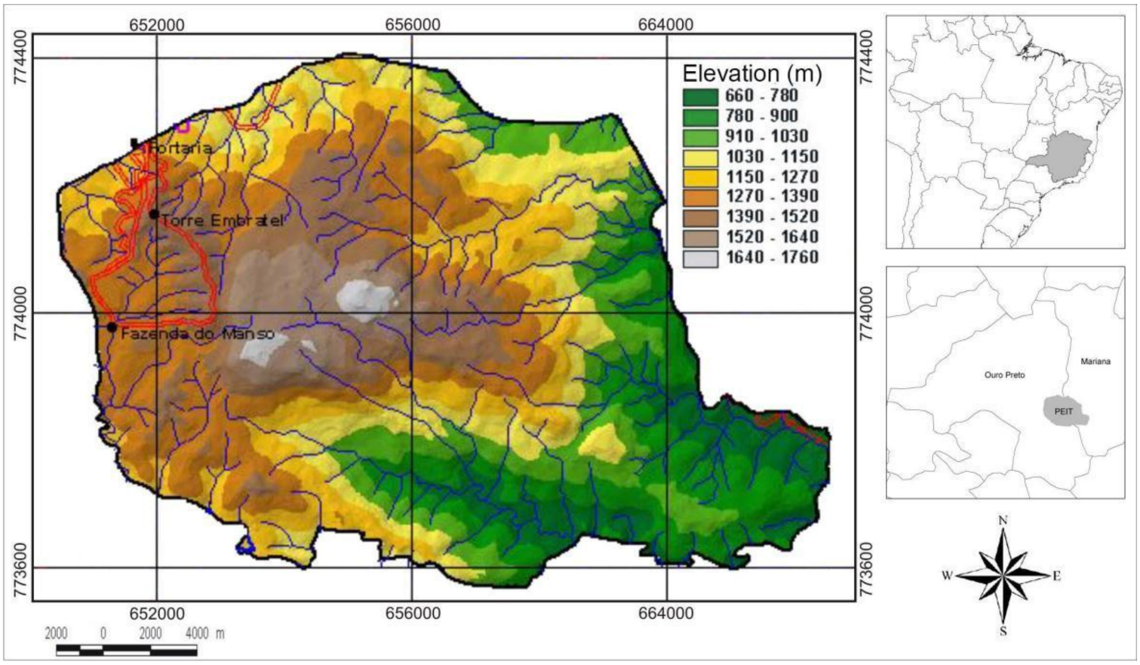

Figure 1. Location of the Itacolomi State Park.
Figura 1. Localização do Parque Estadual do Itacolomi.

States to southern Argentina; [3] Neotropical, taxa with a range of distribution in the tropics of South America, which can extend to Central America and Mexico; [4] West, Central and Eastern South America, taxa distributed across areas in the western, central and eastern South America, up to the far north of Venezuela, Suriname and Guyana; [5] Brazil-wide distribution, includes taxa widely distributed in all regions of Brazil; [6] Central-Eastern Brazil, taxa distributed in the midwest, northeast, southeast, and/or south of Brazil; [7] Atlantic-Northeast-Southeast-Southern Brazil, taxa that occur from the northeast to the south of Brazil; [8] Atlantic-Northeast-Southeastern Brazil, taxa with a range of distribution from northeast to southeastern Brazil; [9] Atlantic-Southeast- Southern Brazil, taxa distributed in the restricted range of the states of southeastern and southern Brazil; [10] Southeastern Brazil, taxa restricted to the states of Espírito Santo, Minas Gerais, Rio de Janeiro, and São Paulo; and [11] Espinhaço Range, taxa restricted to the highlands of the mountain range, in the states of Minas Gerais and Bahia.

The taxa were also classified as generalist or specialist species and according to habitat preference. The species exclusive to the Atlantic domain (which includes Rain Forest, Semideciduous and Deciduous Forests and Ombrophilous Mixed Forest) were considered specialist and those from other biomes, beyond the Atlantic area, such as the Amazon, *Cerrado* and/or *Caatinga*, were considered generalist. The classification of Veloso et al. (1991) modified by Oliveira-Filho (2009) was used for the determination of the taxon habitats. The term *domain* is used here according to Joly et al. (1999).

Maps of geographical taxa distribution representing each pattern were drawn based on information available in the literature and records from herbarium collections available at *species* (CRIA, 2013).

Results

The Leguminosae family in the Itacolomi State Park is represented by 102 specific and/or infraspecific taxa of 43 genera (Table 1). Papilionoideae was the subfamily with the largest number of taxa (48), followed by Mimosoideae (33) and Ceasalpinioideae (21) . One of the species found, *Trifolium repens*, is exotic and occurs sub-spontaneously in the PEIT.

The most representative genera were *Mimosa* L. (11 spp.), *Chamaecrista* Moench. (9 spp.) and *Inga* Mill. (9 spp.), the former two ones predominated in *Campos Rupestres* and the latter in the Semideciduous Forests of PEIT.

Of the sampled taxa, 38 were exclusive to the *Campos Rupestres* (elevation range of 1000−1540m), including *Andira surinamensis* (Bondt) Splitg. ex Pulle (Fig. 3a), *Chamaecrista dentata* (Vogel) H.S.Irwin & Barneby (Fig. 3b), *C. hedysaroides* (Vogel) H.S.Irwin & Barneby (Fig. 3b), *C. ochnacea* (Vogel) H.S.Irwin & Barneby var. *ochnacea* (Fig. 3c), *Mimosa montis-carasae* Barneby (Fig. 3c) and *M. ourobrancoënsis* Burkart (Fig. 3d).

Forty nine taxa were exclusive to Semideciduous Forests, including *Ormosia friburgensis* Taub. ex Harms (Fig. 3d), *Bionia bella* Mart. ex Benth. (Fig. 4a) and *Tachigali friburgensis* (Harms) L.G. Silva & H.C. Lima (Fig. 4a). Leguminosae were predominant in the submontane forests (elevation range of 620−700m) and less representative in lower highland and upper highland forests (elevation range of 700−1360m).

Fifteen taxa occurred in both vegetation types, such as *Crotalaria breviflora* DC. (Fig. 4b), *Abarema langsdorfii* (Benth.) Barneby & J.W.Grimes (Fig. 4c) and *Inga vulpina* Mart. ex Benth. (Fig. 4d).

Most of the identified taxa were trees (35%), followed by shrubs (31.5%), herbs (11.8%), lianas (9.9%) and vines

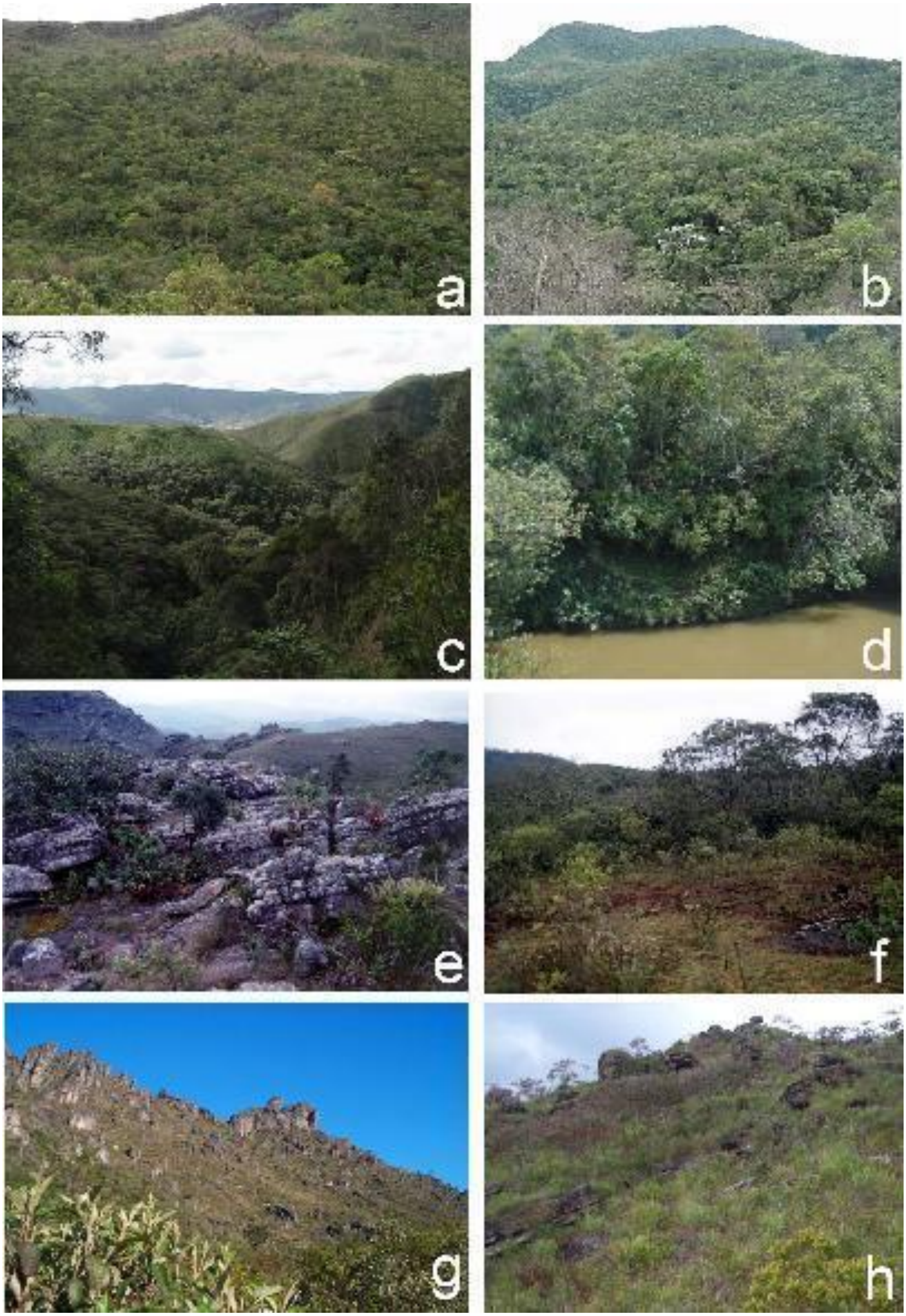

Figure 2. Semideciduous forest and *campos rupestres* of the Itacolomi State Park. a-d. semideciduous forest; e-h. *campos rupestres*.

Figura 2. Florestas Estacionais e campos rupestres do Parque Estadual do Itacolomi. a-d. Florestas Estacionais; e-h. campos rupestres.

(9%). The subshrub habit was the least represented, with 2.8% of the taxa. Trees, vines and lianas were prevalent in the forest areas of the Park, while the shrubs, herbs and subshrubs were most common in the *Campos Rupestres*.

The analysis of the geographical distribution of 102 specific and infraspecific Leguminosae taxa of the PEIT covered the five geographical macroregions (Table 2): Wide geographic distribution (7.8% of the taxa), South America, Central America and North America (4%), Neotropical (16.5%), West, Central and Easten South America (26.3%), and distribution restricted to Brazil (45.6% of the taxa).

Among the taxa of occurrence restricted to the Brazilian territory, seven geographic distribution patterns were defined (Table 2): Brazil-wide distribution (2.9%), Central-Eastern Brazil (11.6%), Atlantic-Northeast-Southeast-Southern Brazil 3.8%), Atlantic-Northeast-Southeastern Brazil (6.8%), Atlantic-Southeast- Southern Brazil (2.9%), Southeastern Brazil (12.7%) and endemic to the Espinhaço Range (4.9%).

The correlation between the patterns of geographic distribution and the number of species per habitat in the PEIT (Fig. 5) showed that in the Semideciduous Forests there is predominance of species of the patterns West, Central and Eastern South America (18 spp), Central-Eastern Brazil (9 spp) and Southeastern Brazil (9 spp.). Note also that 17 species are unique patterns of the Atlantic Forest domain. In *Campos Rupestres* there is predominance of species of the patterns Neotropical (09 spp), Wide geographic distribution (7 spp), South America, Central America and North America (4 spp) and Endemic to the Espinhaço Range (5 spp).

Discussion

The diversity of Leguminosae in PEIT can be considered high compared with other areas of the Espinhaço Range, losing in number of species only to the Serra do Cipó, where 104 species were listed according to Giulietti et al. (1987). Furthermore, it contains 15% of the Leguminosae diversity in the *Campos Rupestres* reported by Dutra et al. (2008a). Considering only the grassland vegetation, the PEI is the fifth richest area of *Campo Rupestre* in Leguminosae, while considering only the areas of the Iron Quadrangle, it is the first richest area in Leguminosae (Dutra et al . 2008a).

Besides this high diversity in *Campos Rupestres* of PEIT, the high percentage of taxons (43%) in Submontane Forests corroborates the results found in the National Park of Itatiaia (PARNA Itatiaia), by Morim (2006). Elevational gradients in species diversity are nearly as ubiquitous as latitudinal gradients, and they provide a number of characteristics that make them perhaps more suitable for uncovering the underlying cause(s) of spatial variation in diversity, as the decline in species richness with increasing altitude is a common pattern in Tropical Forests (Colwell et al. 2004, Sanders & Rabbeck 2012). This was recorded for Leguminosae in areas of *Campos Rupestres* by Dutra (2005), however, in these fields, as well as altitudinal variation, other factors such as topographic variation and heterogeneity of the substrate and microclimate are also determinants for the occurrence of species (Rapini et al. 2008)

Mimosa and *Chamaecrista* , the richest genera in number of species in the *Campos Rupestres* of the PEIT, are widely distributed in the Neotropics and characteristic of dry environments, such as the *Cerrado* (Schrire et al . 2005, Queiroz 2006). *Inga*, the most representative genus in the Semideciduous Forests of the PEIT, is prevalent in tropical and subtropical forests of Tropical America and has high diversity in the Atlantic Domain, with 22 species cited for secondary forests (León 1966, Garcia & Fernandes 2013). The genera *Lupinus* and *Calliandra*, cited as diverse in the *Campos Rupestres* by Giulietti et al. (1997), were not found in the *Campos Rupestres* of the PEIT. The low representation or absence of species of these genera in other *Campos Rupestres* within the Iron Quadrangle had already been recorded by Dutra et al . (2008a).

The highest percentage of shrub and herbaceous species found in *the Campos Rupestres* is mainly due to the presence of representatives of *Desmodium*, *Stylosanthes*, *Aeschynome* and *Zornia*, among others, which are among the genera with high species richness in tropical grasslands. The richness of these genera in the extensive herbaceous-shrub stratum prevalent in *Campos Rupestres* has been observed in other studies and is consistent with the percentage of habit variation in forest and grassland formations (Pirani et al. 2003, Zappi et al. 2003, Ferreira & Forzza 2009).

The analysis of the geographical distribution of Leguminosae taxa in the PEIT showed a high percentage of taxa distribution restricted to the Brazilian territory, with predominance, under the phytogeographical aspect, of components of the flora of areas of *Cerrado* and Atlantic Forest. Morim (2006) reported that 65% of the species recorded in the Itatiaia National Park (RJ) are restricted to Brazil. Filardi et al. (2007) and Nunes et al. (2007) found that 44% of the Leguminosae-Papilionoideae taxa growing in the National Park Serra da Canastra (MG) and 54% of the Leguminosae-Mimosoideae taxa in the State Park of Rio Doce (MG) are unique to the flora of Brazil.

The species with the widest distribution patterns (Wide Geographic Distribution, South America, Central America and North America and Neotropical), are mostly herbaceous plants and subshrubs of *Campos Rupestres* and correspond to ruderal species that occur in different types of vegetation, mainly as weeds in degraded areas, being considered generalists (Miotto 1987, Fortuna-Perez 2010, Lima et al. 2010b) and well represented in the *Campos Rupestres* of the Iron Quadrangle (Dutra et al. 2008a). The wide distribution can also be explained by the presence of neotropical species that have the riverbanks as preferred habitat, such as *Inga marginata* and *Inga vera* subsp. *affinis* that occur in Submontane and Upper Highland Forests, respectively, corroborating Pennington (1997), who explained the occurrence of the wide distribution of these species in the Neotropics by the dispersal of fruits through hydrochory or zoochory.

In the distribution pattern Western, Central and Eastern South America, 56 % of the species are restricted to semi-deciduous forests of the PEIT, among them, the specie *Anadenanthera colubrina* var. *colubrina* is referred as representative in the Semideciduous Forests of Brazil.

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Table 1. Specific and infraspecific Leguminosae taxa of the Itacolomi State Park, their geographic distribution patterns, habits and vegetation types. He = herbaceous; Li = lianas; Sb = subshrubs; Tr = trees; Sh = shrubs; Vi = vines. CRP = *campos rupestres*; SLF = Semideciduous lower highland forest; SMF = semideciduous submontane forest; SUF = Semideciduous upper highland forest.

Tabela 1 Táxons específicos e infra-específicos das Leguminosae do Parque Estadual do Itacolomi, seus padrões de distribuição geográfica, hábitos e formações vegetacionais. He = ervas; Li = lianas; Sb = subarbustos; Sh = arbustos; Tr = árvores; Vi = trepadeiras. CPR = campos rupestres; SLF = Floresta Estacional Montana; SMF = Floresta Estacional Submontana; SUF = Floresta Estacional Altimontana.

Distribution pattern	Specific and infraspecific taxa +*	Habit	Vegetation type
Wide geographic distribution	*Clitoria falcata* var. *falcata* Lam.[19, 43]	Vi	CRP/SMF
	Desmodium adscendens (Sw.) DC.[2, 26]	He	CRP/SUF/SLF/ SMF
	Desmodium barbatum (L.) Benth.	He	CRP
	Desmodium incanum DC.[2, 26]	He	CRP
	Desmodium uncinatum (Jacq.) DC.[2, 26]	Sb	CRP/SUF/SLF
	Mimosa pudica var. *hispida* Brenan[4]	Sb	CRP
	Zornia reticulata Sm[11]	He	CRP
	Trifolium repens L.[8, 26]	He	SUF
South America, Central America and North America	*Centrosema virginianum* (L.) Benth.[5, 45]	Vi	CRP
	Chamaecrista rotundifolia var. *rotundifolia* (Pers.) Greene[28]	He	CRP
	Indigofera suffruticosa Mill.	Ab	CRP/SMF
	Stylosanthes viscosa (L.) Sw.[12, 26]	He	CRP
Neotropical	*Aeschynomene elegans* var. *elegans* Schltdl. & Cham.[20]	He	CRP/SUF
	Anadenanthera peregrina L. (Speg.)[1, 16, 26]	Tr	SUF
	Andira surinamensis (Bondt) Splitg. ex Pulle[39, 47]	Ab	CRP
	Calopogonium mucunoides Desv.[15]	Vi	CRP
	Crotalaria micans Link[22]	Ab	CRP
	Desmodium affine Schltdl.[2, 26]	He	CRP
	Inga marginata Willd.[24, 46]	Tr	SMF
	Inga vera subsp. *affinis* (DC.) T.D.Penn[24, 46]	Tr	SUF/SMF
	Machaerium hirtum (Vell.) Stellfeld[38, 40, 52]	Tr	SMF
	Mimosa diplotricha var. *diplotricha* C.Wright ex Sauvalle[4]	Ab	CRP
	Platypodium elegans Vogel[29, 31, 38]	Tr	SMF
	Poiretia punctata (Willd.) Desv.[45]	Li	SMF
	Pterocarpus rohrii Vahl[29, 34]	Tr	SMF
	Rhynchosia reticulata (Sw.) DC.[48]	Vi	CRP
	Stylosanthes guianensis (Aubl.) Sw.[12, 26]	He	CRP
	Vigna peduncularis (Kunth) Fawc. & Rendle[38]	Vi	CRP/SUF
Western - Central-Eastern South America	*Anadenanthera colubrina* (Vell.) Brenan var. *colubrina*[1, 26]	Tr	SMF
	Bauhinia longifolia (Bong.) Steud.[57]	Tr	SMF
	Bauhinia ungulata var. *cuiabensis* (Bong.) Vaz	Ab	CRP/SLF/SMF
	Bowdichia virgilioides Kunth[26]	Tr	SMF
	Calliandra parvifolia (Hook. & Arn.) Speg.[5]	Tr, Ab	SMF
	Chaetocalyx longiflora Benth. ex A.Gray[50]	Vi	SMF
	Chamaecrista langsdorfii (Kunth ex Vogel) Britton ex Pittier[28]	Ab	CRP
	Chamaecrista trichopoda (Benth.) Britton & Rose ex Britton & Killip[28]	He	CRP
	Camptosema scarlatinum var. *pohlianum* (Mart. ex Benth.) Burkart[26]	Vi	CRP
	Copaifera reticulata Ducke[17]	Tr	SUF/SLF/SMF
	Crotalaria paulina Schrank[22]	Sb	SMF
	Dalbergia frutescens var. *frutescens* (Vell.) Britton[14]	Ab/Li	CRP/SUF
	Dalbergia revoluta Ducke[14]	Tr	SMF
	Desmodium subsericeum Malme[2, 26]	He	CRP
	Dioclea violacea Mart. ex Benth.[15]	Li	SMF
	Inga cylindrica (Vell.) Mart.[24, 46]	Tr	SUF/SLF/SMF
	Inga edulis Mart.[24, 46]	Tr	SMF
	Inga ingoides (Rich.) Willd.[24, 46]	Tr	SLF/SMF
	Machaerium aculeatum Raddi[40]	Li	CRP/SLF/SMF
	Machaerium brasiliense Vogel[40, 52]	Tr/Ab	CRP/SLF/SMF
	Machaerium nyctitans (Vell.) Benth.[42]	Tr	SUF/SLF
	Machaerium villosum Vogel[26]	Tr	SUF/SLF/SMF
	Mimosa pigra var. *dehiscens* (Barneby) Glazier & Mackinder[4]	Ab	CRP
	Periandra mediterranea (Vell.) Taub.[26]	Ab	CRP
	Piptadenia adiantoides (Spreng.) J.F.Macbr.[26]	Li	SUF/SMF
	Senna pendula var. *glabrata* (Humb. & Bonpl. ex Willd.) H.S.Irwin & Barneby[28]	Ab	CRP/SUF
	Sesbania virgata (Cav.) Pers.[26]	Ab	CRP
Brazil-wide distribution	*Crotalaria breviflora* DC.[25]	He/Ab	CRP/SUF
	Inga sessilis (Vell.) Mart.[25]	Tr	SUF
	Phanera radiata (Vell.) Vaz[38]	Li	SLF
Central-Eastern Brazil	*Andira fraxinifolia* Benth.[47]	Tr	SLF/SMF
	Cassia ferruginea (Schrad.) Schrad. ex DC. var. *ferruginea*[28]	Tr	SMF
	Centrosema coriaceum Benth.[5]	Vi	CRP
	Crotalaria velutina Benth.[22]	He	CRP
	Dalbergia villosa (Benth.) Benth. var. *villosa*[32]	Ab/Tr	CRP/SUF/SLF/SMF
	Machaerium oblongifolium Vogel[21]	Li	SUF/SMF
	Mimosa bimucronata (DC.) Kuntze var. *bimucronata*[4, 16]	Ab	SLF/SMF
	Mimosa dolens Vell. var. *dolens*[4,16]	Ab	CRP
	Piptadenia gonoachantha (Mart.) J.F.Macbr.[34, 41, 56]	Tr	SUF/SMF

	Senegalia martiusiana (Steud.) Seigler & Ebinger [44]	Li	SMF
	Senna macranthera var. *nervosa* (Vogel) H.S.Irwin & Barneby [28]	Tr	SUF/SMF
	Senna multijuga var. *lindleyana* (Gard.) H.S.Irwin & Barneby [28]	Tr	SUF
Atlantic - Northeast-Southeast-Southern Brazil	*Abarema langsdorfii* (Benth.) Barneby & J.W.Grimes [6]	Ab/Tr	CRP/SUF/SLF/SMF
	Dalbergia nigra (Vell.) Alemao ex Benth. ✚ [14]	Tr	SLF/SMF
	Inga vulpina Mart. ex Benth. ✚ [24, 46]	Tr/Ab	CRP/SUF
	Swartzia oblata R. S. Cowan [37]	Ab	CRP
Atlantic - Northeast-Southeastern Brazil	*Chamaecrista mucronata* (Spreng.) H.S.Irwin & Barneby ✚ [54]	Ab	CRP
	Melanoxylon brauna Schott ✚ [36, 40]	Tr	SMF
	Mimosa aurivillus Mart. var. *aurivillus* [4, 16]	Ab	CRP
	Mimosa sensitiva var. *malitiosa* Mart. [4, 16]	Vi	CRP
	Pseudopiptadenia contorta (DC.) G.P.Lewis & M.P.Lima [30]	Tr	SMF
	Senna reniformis (G.Don) H.S.Irwin & Barneby [55]	Tr/Ab	CRP/SUF/SLF/SMF
	Tachigali rugosa (Mart. ex Benth.) Zarucchi & Pipoly [33]	Tr	SUF
Atlantic - Southeast-Southern Brazil	*Dalbergia brasiliensis* Vogel [14]	Li	SLF/SMF
	Inga barbata Benth. [25]	Ab	CRP
	Mimosa scabrella Benth. [4, 16]	Tr	SUF
Southeastern Brazil	*Abarema obovata* (Benth.) Barneby & J.W.Grimes ✚ [6]	Tr	SUF/SLF/SMF
	Bionia bella Mart. ex Benth. ✚ [49]	Vi	SUF/SLF/SMF
	Chamaecrista multipennis (H.S.Irwin & Barneby) H.S.Irwin & Barneby [27]	Ab	CRP
	Inga schinifolia Benth. [24, 46]	Tr/Ab	SUF
	Mimosa aurivillus var. *calothamnos* (Mart ex. Benth.) Barneby [4, 16]	Ab	CRP
	Mimosa ourobrancoënsis Burkart ✚ [4]	Ab	CRP
	Ormosia friburgensis Taub. ex Harms ✚ [35, 51]	Tr	SUF
	Piptadenia micracantha Benth. [7, 9, 56]	Li	SUF/SMF
	Senna neglecta var. *oligophylla* (Benth.) H.S.Irwin & Barneby [28]	Ab	CRP
	Senna pneumatica H.S.Irwin & Barneby ✚ [28]	Ab	SUF
	Stryphnodendron polyphyllum Mart. [53]	Tr	SLF/SMF
	Swartzia pilulifera Benth. [37]	Tr	SUF
	Tachigali friburgensis (Harms) L.G. Silva & H.C. Lima ✚ [33]	Tr	SUF/SLF
Endemic to the Espinhaço Range	*Chamaecrista dentata* (Vogel) H.S.Irwin & Barneby ✚ [27]	Ab	CRP
	Chamaecrista hedysaroides (Vogel) H.S.Irwin & Barneby [27]	Ab	CRP
	Chamaecrista ochnacea (Vogel) H.S.Irwin & Barneby var. *ochnacea* [28]	Ab	CRP
	Chamaecrista rotundata var. *grandistipula* (Vogel) H.S.Irwin & Barneby [28]	Ab	CRP
	Mimosa montis-carasae Barneby ✚ [16]	Ab	CRP

✚ Species threatened by extinction according to Biodiversitas (2005) and Brasil (2008).

* References of the geographic distributions: [1]Altshul (1964), [2] Azevedo (1981), [3] Barbosa -Fevereiro (1977), [4]Barneby (1991), [5]Barneby (1998), [6]Barneby & Grimes (1996), [7]Barroso (1965), [8]Bentham (1859), [9]Benham (1876), [10]Brandão (1992), [11]Brandão (1996), [12]Brandão & Costa (1979), [13]Burkart (1970), [14]Carvalho (1997), [15]Carvalho-Okano & Leitão-Filho (1985), [16]Dutra & Morim (2011), [17]Dwyer (1951), [18]Eisinger (1987), [19]Fantz (1980), [20]Fernandes (1996), [21]Filardi (2011), [22]Flores (2004), [23]Flores (2011), [24]Garcia (1998), [25] Garcia & Fernandes (2013), [26]ILDIS (2011), [27]Irwin & Barneby (1978), [28]Irwin & Barneby (1982), [29] Lewis (1987), [30]Lewis & Lima (1991), [31]Lima (2000), [32]Lima (2011a), [33]Lima (2011b), [34]Lima et al. (1994), [35]Lima et al. (2010c), [36]Lorenzi (1992), [37]Mansano et al. (2011), [38]Maréchal et al. (1978), [39]Mattos (1979), [40]Mendonça-Filho (1996), [41]Mendonça et al. (1998), [42]Mendonça-Filho et al. (2007), [43]Miotto (1987), [44]Morim & Barros (2011), [45]Muller (1984), [46]Pennington (1997), [47] Pennington (2003), [48]Poston (1980), [49] Queiroz (1999), [50]Rudd (1958), [51]Rudd (1965), [52]Sartori & Tozzi (1998), [53] Scalon (2007), [54]Souza & Bortoluzzi (2011a), [55]Souza & Bortoluzzi (2011b), [56]Tamashiro (1989), [57]Vaz & Tozzi (2003), [58]Vaz (2011).

It is also considered as a specialist species of the Atlantic domain by Lima (2000). However, this taxon is found in areas of *Caatinga* in northeastern Brazil and in part of Minas Gerais and Maranhão, in Seasonal Forests in the states of Mato Grosso do Sul and Parana, as well as in northeastern Argentina and southeastern Bolivia (Prado & Gibbs 1993); these vegetation types are currently recognized as Seasonally Dry Tropical Forests (SDTF), according to Pennington et al. (2000, 2004, 2006) and Miles et al. (2006).

In the pattern Central-Eastern Brazil there is also predominance of species of Semideciduous Forests of the PEIT, such as *Andira fraxinifolia* and *Piptadenia gonoacantha*, which are generalist species, corroborating Oliveira- Filho & Ratter (1995) that describe this area as an important migratory corridor, through the gallery forests of the *Cerrado* and Atlantic Forest. Although PEIT lies in a transition zone between the Atlantic Forest and areas of *Cerrado*, its legume species indicate that the Atlantic Forest domain has a greater number of taxa than the *Cerrado*.

In the pattern Southeastern Brazil, of the 13 taxa identified, nine were exclusive to the Semideciduous Forests. *Abarema obovata* and *Bionia bella* occur in upper highlands, lower highlands and submontane forests of the PEIT and are restricted to the Atlantic Forest domain, growing in submontane or seasonal forests and highland areas related mainly to the Mantiqueira Range, respectively (Barneby & Grimes 1996, Queiroz 1999, 2008). *Inga schinifolia*, *Ormosia friburgensis* and *Senna pneumatica* are specialist species and occur only in the upper highland forests of the PEIT, confirming reports by Rudd (1965), Garcia (1998) and Irwin & Barneby (1982).

Among the endemic species of the Espinhaço Range, all were exclusive to the *Campos Rupestres*, some can be considered microendemic because they occur only in two or three localities. *Chamaecrista dentata* is restricted to the Cipó Range and Itacolomi Range (Irwin & Barneby 1978); *C. hedysaroides* occurs in the region of Diamantina, Ouro Preto and Caraça Range (Irwin & Barneby 1978);

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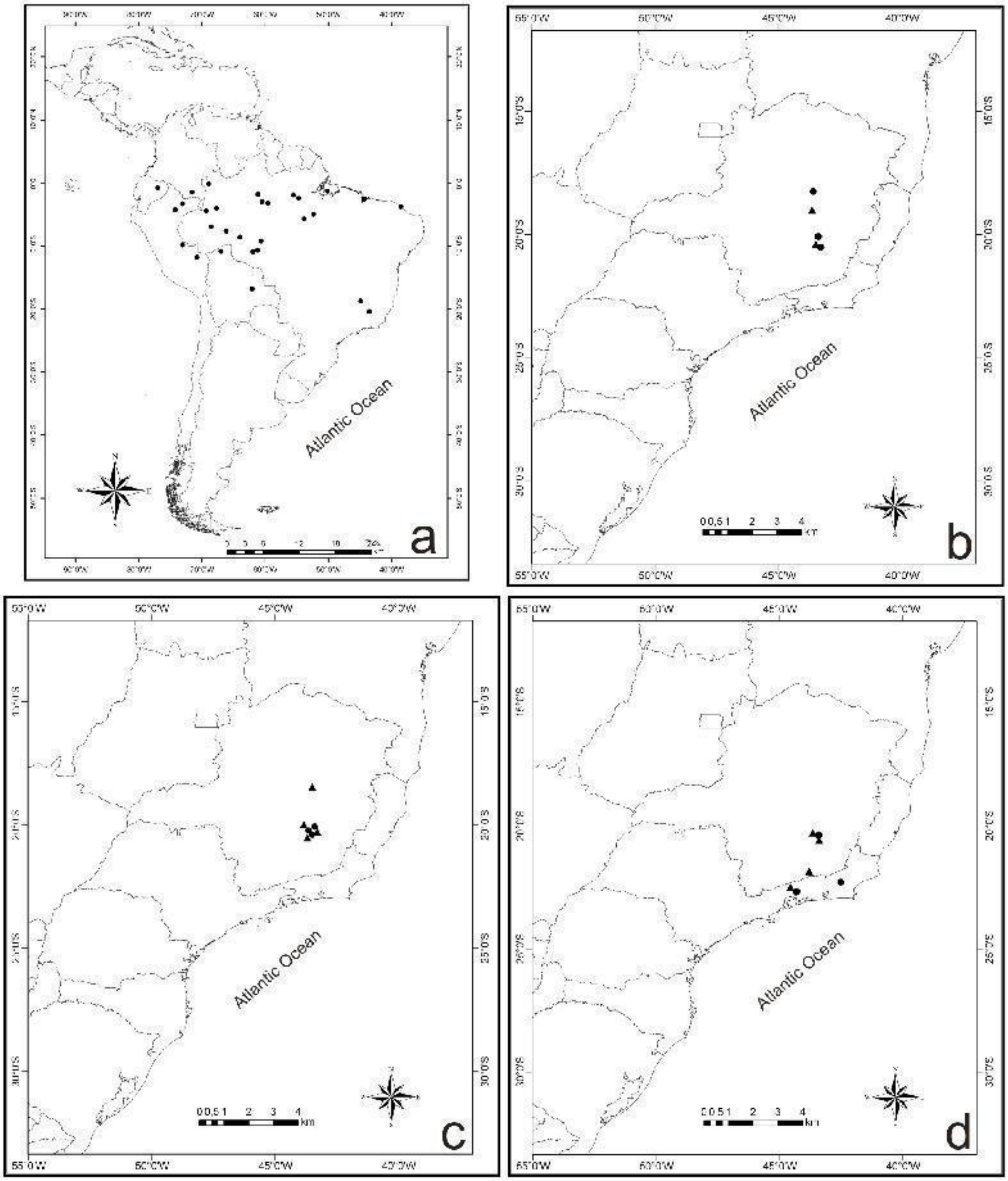

Figure 3. Distribution patterns a. Neotropical *Andira surinamensis* (Source: Pennington 2003, Mattos 1979); b. Endemic to the Espinhaço Range *Chamaecrista dentata* (▲) and *Chamaecrista hedysaroides* (●) (Source: Irwin & Barneby 1982); c. *Chamaecrista ochnacea* var. *ochnacea* (▲) and *Mimosa montis-carasae* (●) (Sources: Irwin & Barneby 1982, Dutra 2009); d. Southeastern Brazil *Mimosa ourobrancoënsis* (▲) and *Ormosia friburgensis* (●) (Sources: Dutra 2009, Rudd 1965).

Figura 3. Padrões de distribuição a. Neotropical *Andira surinamensis* (Fontes: Pennington 2003, Mattos 1979); b. Endêmicas da Cadeia do Espinhaço *Chamaecrista dentata* (▲) e *Chamaecrista hedysaroides* (●) (Fonte: Irwin & Barneby 1982); c. *Chamaecrista ochnacea* var. *ochnacea* (▲) e *Mimosa montis-carasae* (●) (Fontes: Irwin & Barneby 1982, Dutra 2009); d. Brasil Sudeste *Mimosa ourobrancoënsis* (▲) e *Ormosia friburgensis* (●) (Fontes: Dutra 2009, Rudd 1965).

C. ochnacea var. *ochnacea* grows in Nova Lima, Ouro Branco Range and Itacolomi Range (Irwin & Barneby 1978, Dutra et al. 2008b); *C. rotundata* var. *grandistipula* is limited to the region of Diamantina, Cipó Range and Itacolomi Range (Rando & Pirani 2011); and *Mimosa montis-carasae*, unique to Caraça Range and Itacolomi Range (Barneby 1991, Dutra et al. 2008c).

In the PEIT, 45% of the listed *Chamaecrista* species are endemic to the Espinhaço Range, confirming the high degree of endemism of the genus for the flora of this mountain system, showing a pattern already identified for mainly the families of Eriocaulaceae, Velloziaceae, Xyridaceae, and Lythraceae (Giulietti et al. 1987). The states of Bahia and Minas Gerais are cited as a center of diversity for *Chamecrista* , mainly the *Cerrado* and *Campos Rupestres*, especially the portion of the Espinhaço

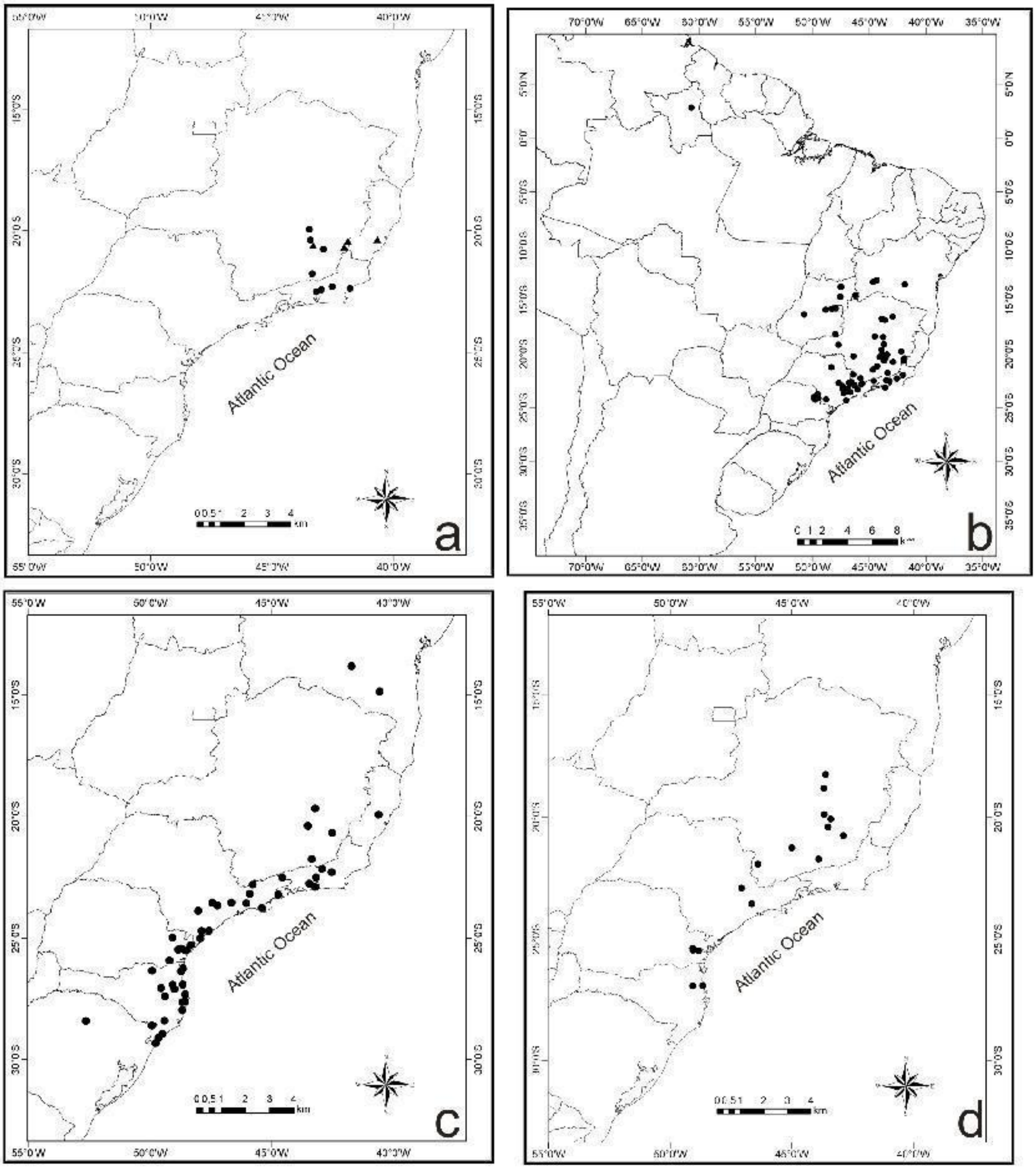

Figure 4. Distribution patterns a. Southeastern Brazil *Bionia bella* (▲) and *Tachigali friburgensis* (●) (Sources: Queiroz 1999, 2008, Silva 2007); b. Brazil-wide distribution *Crotalaria breviflora* (Source: Flores 2004, 2011); c. Atlantic-Northeast-Southeast-Southern Brazil *Abarema langsdorfii* (Source: Barneby & Grimes 1996); d. Atlantic-Northeast-Southeast-Southern Brazil *Inga vulpina* (Source: Garcia 1998).

Figura 4. Padrões de distribuição a. Brasil Sudeste *Bionia bella* (▲) e *Tachigali friburgensis* (●) (Fontes: Queiroz 1999, 2008, Silva 2007); b. Brasil ampla distribuição *Crotalaria breviflora* (Fontes: Flores 2004, 2011); c. Brazil Atlântico-Nordeste-Sudeste-Sul *Abarema langsdorfii* (Fonte: Barneby & Grimes 1996); d. Brazil Atlântico-Nordeste-Sudeste-Sul Brazil *Inga vulpina* (Fonte: Garcia 1998).

Table 2. Number of specific and infraspecific Leguminosae taxa in the Itacolomi State Park and percentage of geographic distribution patterns.

Tabela 2. Número de táxons específicos e infra-específicos de Leguminosae do Parque Estadual do Itacolomi e porcentagem dos padrões de distribuição geográfica.

Distribution pattern	Nr. of taxa	% of taxa
Wide geographic distribution	8	7.8
South America, Central America and North America	4	4.0
Neotropical	16	15.7
West, Central and Eastern South America	27	26.5
Restricted to Brazil	47	46.0
Brazil-wide distribution	3	2.9
Central-Eastern Brazil	12	11.6
Atlantic-Northeast-Southeast-Southern Brazil	4	3.8
Atlantic-Northeast-Southeastern Brazil	7	6.8
Atlantic-Southeast-Southern Brazil	3	2.9
Southeastern Brazil	13	12.7
Endemic to the Espinhaço Range	5	4.9

Range in Minas Gerais, which has several endemic species (Irwin & Barneby 1982, Lewis 1987, Giulietti & Pirani 1988, Harley 1988, Dutra et al. 2008a, Rando & Pirani 2011). In this region, some series of the genus had a significant diversification, which may have been caused by periods of climatic fluctuations that occurred in the Quaternary and resulted in the irregularity in the gene flow between populations and in the evolution of new species (Giulietti et al . 1997).

The distribution patterns of Leguminosae taxa in the Park show that its flora consists of floristic elements of both the Atlantic Forest and the *Cerrado*, the two Brazilian biomes considered hotspots (Mittermeier et al. 2005). The Semideciduous Forests of the PEIT receive the combined contribution of elements from different forest types, especially from those of the Atlantic Forest domain, since the distribution patterns of about 25% of the species were restricted to the Atlantic Forest. The *Campos Rupestres*, however, besides the high number of endemic taxa of the Espinhaço Range, receive the contribution of elements from the *Cerrado* and the Atlantic Forest, due to the presence of Semideciduous Forests that occur in the lower parts of the PEIT, corroborating Santos et al. (2011) that point out the geographical proximity as one of the factors influencing the

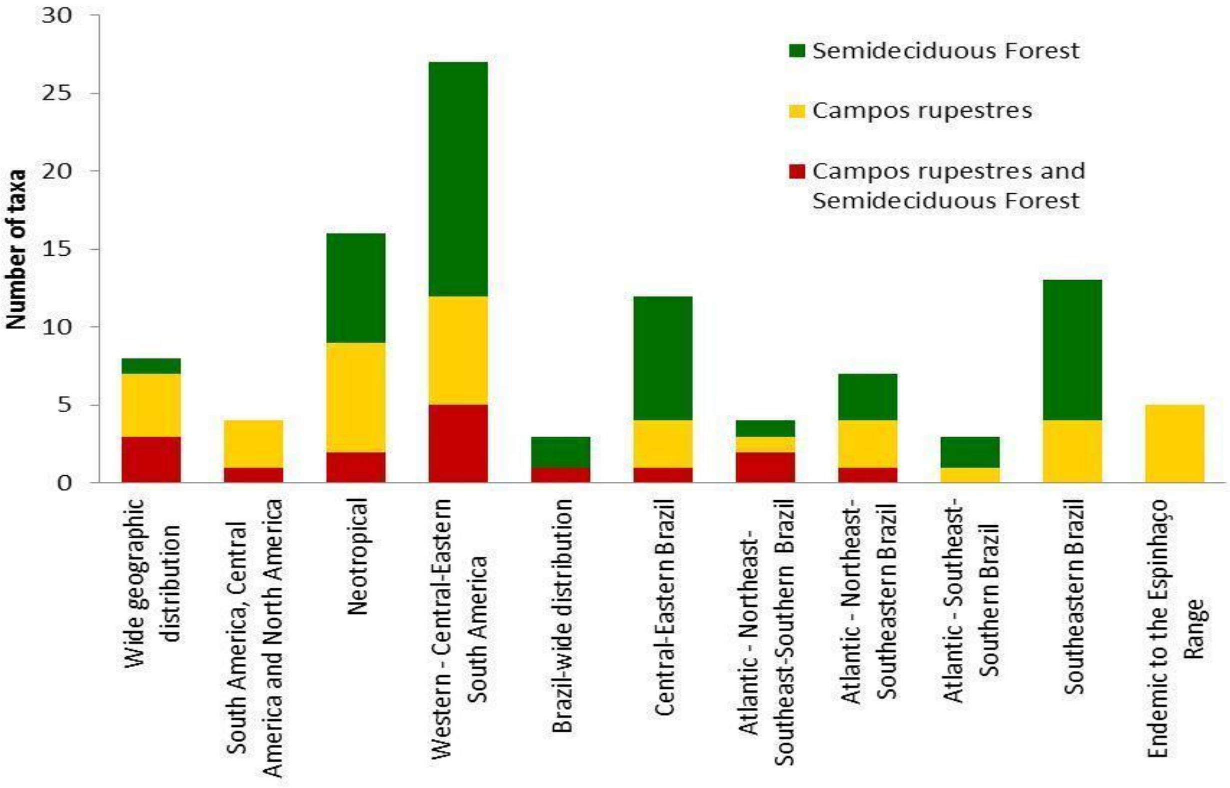

Figure 5. Correlation between geographic distribution patterns and number of taxa found in vegetation types of the Itacolomi State Park.

Figura 5. Correlação entre os padrões de distribuição geográfica e o número de espécies encontradas nas fitofisionomias do Parque Estadual do Itacolomi.

phytogeographic patterns in the *Quadrilátero Ferrífero* and also, as proposed by Harley (1995), the sectorization of the Espinhaço Range. Harley (1995) referred the *Campos Rupestres* that are restricted to the higher and isolated areas and have more humid climate, with greater contact with the Semideciduous Forests than the *Cerrado*, to the southern sector of the Range, which comprises the south of Belo Horizonte and the Ouro Preto region.

Despite the presence of species endemic to the Espinhaço, the analysis of distribution patterns of the Leguminosae in the PEIT does not support the distribution patterns typically found in other areas of the Espinhaço Range, in which forest species are predominantly of wide distribution and the herbaceous-shrub species exhibit stricter standards (Giulietti & Pirani 1988) caused by the history of the region, such as migration routes and past climate changes occurred in southeastern Brazil during the Pleistocene, which promoted the isolation of species (Giulietti et al . 1997).

Among the species found in the Park, 15 are of interest for the conservation of PEIT, because five are endemic to the Espinhaço mountain range and ten appear in the lists of endangered species of the flora of Brazil and Minas Gerais (Table 2). In areas of *Campos Rupestres* within the Park, the species *Chamaecrista dentata*, with only two populations, and *Mimosa ourobrancoënsis*, with a single population, are noteworthy. In these forest formations, many species have a very restricted distribution or are rare.

Senna pneumatica and *Ormosia friburgensis* are restricted to the Upper Highland Forests, and *Melanoxylon brauna* occurs in Submontane Forests. So far, only one population of each of these species has been found. *Dalbergia nigra* occurs in Lower Highlands and Submontane Forests with two populations identified. *Bionia bella* grows in Lower Highlands, Submontane and Upper Highland Forests, with scarce populations scattered throughout the forest formations. It is worth mentioning that the occurrence of all these taxa is restricted to the Atlantic Forest domain.

The representatives of the genera *Abarema*, *Bionia*, *Chamaecrista*, *Inga*, and *Mimosa* have ornamental potential, whereas *Dalbergia nigra* and *Melanoxylon brauna* have timber potential. Therefore, these results do not only reinforce the important role of the PEIT in the conservation of the flora in the southern Espinhaço Range, but also highlight the existence of stocks of species threatened by extinction or with potential for sustainable use.

The presence of distinct and heterogeneous floras in vegetational gradients makes the PEIT an area with high biological diversity. Messias & Souza (2006) reported 80 species of Leguminosae for the PEIT. This study shows an increase of 27.5% in the number of species within the park, which demonstrates the importance of research involving knowledge of biodiversity at the local scale.

Despite being a fully protected conservation unit, difficulties of managing the park prevents effective species protection and the vegetation of the PEIT is still subject to different impacts by uncontrolled urban sprawl, frequent fires, invasion of exotic species and firewood extraction (Messias & Souza 2006). Within the park, it deserves attention, in the areas of *Campo Rupestre*, the trails Calais and the water catchment in Serrinha, home to endemic species of the Espinhaço, and in the Semideciduous Forests, the upper highlands forests, home to most of the forest species of the PEIT that are threatened with extinction.

The findings of this study on the Leguminosae family demonstrate the importance of conserving the vegetation of the Itacolomi Range and the need for studies on other plant families, with a view to the implementation of effective protection policies for the forests and fields of the PEIT.

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References

ALTSHUL, S. von R. 1964. A taxonomic study of the genus *Anadenanthera*. Contr. Gray Herb. 193:1-65.

AZEVEDO, A.M.G. 1981. O gênero *Desmodium* Desv. no Brasil-considerações taxonômicas. Dissertação de Mestrado, Universidade Estadual de Campinas, Campinas, 315 p.

BARBOSA-FEVEREIRO, V.P. 1977. *Centrosema* (A.P. de Candolle) Benthan do Brasil - Leguminosae-Faboideae. Rodriguésia 42:159-219.

BARNEBY, R.C. 1998. Silk tree, Guanacaste, Monkey's earring: a generic system for the synandrous Mimosaceae of the Americas. Mem. New York Bot. Gard. 74:1-223.

BARNEBY, R.C. 1991. Sensitivae Censitae. A description of the genus *Mimosa* Linnaeus (Mimosaceae). New World. Mem. New York Bot. Gard. 65:1-835.

BARNEBY, R.C. & GRIMES, J. 1996. Silk tree, Guanacaste, Monkey's earring: a generic system for the synandrous Mimosaceae of the Americas. Mem. New York Bot. Gard. 74:1-292.

BARROSO, G.M. 1965. Leguminosas da Guanabara. Arquivos do Jardim Botânico do Rio de Janeiro 18:109-177.

BARROSO, G.M., PEIXOTO, A.L., COSTA, C.G., ICHASSO, C.L.F., GUIMARÃES, E.F. & LIMA, H.C. 1991. Sistemática das Angiospermas do Brasil, vol. 2. Imprensa Universitária, Viçosa.

BENTHAM, G. 1859. Papilionaceae. In: Flora Brasiliensis. (C.F.P. Martius, S. Endlicher & I. Urban, eds.). F. Fleischer, Lipsiae, v. 15, p. 1-215.

BENTHAM, G. 1876. Mimoseae. In: Flora Brasiliensis. (C.F.P. Martius, S. Endlicher & I. Urban, eds.). F. Fleischer, Lipsiae, v. 15, p. 34-499.

BIODIVERSITAS. 2005. Lista da flora brasileira ameaçada de extinção segundo avaliação no workshop. http://www.biodiversitas.org.br/florabr/lista_florabr.pdf. (accessed em 14/02/2011)

BRANDÃO, M. 1992. Gênero *Aeschynomene* L.: espécies mineiras e sua distribuição no país. Daphne 2:27-46.

http://dx.doi.org/10.1590/S1676-06033937

BRANDÃO, M. 1996. O gênero *Zornia* Gmell. no Estado de Minas Gerais. Daphne 6:21-39.

BRANDÃO, M. & COSTA, N.M.S. 1979. O gênero *Stylosanthes* Sw. no Brasil. EPAMIG, Belo Horizonte.

BRANDÃO, M. & GAVILANES, M.L. 1994. Composição Florística das áreas recobertas pela Caatinga na área mineira da SUDENE. Informe Agropecuário 17:20-33.

BRANDÃO, M. & GAVILANES, M.L. 1997. Cobertura vegetal do município de Pedro Leopoldo, MG: formações vegetais e composição florística. Daphne 7:32-50.

BRASIL. 2008. Instrução Normativa n° 6, de 23 de setembro de 2008. Anexo 1. Lista oficial das espécies da flora brasileira ameaçada de extinção. Brasília, Ministério do Meio Ambiente.

BURKART, A. 1970. Leguminosas-Faseóleas argentinas de los géneros *Mucuna*, *Dioclea* y *Camptosema*. Darwiniana 16:175-218.

CARVALHO, A.M. 1997. A synopsis of the genus *Dalbergia* (Fabaceae, Dalbergieae) in Brazil. Brittonia 49:87-109. http://dx.doi.org/10.2307/2807701

CARVALHO-OKANO, R. M. & LEITÃO-FILHO, H. F. 1985. Revisão do gênero C*alopogonium* Desv. (Leguminosae-Lotoideae) no Brasil. Revista Brasil. Bot. 8:31-46.

COLWELL, R.K., RAHBEK, C. & GOTELLI , N.C. 2004. The Mid-domain effect and species richness patterns: what have we learned so far? The American Naturalist 163(3): E1-23.

CRIA (Centro de Referência em Informação Ambiental). 2013. *species* Link. http://splink.cria.org.br/(accessed 13/02/2012)

DRUMMOND, G.M.; MARTINS, C.S.; MACHADO, A.B.M.; SEBAIO, F.A. & ANTONINI, Y. 2005. Biodiversidade em Minas Gerais: um atlas para sua conservação. Fundação Biodiversitas, Belo Horizonte.

DUTRA, V. F. 2005. Leguminosae Adans. nos campos rupestres do Parque Estadual do Itacolomi, Minas Gerais, Brasil: florística, preferência por habitat, aspectos reprodutivos e distribuição geográfica. Dissertação de Mestrado, Universidade Federal de Viçosa, Viçosa, 171p. DUTRA, V.F. 2009. Diversidade de *Mimosa* L. (Leguminosae) nos campos rupestres de Minas Gerais: taxonomia, distribuição geográfica e filogeografia. Tese de doutorado, Universidade Federal de Viçosa, Viçosa, 280p.

DUTRA, V.F., GARCIA, F.C.P., LIMA, H. C. & QUEIROZ, L.P. 2008a. Diversidade florística de Leguminosae Adans. em áreas de campos rupestres. Megadiversidade 4: 105-113.

DUTRA, V.F., GARCIA, F.C.P., LIMA, H. C. 2008b. Caesalpinioideae (Leguminosae) nos Campos Rupestres do Parque Estadual do Itacolomi, MG, Brasil. Acta Bot. Brasil. 22:547-558. http://dx.doi.org/10.1590/S0102-33062008000200021

DUTRA, V.F., GARCIA, F.C.P., LIMA, H. C.2008c. Mimosoideae (Leguminosae) nos campos rupestres do Parque Estadual do Itacolomi, Minas Gerais, Brasil. Rodriguésia 59:573-585.

DUTRA, V.F., GARCIA, F.C.P., LIMA, H. 2009. Papilionoideae (Leguminosae) nos Campos Rupestres do Parque Estadual do Itacolomi, MG, Brasil. Acta Bot. Brasil. 23:145-159. http://dx.doi.org/10.1590/S0102-33062009000100018

DUTRA, V.F. & MORIM, M.P. 2011. *Mimosa*. In Lista de Espécies da Flora do Brasil. http://floradobrasil.jbrj.gov.br/2011/FB023084 (accessed 13/02/2012)

DWYER, J.D. 1951. The Central American, West Indian and South American species of *Copaifera* (Caesalpiniaceae). Brittonia 7:143-172. http://dx.doi.org/10.2307/2804703

EISINGER, S.M. 1987. O gênero *Indigofera* L. (Leguminosae-Papilionoideae-Indigofereae) no Rio Grande do Sul. Acta Bot. Brasil. 1:123-140.

FANTZ, P.R. 1980. Flora of Panama. Ann. Missouri Bot. Gard. 67:582-593.

FERNANDES, A. 1996. O táxon *Aeschynomene* no Brasil. Editora Universidade Federal do Ceará, Fortaleza.

FERREIRA, F.M. & FORZZA, R. 2009. Florística e caracterização da vegetação da Toca dos Urubus, Baependi, Minas Gerais, Brasil. Biota Neotrop. 9(4):1-18. http://dx.doi.org/10.1590/S1676-06032009000400014

FILARDI, F.L.R. 2011. *Machaerium*. In Lista de Espécies da Flora do Brasil. http://floradobrasil.jbrj.gov.br/2011/FB23055 (accessed 13/02/2012)

FILARDI, F.L.R., GARCIA, F.C.P., DUTRA, V.F. & SÃO-THIAGO, P.S. 2007. Papilionoideae (Leguminosae) do Parque Nacional da Serra da Canastra, Minas Gerais, Brasil. Hoehnea 34:383-408.

FLORES, A.S. 2011. *Crotalaria*. In Lista de Espécies da Flora do Brasil. http://floradobrasil.jbrj.gov.br/2011/FB22902 (accessed 13/02/2012)

FLORES, A.S. 2004. Taxonomia, números cromossômicos e química de espécies de *Crotalaria* L. (Leguminosae-Papilionoideae) no Brasil. Tese de doutorado, Universidade Estadual de Campinas, Campinas, 201 p.

FORTUNA-PEREZ, A.P. 2010. *Zornia*. In Catálogo de Plantas e fungos do Brasil vol. 2. (R.C. Forzza et al., eds.). Andrea Jakobsson Estudio: Instituto de Pesquisas Jardim Botânico do Rio de Janeiro, Rio de Janeiro, pp. 1100-1101.

GARCIA, F.C.P. 1998. Relações sistemáticas e fitogeografia do gênero *Inga* Miller (Leguminosae, Mimosoideae, Ingeae) nas florestas da costa sul e sudeste do Brasil. Tese de doutorado, Universidade Estadual Paulista, Rio Claro, 248 p.

GARCIA, F.C.P. & FERNANDES, J.M. 2013. *Inga*. In Lista de Espécies da Flora do Brasil. http://floradobrasil.jbrj.gov.br/2011/FB22803 (accessed 13/02/2012)

GENTRY, A.H. 1995. Patterns of diversity and floristic composition in neotropical montane forests. In Biodiversity and Conservation of Neotropical Montane Forests. Proceedings of the Neotropical Montane Forests Biodiversity and Conservation Symposium. (S.P. Churchill et al., eds.). The New York Botanical Garden, New York, p. 103-26.

GIULIETTI, A. M.; HARLEY, R. M.; QUEIROZ, L. P.; WANDERLEY, M. G. L. & PIRANI, J. R. 2002. Caracterização e endemismos nos Campos rupestres da Cadeia do Espinhaço. In Tópicos atuais em Botânica (T. B. Cavalcanti & B. M. T. Walter, eds.). Brasília, SBB/ Embrapa, p. 311-318.

GIULIETTI, A.M., MENEZES, N.L., PIRANI, J.R., MEGURO, M. & WANDERLEY, M.G.L. 1987. Flora da Serra do Cipó: caracterização e lista das espécies. Bol. Bot. Univ. São Paulo 9:1-151.

GIULIETTI, A. M. & PIRANI, J.R. 1988. Patterns of geographic distribution of some plant species from the Espinhaço Range, Minas Gerais and Bahia, Brazil. In Proceedings of a Workshop on Neotropical Distribution Patterns (W.R. Heyer & P.E. Vanzolini, eds.). Academia Brasileira de Ciências, Rio de Janeiro, p.39-67.

GIULIETTI, A.M.; PIRANI, J.R. & HARLEY, R.M. 1997. Espinhaço Range region, Eastern Brazil. In Centres of plants diversity 3 (S.D. Davis et al., eds). Information Press, Oxford, p. 397-404.

GONTIJO, B.M. 2008. Uma geografia para a Cadeia do Espinhaço. Megadiversidade 4:7-15. GUEDES-BRUNI, R.R., MORIM, M.P., LIMA, H.C., SYLVESTRE, L. da S. 2002. Inventário Florístico. In Manual Metodológico para estudos botânicos na Mata Atlântica (L. da S. Sylvestre & M.M.T., Rosa, orgs.). Seropédica, Rio de Janeiro, p. 24-49.

HARLEY, R.M. 1995. Introduction. In Flora of the Pico das Almas, Chapada Diamantina, Bahia, Brazil (B.L. Stannard, ed). Royal Botanical Gardens, Kew, p. 1-40.

HARLEY, R.M. 1988. Evolution and distribution of *Eriope* (Labiatae), and its relatives in Brazil. In Proceedings of a Workshop on Neotropical Distribution Patterns (W.R. Heyer & P.E. Vanzolini, eds.). Academia Brasileira de Ciências, Rio de Janeiro, p.71-119.

IBGE (Instituto Brasileiro de Geografia e Estatística). 2012. Manual técnico da vegetação brasileira. Rio de Janeiro.

ILDIS. 2011. International Legumes Database & Information Service. http://www.ildis.org/ (accessed 13/02/2012) IRWIN, H.S. & BARNEBY, R.C. 1978. Monographic studies in *Cassia* (Leguminosae-Caesalpinioideae) III. Sections *Absus* and *Grimaldia*. Mem. New York Bot. Gard. 30:1-300.

IRWIN, H.S. & BARNEBY, R.C. 1982. The American Cassiinae – A synoptical revision of Leguminosae – Tribe Cassieae subtribe Cassiinae in the New World. Mem. New York Bot. Gard. 35:1-918.

JOLY, C.A., AIDAR, M.P.M., KLINK, C.A., McGRATH, D.G., MOREIRA, A.G., MOUTINHO, P., NEPSTAD, D.C., OLIVEIRA, A. A., POTT, A., RODAL, M.J.N. & SAMPAIO, E.V.S.B. 1999. Evolution of the Brazilian phytogeography classification systems: implications for biodiversity conservation. Ciência e Cultura 51(5/6):331-368.

LÉON, J. 1966. Central American and West Indian species of *Inga* (Leguminosae). Annals of the Missouri Botanical Garden 53:265-359.

LEWIS, G.P. 1987. Legumes of Bahia. Royal Botanic Gardens, Kew.

LEWIS, G.P. & LIMA, M.P.M. 1991. *Pseudopiptadenia* Rauschert no Brasil (Leguminosae- Mimosoideae). Arquivos do Jardim Botânico do Rio de Janeiro 30:43-67.

LEWIS, G.P., SCHRIRE, B.D., MACKINDER, B.A. & LOCK, J.M. 2005. Legumes of the World. Kew, Royal Botanic Gardens.

LIMA, H.C. 2000. Leguminosas arbóreas da Mata Atlântica: uma análise da riqueza, padrões de distribuição geográfica e similaridades florísticas em remanescentes florestais do estado do Rio de Janeiro. Tese de doutorado, Universidade Federal do Rio de Janeiro, Rio de Janeiro, 156 p.

LIMA, H.C. 2011a. *Dalbergia*. In Lista de Espécies da Flora do Brasil. http://floradobrasil.jbrj.gov.br/2011/FB22908 (accessed 13/02/2012)

LIMA, H.C. 2011b. *Tachigali*. In Lista de Espécies da Flora do Brasil. http://floradobrasil.jbrj.gov.br/2011/FB23195 (accessed 13/02/2012)

LIMA, H.C., CORREIA, C.M.B. & FARIAS, D.S. 1994. Leguminosae. In Reserva Ecológica de Macaé de Cima, Nova Friburgo, RJ: Aspectos florísticos das espécies vasculares, v.1 (M.P.M. Lima & R.R. Guedes-Bruni, orgs.). Jardim Botânico do Rio de Janeiro, Rio de Janeiro, p.167-228.

LIMA, H.C., QUEIROZ, L.P., MORIM, M.P., SOUZA, V.C., DUTRA, V.F., BORTOLUZZI, R.L.C., IGANCI, J.R.V., FORTUNATO, R.H., VAZ, A.M.S.F., SOUZA, E.R., FILARDI, F.L.R., VALLS, J.F.M., GARCIA, F.C.P., FERNANDES, J.M., MARTINS-DA-SILVA, R.C.V., PEREZ, A.P.F., MANSANO, V.F., MIOTTO, S.T.S., TOZZI, A.M.G.A., MEIRELES, J.E., LIMA, L.C.P., OLIVEIRA, M.L.A.A., FLORES, A.S., TORKE, B.M., PINTO, R.B., LEWIS, G.P., BARROS, M.J.F., RIBEIRO, R.D., SCHÜTZ, R., PENNINGTON, T., KLITGAARD, B.B., RANDO, J.G., SCALON, V.R., CARDOSO, D.B.O.S., COSTA, L.C., SILVA, M.J., MOURA, T.M., BARROS, L.A.V., SILVA, M.C.R., QUEIROZ, R.T., SARTORI, A.L.B. & CAMARGO, R. 2010a. Fabaceae. In Catálogo de Plantas e fungos do Brasil vol. 2. (R.C. Forzza et al., eds.). Andrea Jakobsson Estudio: Instituto de Pesquisas Jardim Botânico do Rio de Janeiro, Rio de Janeiro, p. 989-1102.

LIMA, L.C.P., GARCIA, F.C.P. & SARTORI, A.L.B. 2007. Leguminosae nas florestas estacionais do Parque Estadual do Itacolomi, Minas Gerais, Brasil: ervas, arbustos, subarbustos, lianas e trepadeiras. Rodriguésia 58: 331-358.

LIMA, L.C.P., OLIVEIRA, M.L.A.A. & TOZZI, A.M.G. 2010b. *Desmodium* . In Catálogo de Plantas e fungos do Brasil vol. 2. (R.C. Forzza et al., eds.). Andrea Jakobsson Estudio: Instituto de Pesquisas Jardim Botânico do Rio de Janeiro, Rio de Janeiro, p. 1029-1030.

LIMA, L.C.P., GARCIA, F.C.P. & SARTORI, A.L.B. 2010c. As Leguminosas arbóreas das florestas estacionais do Parque Estadual do Itacolomi, Minas Gerais, Brasil. Rodriguésia 61:441-466.

LIMA, M.P.M., GUEDES-BRUNI, R.R., SYLVESTRE, L.S., PESSOA, S.V.A. & ANDREATA, R.H.P. 1997. Padrões de distribuição geográfica das espécies vasculares da Reserva Ecológica de Macaé de Cima. In Serra de Macaé de Cima: diversidade florística e conservação em Mata Atlântica (H.C. Lima & R.R. Guedes-Bruni, eds.). Jardim Botânico, Rio de Janeiro, p.103-123.

LORENZI, H. 1992. Árvores brasileiras: manual de identificação e cultivo de plantas arbóreas nativas do Brasil v1. Plantarum, Nova Odessa.

MANSANO, V.F., PINTO, R.B. & TORKE, B.M. 2011. *Swartzia.* In Lista de Espécies da Flora do Brasil. http://floradobrasil.jbrj.gov.br/2011/FB23178 (accessed 13/02/2012)

MARÉCHAL, R., MASCHERPA, J. M. & STAINER, F. 1978. Étude taxonomique d'un groupe complex d'espéces des genres *Phaseolus* et *Vigna* (Papilionaceae) sur la base de données morphologiques et polliniques, traitées par l'analyse informatique. Boissiera 28:1-273.

MATTOS, N.F. 1979. O gênero *Andira* Lam. (Leguminosae-Papilionoideae) no Brasil. Acta Amazônica 9:241-266.

MEGURO, M.; PIRANI, J. R.; GIULIETTI, A. M. & MELLO-SILVA, R. 1994. Phytophysiognomy and composition of the vegetation of Serra do Ambrósio, Minas Gerais, Brazil. Revista Brasil. Bot. 17:149-166.

MENDONÇA-FILHO, C.V. 1996. Braúna, angico, jacarandá e outras leguminosas de Mata Atlântica: Estação Biológica de Caratinga, Minas Gerais. Fundação Botânica Margaret Mee; Fundação Biodiversitas, Belo Horizonte.

MENDONÇA-FILHO, C.V., TOZZI, A.M.G.A. & MARTINS, E.R.F. 2007. Revisão taxonômica de *Machaerium* sect. *Oblonga* (Benth.) Taub. (Leguminosae, Papilionoideae, Dalbergieae). Rodriguésia 58:283-312.

MENDONÇA, R.C., FELFILI, J.M., WALTER, B.M.T., SILVA JR., M.C., REZENDE, A.V., FILGUEIRAS, T.S. & NOGUEIRA, P.E. 1998. Flora vascular do cerrado. In Cerrado: Ambiente e Flora. (S.M. Sano & S.P. Almeida, eds.). Embrapa-CPAC, Planaltina, p.289-539.

MESSIAS, M.C.T.B.; DIAS, S.J.; ROSCHEL, M.B.; SOUSA, H.C. & MATOS, A.M. 1997. Levantamento florístico das matas e distribuição de algumas espécies endêmicas da área do Parque Estadual do Itacolomi. UFOP/BIRD/IEF-PROFLORESTA. Relatório Técnico, Ouro Preto.

MESSIAS, M.C.T.B. & SOUZA, H.C. 2006. Plano de Manejo do parque Estadual do Itacolomi - Flora. Relatório Final, Ouro Preto.

MILES, L., NEWTON, A.C., DEFRIES, R..S., RAVILIOUS, C., MAY, I., BLYTH, S., KAPOS, V. & GORDON, J. E. 2006. A global overview of the conservation status of tropical dry forests. Journal of Biogeography 33:491-505. http://dx.doi.org/10.1111/j.1365-2699.2005.01424.

MIOTTO, S.T.S. 1987. Os gêneros *Centrosema* (DC.) Benth. e *Clitoria* L. (Leguminosae, Faboideae) no Rio Grande do Sul. Iheringia, série Botânica 36:15-39.

MITTERMEIER, R.A., GIL, P.R., HOFFMANN, M., PILGRIM, J., BROOKS, T., MITTERMEIER, C.G., LAMOREUX, J. & FONSECA, G.A.B. 2005. Hotspots Revisited: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions. CEMEX; Agrupación Sierra Madre, Washington.

MORIM, M.P. 2006. Leguminosae arbustivas e arbóreas da floresta atlântica do Parque Nacional do Itatiaia, sudeste do Brasil: padrões de distribuição. Rodriguésia 57:27-45.

MORIM, M.P. & BARROS, M.J.F. 2011. *Senegalia*. In Lista de Espécies da Flora do Brasil. Jardim http://floradobrasil.jbrj.gov.br/2011/FB100997 (accessed 13/02/2012)

MULLER, C. 1984. Revisão Taxonômica do gênero *Poiretia* Vent. (Leguminosae) para o Brasil. Dissertação de Mestrado, Universidade Estadual de Campinas, Campinas, 150p.

NALINI JUNIOR, H.A., GARCIA, M.P.L & CASTRO, P.T.A. 2006. Plano de Manejo do parque Estadual do Itacolomi – Meio físico. Relatório Final, Ouro Preto.

NUNES, S.R.D.F.S., GARCIA, F.C.P., LIMA, H.C. & CARVALHO-OKANO, R.M. 2007. Mimosoideae (Leguminosae) arbóreas do Parque Estadual do Rio Doce, Minas Gerais, Brasil: distribuição geográfica e similaridade florística na Floresta Atlântica no Sudeste do Brasil. Rodriguésia 58:403-421.

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. & RATTER, J.A. 1995. A study of the origin of central Brazilian forests by the analysis of plant species distribution patterns. Edinburgh J. Bot. 52:141-194.

OLIVEIRA-FILHO, A.T.; VILELAS, E.A.; GAVILANES, M.L.; CARVALHO, D.A. 1994. Comparison of the flora and soils of six areas of Montane Semideciduous Forest in southern Minas Gerais, Brazil. Edinburgh J. Bot. 51:355-389.

PENNINGTON, R.T. 2003. Monograph of *Andira* (Leguminosae-Papilionoideae). Syst. Bot. Monogr. 64: 1-143.

PENNINGTON, R.T., PRADO, D.A. & PENDRY, C. 2000 Neotropical seasonally dry forests and Pleistocene vegetation changes. Journal of Biogeography 27:261–273.

PENNINGTON, R.T., LAVIN, M., PRADO, D.E., PENDRY, C.A., PELL, S.K. & BUTTERWORTH, C.A. 2004. Historical climate change and speciation: neotropical seasonally dry forest plants show patterns of both Tertiary and Quaternary diversification. Philosophical Transactions of the Royal Society of London Series B-Biological Sciences 359: 515–538.

PENNINGTON, R.T., RICHARDSON, J.E. & LAVIN, M. 2006. Insights into the historical construction of species-rich biomes from dated plant phylogenies, neutral ecological theory and phylogenetic community structure. New Phytologist 172: 605–616.

PENNINGTON, T.D. 1997. The genus *Inga*: Botany. Royal Botanic Gardens, Kew.

PERON, M.V. 1989. Listagem preliminar da flora fanerogâmica dos Campos Rupestres do Parque Estadual do Itacolomi, Ouro Preto/Mariana, MG. Rodriguésia 41:63-69.

PIRANI, J.R., MELLO-SILVA, R. & GIULIETTI, A.M. 2003. Flora de Grão-Mogol, Minas Gerais, Brasil. Bol. Bot. Univ. São Paulo 21:1-24.

POSTON, M. E. 1980. Flora of Panama. Ann. Missouri Bot. Gard. 67:582-593.

PRADO, D.E. & GIBBS, P.E. 1993. Patterns of species distributions in the dry seasonal forests of South America. Ann. Missouri Bot. Gard. 80:902-927.

QUEIROZ, L.P. 1999. Sistemática e filogenia do gênero *Camptosema* W.J.Hook. & Arn. (Leguminosae: Papilionoideae: Phaseoleae). Tese de Doutorado, Universidade de São Paulo, São Paulo, 259p.

QUEIROZ, L.P. 2006. The Brazilian Caatinga: phytogeographical patterns inferred from distribution data of the Leguminosae. In Neotropical Savannas and Seasonally Dry Forests: plant diversity, biogeography, and conservation (R.T. Pennington, G.P. Lewis & J.A Ratter, eds.). Taylor & Francis Boca Raton, p.122 -157.

QUEIROZ, L.P. 2008. Re-Establishment, synopsis and new combinations in the genus *Bionia* Mart. ex Benth. (Leguminosae: Papilionoideae). Neodiversity 3: 13-18.

RANDO,J.G&PIRANI,J.R.2011.Padrões de distribuição geográfica das espécies de *Chamaecrista* sect. *Chamaecrista* ser. *Coriaceae* (Benth.) H. S. Irwin & Barneby, Leguminosae – Caesalpinioideae. Revista Brasil. Bot. 34:499-513. http://dx.doi.org/10.1590/S0100-84042011000400004

RAPINI, A; RIBEIRO, P.L.; LAMBERT, S. & PIRANI, J.R. 2008. A flora dos campos rupestres da Cadeia do Espinhaço. Megadiversidade 4:16-24.

RIBEIRO, J.F. 1998. Cerrado: Matas de galeria. Embrapa-CPAC, Planaltina.

RUDD, V.E. 1958. A revision of the genus *Chaetocalyx*. Contributions from the National Herbarium 32:207-245.

RUDD, V.E. 1965. The American species of *Ormosia* (Leguminosae). Contributions from the National Herbarium 32:278-384.

SANDERS, N.J. & RAHBEK, C. 2012. The patterns and causes of elevational diversity gradients. Ecography 35: 1–3.

SANTOS, M.F.; SERAFIM, H. & SANTO, P.T. 2011. An analysis of species distribution patterns in the Atlantic Forests of Southeastern Brazil. Edinburgh J. Bot. 68:373-400.

SARTORI, A.L.B. & TOZZI, A.M.G.A. 1998. As espécies de *Machaerium* Pers. (Leguminosae-Papilioinoideae-Dalbergieae) ocorrentes no Estado de São Paulo. Revista Brasil. Bot. 21:211-246. http://dx.doi.org/10.1590/S0100-84041998000300001

SCALON, V.R. 2007. Revisão Taxonômica do gênero *Stryphnodendron* Mart. (Leguminosae-Mimosoideae). Tese de doutorado, Universidade de São Paulo, São Paulo, 264p.

SCHRIRE, B.D.; LEWIS, G.P. & LAVIN, M. 2005. Biogeography of the Leguminosae. In Leguminosae of the world (G.P. Lewis, B. D. Schrire, B. A. Mackinder & J. M. Lock, eds.). Royal Botanic Gardens, Kew, p. 21-54.

SILVA, L.F.G. 2007. Taxonomia das espécies dos gêneros *Tachigali* Aubl. e *Sclerolobium* Vogel (Leguminosae - Caesalpinioideae) da Mata Atlântica. Dissertação de Mestrado, Jardim Botânico do Rio de Janeiro, Rio de Janeiro, 65p .

SOUZA, V.C. & BORTOLUZZI, R.L.C. 2011a. *Chamaecrista.* In Lista de Espécies da Flora do Brasil. http://floradobrasil.jbrj.gov.br/2011/FB22876 (accessed 13/02/2012)

SOUZA, V.C. & BORTOLUZZI, R.L.C. 2011b. *Senna.* In Lista de Espécies da Flora do Brasil. http://floradobrasil.jbrj.gov.br/2011/FB23149 (accessed 13/02/2012)

TAMASHIRO, J.Y. 1989. Estudos taxonômicos morfológicos do gênero *Piptadenia*, sensu Bentham no sudeste do Brasil. Avaliação das modificações taxonômicas recentemente propostas. Dissertação de Mestrado, Universidade Estadual de Campinas, Campinas, 99p.

VAZ, A.M.S.F. 2011. *Phanera.* In Lista de Espécies da Flora do Brasil. http://floradobrasil.jbrj.gov.br/2011/FB25673 (accessed 13/02/2012)

VAZ, A.M.S.F. & TOZZI, A.M.G.A. 2003. *Bauhinia* ser. *Cansenia* (Leguminosae: Caesalpinioideae) no Brasil. Rodriguésia 54:55-143.

VELOSO, H.P., RANGEL FILHO, A.L. & LIMA, J.C.A. 1991. Classificação da vegetação brasileira, adaptada a um sistema universal. IBGE, Rio de Janeiro.

ZAPPI, D.C., LUCAS, E., STANNARD, B.L., LUGHADHA, E.N., PIRANI, J.R., QUEIROZ, L.P., ATKINS, S., HIND, D.J.N., GIULIETTI, A.M., HARLEY, R.M. & CARVALHO, A.M. 2003. Lista das plantas vasculares de Catolés, Chapada Diamantina, Bahia, Brasil**.** Bol. Bot. Univ. São Paulo 21:345-398.

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inventory

Anurans of a threatened savanna area in western Brazil

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Abstract **-** The Upper Paraguay River Basin is located in the center of South America and harbors one of the largest wetland in the world, known as Pantanal. This floodplain is surrounded by uplands, which presently have most of their area converted into pastures or monocultures, besides being poorly known scientifically. Also, most of these upland areas are considered conservation priorities. Here we present a list of anuran species from a savanna-like area (municipality of Camapuã, state of Mato Grosso do Sul, Brazil) inserted in the uplands surrounding the Pantanal floodplain, in the Upper Taquari River sub-basin, and evaluate the effectiveness of the sampling effort. Data were obtained through active searches in 22 plots in aquatic habitats, during the rainy season (from December 2009 to April 2010). We found 26 species, in four families. Although sampling effort was found to sufficiently represent the local anuran assemblage, future inventories in this region should ideally include samplings during the dry and early rainy seasons, and include both active and passive capturing methods.
Keywords: *Amphibia, veredas, Upper Taquari River sub-basin, biological inventories, environmental degradation.*

SUGAI, J. L. M. M.; TERRA, J. S. E FERREIRA, V. L. **Anuros de uma ameaçada área de savana no oeste do Brasil.** *Biota Neotropica.* 14(1): e20134058. biotaneotropica.org.br/v14n1/pt/abstract?inventory+bn00314012014

Resumo **-** A bacia do Alto Paraguai, localizada no centro da América do Sul, abriga uma das maiores áreas inundáveis do mundo, conhecida como Pantanal. Essa planície alagável é rodeada por planaltos, os quais possuem grande parte de sua área convertida em pastagens ou monoculturas, além de serem pouco conhecidos cientificamente. Além disso, a maioria das áreas de planalto são consideradas prioritárias para a conservação. Apresentamos uma lista de espécies de anuros de uma área semelhante a savanas (município de Camapuã, estado de Mato Grosso do Sul, Brasil) inserida nos planaltos de entorno do Pantanal, na sub-bacia do Alto Taquari, e avaliamos a efetividade do esforço amostral. Os dados foram obtidos através de busca ativa em 22 parcelas em ambientes aquáticos, durante a estação chuvosa (de Dezembro de 2009 a Abril de 2010). Encontramos 26 espécies, em quatro famílias. Apesar de considerarmos o esforço amostral suficiente para representar da comunidade de anuros local, sugerimos que futuros inventários nessa região contemplem a estação seca e início da chuvosa, bem como o uso adicional de métodos passivos de captura.
Palavras-chave: *Amphibia, veredas, sub-bacia do Alto Taquari, inventários biológicos, degradação ambiental.*

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Introduction

The Upper Paraguay River basin, located in the center of South America (Brazil, Paraguay and Bolivia), is an unique region for harboring the sedimentary depression known as Pantanal, one of the largest wetlands in the world (Harris et al. 2006). It is formed by the Paraguay River and its tributaries, which have headwaters in upland areas surrounding the floodplain (Harris et al. 2006, Galdino & Vieira 2006). In the Brazilian part of the Upper Paraguay River basin, the fauna and flora consist mainly of species typical from the savanna-like Cerrado morphoclimatic domain (sensu Ab'Saber 1977), with influence from Amazon Forest in the northern region, Chaco in the southwestern region and Atlantic Forest in the southern region (Silva et al. 2000, Harris et al. 2006, Strüssmann et al. 2011).

Most of the Pantanal is still covered by natural vegetation (approximately 85%) since the flooding cycles hinder the expansion of agriculture and livestock (WWF 2010). However, more than half of the upland area around it was converted into pastures or monocultures like cotton, soybean and sugar cane (WWF 2010). One of the most degraded upland areas is the Upper Taquari River sub-basin, with only 34.4% of the original vegetation (WWF 2010). The removal of native vegetation causes huge erosions due to the high soil fragility, besides silting streams and rivers (Galdino & Vieira 2006). Most of the upland areas in Upper Paraguay River basin (including the Upper Taquari River sub-basin) are therefore considered priorities for conservation of Brazilian biodiversity and require both urgent reduction of environmental degradation and creation of conservation units (MMA 2007).

Environmental degradation is the main cause of worldwide biodiversity loss (Gibbons et al. 2000, Sala et al. 2000), which is not different regarding amphibians (Alford & Richards 1999, Young et al. 2001, Cushman 2006). In the new world, habitat loss affects 89% of all threatened amphibian species and is about three times more dominant than any other threat (Young et al. 2004). Environmental degradation causes loss of breeding sites, shelter and connectivity between aquatic habitats, leading to population declines, local extinctions and changes in community structure (Cushman 2006). In areas subjected to high levels of environmental degradation, such as the Upper Taquari River sub-basin, lots of data about natural history and distribution of anuran species are lost before being recorded, which leads to urgent need of field studies to record these information.

Most studies about anuran assemblages done in the Cerrado ecorregion (sensu Olson et al. 2001) are concentrated in its southeasternmost portion, with a lack of information about assemblages in other regions (Diniz-Filho et al. 2006). Information about the species richness and composition in the Upper Paraguay River basin are scarce (Strüssmann et al. 2000, Gordo & Campos 2003, 2005, Uetanabaro et al. 2006, 2007, Souza et al. 2010, Pansonato et al. 2011), and records involving the Upper Taquari River sub-basin (Strüssmann et al. 2000, Uetanabaro et al. 2006) are even rarer. At least 90 anuran species are estimated to occur in the Upper Paraguay River basin, and new occurrences are expected particularly in poorly known areas (Strüssmann et al. 2011). Aiming at decreasing lack of knowledge on the anurofauna in this watershed, we present a list of species from a Cerrado area in the municipality of Camapuã (state of Mato Grosso do Sul), inserted in the Upper Taquari River sub-basin. To improve future samplings, we also present an evaluation of the quality of the sampling effort.

Material and Methods

We sampled aquatic habitats in the surroundings of Pontinha do Cocho (19°01'07" S, 53°53'44" W), a small village in the municipality of Camapuã, state of Mato Grosso do Sul, Brazil (Figure 1). The sampled area ins located in the Upper Taquari River sub-basin, which is part of the ecological corridor between the Pantanal floodplain and important conservation units in the Cerrado ecorregion (Emas National Park and Nascentes do Taquari State Park) (MMA 2007; Figure 1). Local rainy season lasts from October to March and the dry season, from May to September, and average annual rainfall is 1506 mm (Soriano & Galdino 2006). The predominant human activity is cattle ranching, which requires large areas of pasture (Galdino & Vieira 2006). The region presents phytophysiognomies ranging from forest to savanna, including riparian forests, marshes and pasture areas (Oliveira-Filho & Ratter 2002, WWF 2010). Despite the predominance of degraded areas, there are fragments of riparian forests and marshes without the direct influence of livestock.

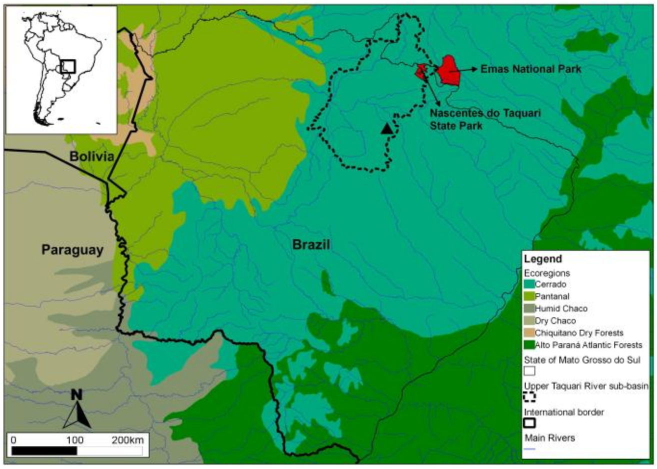

Figure 1. Map of the State of Mato Grosso do Sul, Brazil, with its location in South America showed in the upper left corner. The ecoregions follow the classification of Olson et al. (2001). The black triangle represents the location of the sampled area, inserted in the Upper Taquari River sub-basin (dashed line), which connects the Pantanal to important conservation units in the Cerrado (indicated in red).

Figura 1. Mapa do estado de Mato Grosso do Sul, Brazil, com sua localização na América do Sul mostrada no canto superior esquerdo. As ecorregiões seguem a classificação de Olson et al. (2001). O triângulo preto representa a localização da área amostrada, inserida na sub-bacia do Alto Taquari (linha tracejada), a qual liga o Pantanal a importantes unidades de conservação do Cerrado (indicadas em vermelho).

We sampled three types of aquatic habitats during the rainy season: *veredas*, permanent lagoons and temporary ponds. *Veredas* are marshy areas with slow running water, where groundwater emerges and is common the presence of the Buriti palm (*Mauritia flexuosa* L.f.) (Ribeiro & Walter 1998). Permanent lagoons are large water bodies formed by impoundments of small streams or *veredas*, while temporary ponds are natural depressions with accumulated rainwater. We performed three consecutive field samplings, all of them after the onset of the rains: from December 20 to 25, 2009; from January 23 to February 1, 2010; from March 15 to April 10, 2010. We sampled 18 points at *veredas*, two at permanent lagoons and two at temporary ponds, totaling 22 points (Table 1). Four were sampled in the first field sampling, five in the second, and 13 in the third. Once at each point, immediately after the nightfall (between 18 h 30 min and 19 h 30 min), two researchers actively searched for anurans (visually and acoustically; Crump & Scott 1994), for three hours on average.

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Table 1. Geographic coordinates of the 22 sampled aquatic habitats in the surroundings of Pontinha do Cocho village, municipality of Camapuã, state of Mato Grosso do Sul, Brazil.
Tabela 1. Coordenadas geograficas das 22 localidades amostradas em três tipos de ambientes aquáticos no entorno do vilarejo de Pontinha do Cocho, município de Camapuã, stato de Mato Grosso do Sul, Brasil.

Sampled location	Geographic coordinates
Temporary pond 1	19° 2'12.78"S, 53°53'44.92"W
Temporary pond 2	19° 0'50.10"S, 53°51'32.91"W
Permanent lagoon 1	19° 0'52.38"S, 53°51'29.89"W
Permanent lagoon 2	19° 1'31.02"S, 53°51'34.46"W
Vereda 1	19° 2'55.44"S, 53°53'46.17"W
Vereda 2	19° 1'19.26"S, 53°50'28.88"W
Vereda 3	19° 0'35.89"S, 53°51'40.38"W
Vereda 4	19° 0'54.45"S, 53°51'26.07"W
Vereda 5	19° 3'14.97"S, 53°53'44.14"W
Vereda 6	19° 1'15.08"S, 53°50'9.95"W
Vereda 7	19° 2'46.79"S, 53°53'51.03"W
Vereda 8	19° 5'58.58"S, 53°52'5.49"W
Vereda 9	19° 0'9.90"S, 53°51'25.20"W
Vereda 10	19° 0'28.35"S, 53°51'25.19"W
Vereda 11	19° 1'38.70"S, 53°50'47.39"W
Vereda 12	19° 1'38.16"S, 53°51'31.52"W
Vereda 13	19° 2'16.01"S, 53°49'54.23"W
Vereda 14	19° 0'45.23"S, 53°52'3.19"W
Vereda 15	19° 5'20.26"S, 53°52'43.50"W
Vereda 16	19° 2'8.26"S, 53°50'23.04"W
Vereda 17	19° 1'28.34"S, 53°51'30.82"W
Vereda 18	19° 1'8.05"S, 53°50'32.78"W

We constructed a rarefaction curve based on the samples and using the software EstimateS version 8.2.0 and 1000 randomizations (Colwell 2006). Rarefaction curves represent the statistical expectation of species richness at different numbers of individuals or samples (Gotelli & Colwell 2001). To evaluate the effectiveness of our sampling effort, we generated a nonlinear model from the rarefaction curve using the Clench equation: $Sn=a\cdot n/(1+b\cdot n)$ (Soberón & Llorente 1993). In this equation, n is the number of samples or individuals, Sn is estimated richness with n number of samples or individuals, and a and b are model parameters which determine the increase of species and the shape of the curve (Soberón & Llorente 1993), respectively. Then, we estimated the percentage of total species estimated by the model and calculated the tangent at the largest sample size of the rarefaction curve (Jiménez-Valverde & Hortal 2003). The tangent value represents the rate of species richness increase with higher sampling effort, and if it is small (near 0.1; above 0.3 can be considered high) few additional species are expected, even after larger sampling efforts (Jiménez-Valverde & Hortal 2003). We calculated the proportion of the maximum richness and the tangent value using the a and b model parameters (Jiménez-Valverde & Hortal 2003).

Voucher material of species that could not be correctly identified at the field was deposited at the zoological collection of Universidade Federal de Mato Grosso do Sul (ZUFMS AMP; Appendix 1). Tissue samples and recorded vocalizations were also deposited at ZUFMS (Appendix 2 and 3). License for collection and transportation of animals (number 23112-1) was provided by Instituto Chico Mendes de Conservação da Biodiversidade/Sistema de Autorização e Informação em Biodiversidade (ICMBio/SISBIO). Nomenclature follows Frost (2013).

Results

We found 26 species in 13 genera and four families (Table 2, Figure 2). The richest family was Hylidae (13 species), followed by Leptodactylidae (11 species). Bufonidae and Microhylidae were represented by only one species each. The rarefaction curve (Figure 3) did not reach an asymptote, but the tangent on the larger sample size was small (0.2). Moreover, the model estimates that we recorded 78% of the richness estimated at the asymptote, which can be considered a good sampling effort. Both the recorded tangent value and richness proportion indicate a small increase in species richness, with increasing sampling (Jiménez-Valverde & Hortal 2003).

Table 2. Anuran families and species registered in the sampled aquatic habitats in the surroundings of Pontinha do Cocho village, municipality of Camapuã, state of Mato Grosso do Sul, Brazil. PL: permanent lagoon; TP: temporary pond; VE: *vereda*.
Tabela 2. Famílias e espécies de anuros registrados nos corpos d'água amostrados no entorno do vilarejo de Pontinha do Cocho, município de Camapuã, estado de Mato Grosso do Sul, Brasil. PL: lagoa permamente; TP: poça temporária; VE: *vereda*.

Family/species	PL	TP	VE
BUFONIDAE			
Rhinella schneideri (Werner, 1894)	X		
HYLIDAE			
Dendropsophus elianeae (Napoli & Caramaschi, 2000)		X	X
Dendropsophus jimi (Napoli & Caramaschi, 1999)			X
Dendropsophus nanus (Boulenger, 1889)	X	X	X
Dendropsophus minutus (Peters, 1872)	X	X	X
Hypsiboas albopunctatus (Spix, 1824)			X
Hypsiboas raniceps Cope, 1862	X	X	X
Hypsiboas aff. geographicus			X
Hypsiboas punctatus (Schneider, 1799)			X
Phyllomedusa azurea Cope, 1862	X	X	
Pseudis platensis Gallardo, 1961	X		X
Scinax fuscovarius (Lutz, 1925)	X		X
Scinax fuscomarginatus (Lutz, 1925)		X	X
Trachycephalus typhonius (Linnaeus, 1758)	X		X
LEPTODACTYLIDAE			
Adenomera cf. diptyx (Boettger, 1885)			X
Eupemphix nattereri Steindachner, 1863	X	X	
Leptodactylus furnarius Sazima & Bokermann, 1978			X
Leptodactylus fuscus (Schneider, 1799)			X
Leptodactylus podicipinus (Cope, 1862)		X	X
Leptodactylus latrans (Steffen, 1815)			X
Leptodactylus mystacinus (Burmeister, 1861)			X
Physalaemus albonotatus (Steindachner, 1864)		X	
Physalemus cuvieri Fitzinger, 1826			X
Pseudopaludicola ternetzi Miranda-Ribeiro, 1937			X
Pseudopaludicola saltica (Cope, 1887)			X
MICROHYLIDAE			
Elachistocleis matogrosso Caramaschi, 2010			X

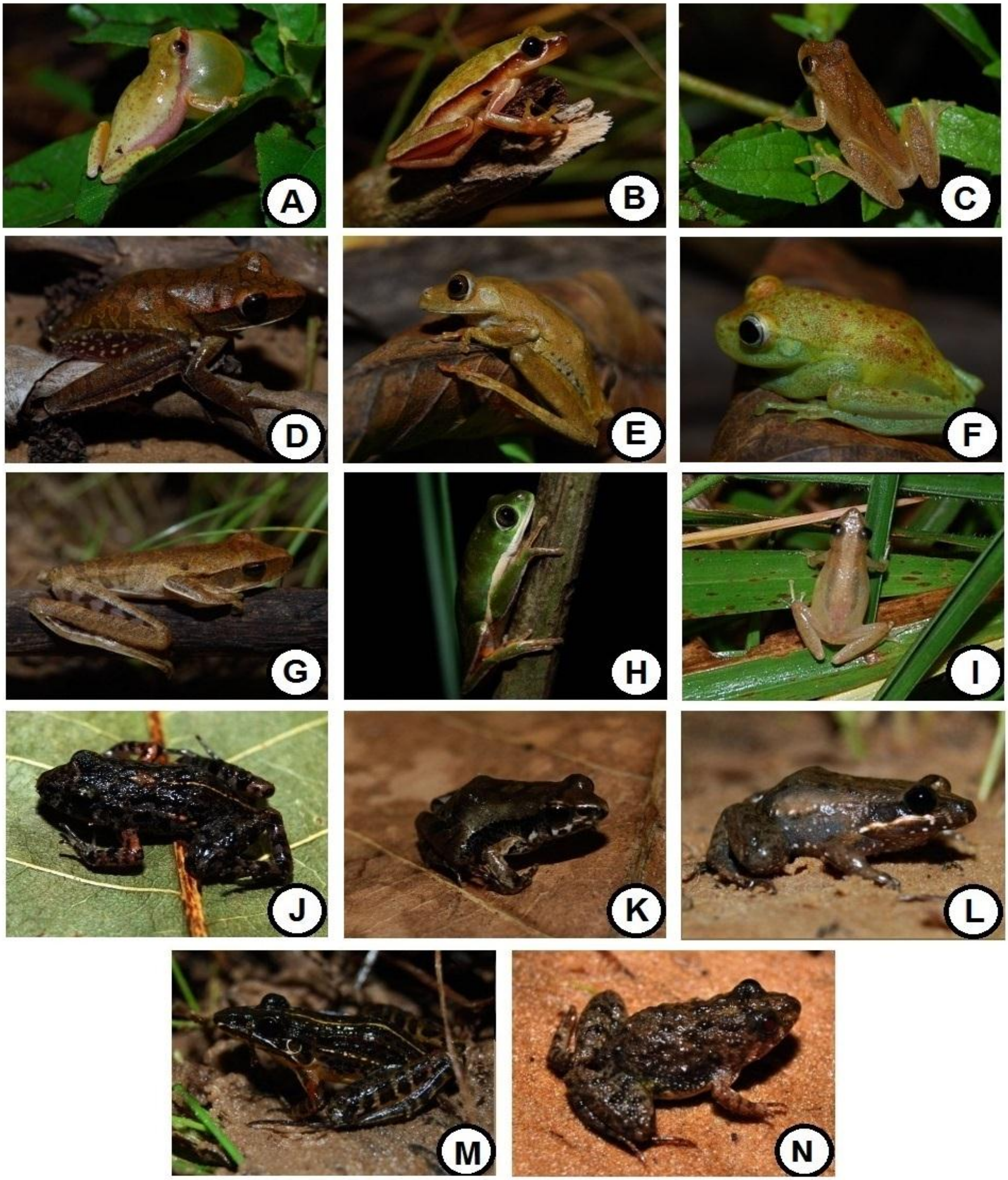

Figure 2. Photographs of some anuran species registered in the surroundings of Pontinha do Cocho village, municipality of Camapuã, Mato Grosso do Sul state, Brazil. A) *Dendropsophus elianeae*; B) *D. jimi*; C*) D. minutus;* D) *Hypsiboas albopunctatus;* E) *H.* aff. *geographicus*; F) *H. punctatus;* G) *H. raniceps*; H) *Phyllomedusa azurea*; I) *Scinax fuscomarginatus*; J) *Adenomera* cf. *diptyx*; K) *Physalaemus cuvieri*; L) *Leptodactylus podicipinus*; M) *Leptodactylus furnarius;* N) *Pseudopaludicola ternetzi*.

Figura 2. Fotografias de algumas espécies de anuros registradas no entorno do vilarejo de Pontinha do Cocho, município de Camapuã, estado de Mato Grosso do Sul, Brasil. A) *Dendropsophus elianeae*; B) *D. jimi*; C*) D. minutus;* D) *Hypsiboas albopunctatus;* E) *H.* aff. *geographicus*; F) *H. punctatus;* G) *H. raniceps*; H) *Phyllomedusa azurea*; I) *Scinax fuscomarginatus*; J) *Adenomera* cf. *diptyx*; K) *Physalaemus cuvieri*; L) *Leptodactylus podicipinus*; M) *Leptodactylus furnarius;* N) *Pseudopaludicola ternetzi*.

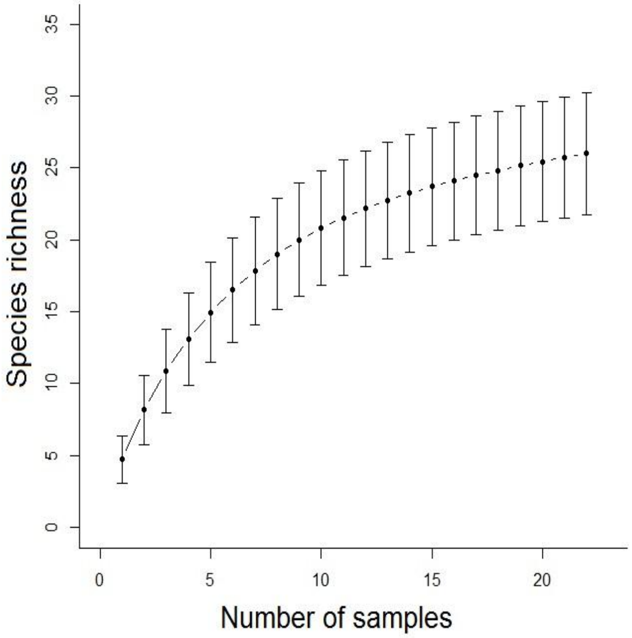

Figure 3. Rarefaction curve made for the 22 sampled points in the municipality of Camapuã, Mato Grosso do Sul state, Brazil. The vertical bars indicate the upper and lower limits of the 95% confidence interval.

Figura 3. Curva de rarefação feita para os 22 pontos amostrados no município de Camapuã, estado de Mato Grosso do Sul, Brasil. As barras verticais indicam o limite superior e inferior do intervalo de confiança de 95%.

Discussion

All species registered in this study have already been recorded in the Upper Taquari River sub-basin (Strüssmann et al. 2000) or in nearby areas (Uetanabaro et al. 2006, Silva-Junior et al. 2009). Four out of the 26 species found (*Dendropsophus jimi, Hypsiboas* aff. geographicus, *Leptodactylus furnarius* and *Pseudopaludicola ternetzi*) have been rarely recorded in Mato Grosso do Sul. *Dendropsophus jimi* was recorded in the municipalities of Chapadão do Sul and Costa Rica (Uetanabaro et al. 2006). Hypsiboas aff. geographicus was recorded in the municipality of Coxim (Strüssmann et al. 2000) and in Amolar mountain range, municipality of Corumbá (Gordo & Campos 2003, 2005). Our record for this species extends its distribution to nearly 150 km southeast of Coxim. *Leptodactylus furnarius* was recorded in the municipalities of Costa Rica (Uetanabaro et al. 2006) and Sonora (Silva-Junior et al. 2009). The record for *P. ternetzi*, confirmed by bioacustic data (Pansonato, A., unpublished data), is the first one for the species in Mato Grosso do Sul.

Phyllomedusa azurea and *Pseudis paradoxa* are classified as "Data Deficient" among the categories of the International Union for Conservation of Nature (IUCN) Red List (Angulo 2008a, b). The remaining species (except for *Hypsiboas* aff. *geographicus*) are classified as "Least Concern" (IUCN 2013). *Hypsiboas* aff. *geographicus* probably represents an undescribed species, for which few data are available (Strüssmann et al. 2000, Gordo e Campos 2005, Pansonato et al. 2011).

We did not sample during the dry season and early rainy season, which probably decreased the possibilities of recording some additional species expected for the region due to nearby records and availability of reproductive habitats (such as *Hypsiboas lundii* and species of the *Rhinella granulosa* group), mainly active during these periods (Strüssmann et al. 2000, Uetanabaro et al. 2006). Furthermore, active searches are not efficient for sampling fossorial and criptozoic *taxa* (Crump & Scott 1994), and probably more species with these habits would have been recorded if we had used more than one sampling method (e.g., active search + pitfall traps). This region also harbors areas with mounds and rocky outcrops where associated species – which do not occur in the aquatic habitats sampled – are expected to be found (Strüssmann et al. 2000, Uetanabaro et al. 2006).

Despite almost half of the species recorded during this study present taxonomic problems (*Adenomer* cf. *diptyx*: Heyer 1984, De la Riva 1996; *Hypsiboas* aff. *geographicus*: Duellman 1973) or may represent species complexes due to great morphological, bioacustic, chromosomal or genetic variation (*Dendropsophus nanus*: Medeiros et al. 2003, Reichle et al. 2004; *D. minutus*: Kaplan 1994, Hawkins et al. 2007; *Hypsiboas punctatus*: Napoli & Cruz 2005; *Scinax fuscovarius*: Faivovich et al. 2005, Aquino et al. 2010; *S. fuscomarginatus*: Cardoso & Pombal Jr. 2010, Pombal Jr. et al. 2011; *Leptodactylus fuscus:* Heyer & Reid 2003, Camargo et al. 2006; *L. latrans*: Gallardo 1964, De la Riva & Maldonado 1999, Heyer et al. 2010a; *L. mystacinus*: Heyer et al. 2003, Heyer et al. 2010b; *Physalaemus albonotatus*: Aquino et al. 2004, Jansen et al. 2011), nomenclature changes depend on future taxonomic revision. Well-resolved taxonomy and systematics are assumptions to identify species at risk and to improve the current knowledge about the diversity and distribution of species (Young et al. 2001, Aleixo 2009). Species richness reported in many inventories is underestimated due to cryptic species, which are sometimes revealed by including non-morphological characters in taxonomic analysis (Fouquet et al. 2007a, b). Although several recent studies have revised problematic taxonomic groups in Anura (e.g. *Pseudopaludicola*; Duarte et al. 2010, Fávero et al. 2011, Pansonato et al. 2012, 2013), there are still many in need of studies using integrative taxonomy, such as *Adenomera* and *Scinax* (Heyer 1984, Kwet 2007, Zaracho & Hernando 2011, Nunes et al. 2012). Samplings in poorly known regions, such as that of the present study, contribute to taxonomic and systematic revisions with vouchers, vocalizations records, material for molecular analysis and species distribution data.

An increase in the species list for the Upper Taquari River sub-basin is expected following additional samplings, especially in marsh or rocky outcrop areas, habitats not yet converted into pastures or monocultures. We suggest that future inventories in this region encompass both the dry and early rainy seasons and involve passive capture methods (e.g. pitfall traps) in addition to active searches. Despite the local environmental degradation and the lack of biological knowledge, this particular watershed is an important area for the conservation of Cerrado anuran assemblages because it harbors species that are poorly known scientifically. Furthermore, it is part of the ecological corridor between the Pantanal floodplain and important conservation units in the Cerrado (MMA 2007).

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References

AB'SABER, A.N. 1977. Os domínios morfoclimáticos na América do Sul. USP/IGEOG, São Paulo, Geomorfologia 52:1-23.

ALEIXO, A. 2009. Conceitos de espécie e suas implicações para a conservação. Megadiversidade 5(1-2):87-95.

ALFORD, R.A. & RICHARDS, S.J. 1999. Global amphibian declines: a problem in applied ecology. Ann. Rev. Ecol. Syst. 30:133-165.

ANGULO, A. 2008a. *Pseudis platensis*. In IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. http://www.iucnredlist.org (ultimo acesso em 13/12/2013).

ANGULO, A. 2008b. *Phyllomedusa azurea*. In IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. http://www.iucnredlist.org (ultimo acesso em 13/12/2013).

AQUINO, L., REICHLE, S., SILVANO, D. & LANGONE, J. 2004. *Scinax fuscovarius*. In IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. http://www.iucnredlist.org (ultimo acesso em 13/12/2013).

AQUINO, L., BASTOS, R., REICHLE, S., SILVANO, D., BALDO, D. & LANGONE, J. 2010. *Scinax fuscovarius*. In IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. http://www.iucnredlist.org (ultimo acesso em 13/12/2013).

CAMARGO, A., DE SÁ, R.O. & HEYER, W.R. 2006. Phylogenetic analyses of mtDNA sequences reveal three cryptic lineages in the widespread neotropical frog *Leptodactylus fuscus* (Schneider, 1799) (Anura, Leptodactylidae). Biol. J. Linn. Soc. 87:325-341.

CARDOSO, M.W. & POMBAL-JÚNIOR., J.P. 2010. A new species of small Scinax Wagler, 1830 (Amphibia, Anura, Hylidae) of the Scinax ruber clade from Cerrado of central Brazil. Amphibia-Reptilia 31:411–418.

COLWELL, R.K. 2006. EstimateS: Statistical estimation of species richness and shared species from samples. Version 8.

CRUMP, M.L. & SCOTT JR, N.J. 1994. Visual encounter surveys. In Measuring and Monitoring Biological Diversity Standard Methods for Amphibians (W. R. Heyer, M. A. Donnelly, R. W. McDiarmid, L. A. C. Hayek & M. S. Foster, eds). Smithsonian Institution Press, Washington, p.84-92.

CUSHMAN, S.A. 2006. Effects of habitat loss e fragmentation on amphibians: a review e prospectus. Biol. Cons. 128:231-240.

DE LA RIVA, I. 1996. The specific name of Adenomera (Anura: Leptodactylidae) in the Paraguay River Basin. J. Herpetol. 30(4):556-558.

DE LA RIVA, I. & MALDONADO, M. 1999. First record of *Leptodactylus ocellatus* (Lunnaeus, 1758) (Amphibia, Anura, Leptodactylidae) in Bolivia and comments on related species. Graellsia 55:193-197.

DINIZ-FILHO, J.A.F., BINI, L.M., RANGEL, T.F.L.V.B., CARVALHO, P., PINTO, M.P., COUTO, M.S.D.S. & BASTOS, R.P. 2006. Conservation biogeography of anurans in Brazilian Cerrado. Biodivers. Conserv. 16:997-1008.

DUARTE, T.C., VEIGA-MENONCELLO, A.C.P., LIMA, J.F.R., STRÜSSMANN, C., DEL-GRANDE, M.L., GIARETTA, A.A., PEREIRA, E.G., ROSSA-FERES, D.C. & RECCO-PIMENTEL, S.M. 2010. Chromosome analysis in *Pseudopaludicola* (Anura, Leiuperidae), with description of sex chromosomes XX/XY in *P. saltica*. Hereditas 147:43-52.

DUELLMAN, W.E. 1973. Frogs of the *Hyla geographica* group. Copeia 1973(3):515-532.

FAIVOVICH, J., HADDAD, C.F.B., GARCIA, P.C.A., FROST, D.R., CAMPBELL, J.A., WHEELER, W.C. 2005. Systematic review of the frog family Hylidae, with special reference to Hylinae: phylogenetic analysis and taxonomic revision. Bull. Am. Mus. Nat. Hist. 294:1-240.

FÁVERO, E.R., VEIGA-MENONCELLO, A.C.P., ROSSA-FERES, D.C., STRÜSSMANN, C., GIARETTA. A.A., ANDRADE, G.V., COLOMBO, P. & RECCO-PIMENTEL, S.M. 2011. Intrageneric karyotypic variation in *Pseudopaludicola* (Anura: Leiuperidae) and its taxonomic relatedness. Zool. Stud. 50(6):826-836.

FOUQUET A., GILLES, A., VENCES, M., MARTY, C., BLANC, M. & GEMMELL, N.J. 2007a. Underestimation of species richness in Neotropical frogs revealed by mtDNA analyses. PLoS ONE 2(10):e1109.

FOUQUET, A., VENCES, M., SALDUCCI, M.D., MEYER, A., MARTY, C., BLANC, M. & GILLES, A. 2007b. Revealing cryptic diversity using molecular phylogenetics and phylogeography in frogs of the *Scinax ruber* and *Rhinella margaritifera* species groups. Mol. Phylogenet. Evol. 43(2):567-582.

FROST, D.R. 2013. Amphibian species of the world: an online regerence. Version 5.6. http://research.amnh.org/herpetology/amphibia/index.html (ultimo acesso em 12/06/2013).

GALDINO, S. & VIEIRA, L.M.. 2006. A Bacia do Rio Taquari e seus problemas ambientais e socioeconômicos. In Impactos ambientais e socioeconômicos na Bacia do Rio Taquari – Pantanal (S. Galdino, L.M. Vieira & L.A. Pellegrin, eds.). Embrapa Pantanal, Corumbá, p.29-41.

GALLARDO, J.M. 1964. Consideraciones sobre *Leptodactylus ocellatus* (L.) (Amphibia, Anura) y especies aliadas. Physis 24(68): 373-384.

GIBBONS, J.W., SCOTT, D.E., RYAN, T.J., BUHLMANN, K.A., TUBERVILLE, T.D., METTS, B.S., GRANDENE, J.L., MILLS, T., LEIDEN, Y., POPPY, S. & WINNE, C.T. 2000. The global decline of reptiles, deja-vu amphibians. Bioscience 50(8):653-667.

GORDO, M.; CAMPOS, Z. 2003. Listagem de anuros da Estação Ecológica Nhumirim e arredores, Pantanal Sul. Embrapa Pantanal, Série Documentos 58:1-21.

GORDO, M. & CAMPOS, Z.M.S. 2005. Anuros das serras de entorno do Pantanal Sul. Embrapa Pantanal, Série Documentos 78:1-21.

GOTELLI, N. & COLWELL, R.K. 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecol. Lett. 4:379-391.

HARRIS, M.B.; ARCANGELO, C.; PINTO, E.C.T.; CAMARGO, G.; RAMOS-NETO, M.B. e SILVA, S.M. 2006. Estimativa da perda de cobertura vegetal original na Bacia do Alto Paraguai e Pantanal brasileiro: ameaças e perspectivas. Natur. Conserv. 4(2):164-179.

HAWKINS, M.A., SITES, J.W. & NOONA, B.P. 2007. *Dendropsophus minutus* (Anura : Hylidae) of the Guiana Shield: using DNA barcodes to assess identity and diversity. Zootaxa 1540:61–67.

HEYER, W.R. 1984. The systematic status of *Adenomera griseigularis* Henle, with comments on systematic problems in the genus *Adenomera* (Amphibia, Leptodactylidae). Amphibia-Reptilia 5:97-100.

HEYER, M.M., HEYER, W.R., SPEAR, S. & DE SÁ, R.O. 2003. *Leptodactylus mystacinus (Burmeister)*.Cat. Am. Amph. Rept. 767: 1-9.

HEYER, W.R. & REID, Y.R. 2003. Does advertisement call variation coincide with genetic variation in the genetically diverse frog taxon currently known as Leptodactylus fuscus (Amphibia: Leptodactylidae)? An. Acad. Bras. Ciênc. 75(1):39-54.

HEYER, W.R., LANGONE, J., LA MARCA, E., AZEVEDO-RAMOS, C., DI TADA, I., BALDO, D., LAVILLA, E., NORMAN, S., AQUINO, L. & HARDY, J. 2010a. *Leptodactylus latrans*. In IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. http://www.iucnredlist.org/ (ultimo acesso em 13/12/2013).

HEYER, W.R., SILVANO, D., REICHLE, S., LAVILLA, E. & DI TADA, I. 2010b. *Leptodactylus mystacinus*. In IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. (ultimo acesso em 13/12/2013).

IUCN. 2013. The IUCN Red List of Threatened Species. http://www.iucnredlist.org (ultimo acesso em 13/12/2013).

JANSEN, M., BLOCH, R., SCHULZE, A. & PFENNINGER, M. 2011. Integrative inventory of Bolivia's lowland anurans reveals hidden diversity. Zool. Scrip. 40(6):567-583.

JIMÉNEZ-VALVERDE, A. & HORTAL, J. 2003. Las curvas de acumulación de especies y la necesidad de evaluar la calidad de los inventarios biológicos. Rev. Ibér. Aracnol. 8:151–161.

KAPLAN, M. 1994. A new species of frog of the genus *Hyla* from the Cordillera Oriental in northern Columbia with comments on the taxonomy of *Hyla minuta*. J. Herpetol. 28(1):79-87.

KWET, A. 2007. Bioacoustic variation in the genus *Adenomera* in southern Brazil, with revalidation of *Leptodactylus nanus* Müller, 1922 (Anura: Leptodactylidae). Mus. Nat. kd. Berl. Zool. 83:56-68.

MEDEIROS, L.R., ROSSA-FERES, D.C. & RECCO-PIMENTEL, S.M. 2003. Chromosomal differentiation of Hyla nana and Hyla sanborni (Anura Hylidae) with a description of NOR polymorphism in H nana. J. Hered. 94(2):149–154.

MMA. 2007. Áreas Prioritárias para Conservação, Uso Sustentável e Repartição de Benefícios da Biodiversidade Brasileira: Atualização - Portaria MMA n°9, de 23 de janeiro de 2007. Ministério do Meio Ambiente, Secretaria de Biodiversidade e Florestas, Brasília.

NAPOLI, M.F. & CRUZ, I.C.S. 2005. The advertisement call of *Hyla atlantica* Caramaschi & Velosa, 1996, with considerations on its taxonomic status (Amphibia, Anura, Hylidae). Arq. Mus. Nac. Rio de Janeiro 63(2):283-288.

NUNES, I., KWET, A. & POMBAL-JÚNIOR, J.P. 2012. Taxonomic Revision of the Scinax alter Species Complex (Anura: Hylidae). Copeia 2012(3): 554-569.

OLIVEIRA-FILHO, A.T. & RATTER, A. 2002. Vegetation Physiognomies e Woody Flora of the Cerrado Biome. In The Cerrados of Brazil: Ecology and Natural History of a Neotropical Savanna (P.S. Oliveira & R.J. Marquis, eds.). Columbia University Press, Nova York, p.91-120.

OLSON, D.M., DINERSTEIN, E., WIKRAMANAYAKE, E.D., BURGESS, N., POWELL, G.V.N., UNDERWOOD, E., D'AMICO, J.A., STRAND, H.E., MORRISON, J.C., LOUCKS, C.J., ALLNUTT, T.F., RICKETTS, T.H., KURA, Y., LAMOREUX, J.F., WETTENGEL, W.W., HEDAO, P. & KASSEM, K.R. 2001. Terrestrial ecoregions of the world: a new map of life on Earth. Bioscience 51(11):933–938.

PANSONATO, A., MOTT, T. & STRÜSSMANN, C. 2011. Diversidade de anfíbios anuros em uma area na porção noroeste do Pantanal brasileiro. Biota Neotrop. 11(4):77-86 http://www.biotaneotropica.org.br/v11n4/pt/abstract?article+bn01711042011 (ultimo acesso em 12/06/2013).

PANSONATO, A., MORAIS, D.H., ÁVILA, R.W., KAWASHITA-RIBEIRO, R.A., STRÜSSMANN, C. & MARTINS, I.A. 2012. A new species of *Pseudopaludicola* Miranda-Ribeiro, 1926 (Anura: Leiuperidae) from the state of Mato Grosso, Brazil, with comments on the geographic distribution of *Pseudopaludicola canga* Giaretta & Kokubum, 2003. Zootaxa 3523:49-58.

PANSONATO, A., STRÜSSMANN, C., MUDREK, J.R. & MARTINS, I.A. 2013. Morphometric and bioacoustic data on three species of *Pseudopaludicola* Miranda-Ribeiro, 1926 (Anura: Leptodactylidae: Leiuperinae) described from Chapada dos Guimarães, Mato Grosso, Brazil, with the revalidation of *Pseudopaludicola ameghini* (Cope, 1887). Zootaxa 3620(1):147-162.

POMBAL-JÚNIOR., J.P., BILATE, M., GAMBALE, P.G., SIGNORELLI, L. & BASTOS, R.P. 2011. A New Miniature Treefrog of the *Scinax ruber* Clade from the Cerrado of Central Brazil (Anura: Hylidae). Herpetologica 67(3):288-299.

REICHLE, S., AQUINO, L., COLLI, G., SILVANO, D., AZEVEDO-RAMOS, C. & BASTOS, R. 2004. *Dendropsophus nanus*. In IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. http://www.iucnredlist.org (ultimo acesso em 13/12/2013).

RIBEIRO, J.F. & WALTER, B.M.T. 1998. Fitofisionomias do bioma Cerrado. In Cerrado: Ambiente e Flora (S.M. Sano & S.P. Almeida, eds.). Embrapa Cerrado, Planaltina, p.89-166.

SALA, O.E., CHAPIN, F.S.I., ARMESTO, J.J., BERLOW, E., BLOOMFIELD, J., DIRZO, R., HUBER-SANWALD, E., HUENNEKE, L.F., JACKSON, R.B., KINZIG, A., LEEMANS, R., LODGE, D.M., MOONEY, H.A., OESTERHELD, M., POFF, N.L., SYKES, M.T., WALKER, B.H., WALKER, M. & WALL, D.H. 2000. Global biodiversity scenarios for the year 2100. Science 287:1770-1774.

SILVA, M.P., MAURO, R., MOURÃO, G. & COUTINHO, M. 2000. Distribuição e quantificação de classes de vegetação do Pantanal através de levantamento aéreo. Rev. Bras. Bot. 23(2):143-152.

SILVA-JUNIOR., N.J., CINTRA, C.E.D., SILVA, H.J.R., COSTA, M.C., SOUZA, C.A., PACHECO-JUNIOR., A.A. & Gonçalves, F.A. 2009. Herpetofauna, Ponte de Pedra Hydroelectric Power Plant, states of Mato Grosso and Mato Grosso do Sul, Brazil. Check List 5(3):518-525.

SOBERÓN, J. & LLORENTE, J. 1993. The use of species accumulation functions for the prediction of species richness. Conserv. Biol. 7(3):480-488.

SORIANO, B.M.A. & GALDINO, S. 2006. Evolução da erosividade das chuvas na bacia do Alto Taquari. In Impactos ambientais e socioeconômicos na Bacia do Rio Taquari - Pantanal (S. Galdino, L.M. Vieira & L.A. Pellegrin, eds.). Embrapa Pantanal, Corumbá, p.119-124.

SOUZA, F.L., UETANABARO, M., LANDGREF-FILHO, P., PIATTI, L. & PRADO, C.P.A. 2010. Herpetofauna, municipality of Porto Murtinho, Chaco region, state of Mato Grosso do Sul, Brazil. Check List 6(3):470-475.

STRÜSSMANN, C., PRADO, C.P.A., UETANABARO, M. & FERREIRA, V.L. 2000. Amphibians recorded during the AquaRAP survey of localities in the southern Pantanal floodplains e surrounding Cerrado, MS, Brasil. In Rapid assessment program, bulletin of biological assessment. A biological assessment of the aquatic ecosystems of the Pantanal, Mato Grosso do Sul, Brasil (P. Willink *et al.* eds). Conservation International, Washington, p.98-102.

STRÜSSMANN, C., PRADO, C.P.A., FERREIRA, V.L. & KAWASHITA RIBEIRO, R. 2011. Diversity, ecology, management and conservation of amphibians and reptiles of the Brazilian Pantanal: a review. In: The Pantanal: Ecology, biodiversity ad sustainable management of a large neotropical seasonal wetland (W.J. Junk, C.J. Da Silva & K.M. Wantzen eds.). Pensoft Publishers. Sofia-Moscow. p.497-521.

UETANABARO, M.O., GUIMARÃES, L.D., BEDA, A.F., FILHO, P.L., PRADO, C.P.A., BASTOS, R.P. & AVILA, R.W. 2006. Inventário da Herpetofauna no complexo Aporé-Sucuruí. In Biodiversidade do Complexo Aporé-Sucuruí – Subsídios à Conservação e Manejo do bioma Cerrado (Pagotto, T.C.S. e Souza, P.S. eds.). Campo Grande, Editora UFMS. p129-142.

UETANABARO, M., SOUZA, F.L., LANDGREF-FILHO, P., BEDA, A.F. & BRANDÃO, R.A. 2007. Anfíbios e répteis do Parque Nacional da Serra da Bodoquena, Mato Grosso do Sul, Brasil. Biota Neotrop. 7(3):279-289 http://www.biotaneotropica.org.br/v7n3/pt/abstract?inventory+bn01207032007 (ultimo acesso em 12/06/2013).

WWF – WORLD WILDLIFE FUND. 2010. Monitoramento das alterações da cobertura vegetal e uso do solo na Bacia do Alto Paraguai. Disponível em: http://www.wwf.org.br/informacoes/bliblioteca/?25181/Monitoramento-das-alteracoes-dacobertura-veget al.-e-uso-do-solo-na-Bacia-do-Alto-Paraguai (ultimo acesso em 13/12/2013).

YOUNG, B.E., LIPS, K.R., REASER, J.K., IBÁÑES, R., SALAS, A.W., CEDEÑO, J.R., COLOMA, L.A., RON, S., MARCA, E., MEYER, J.R., MUÑOZ, A., BOLAÑOS, F., CHAVES, G. & ROMO, D. 2001. Population declines and priorities for amphibian conservation in Latin America. Conserv. Biol. 15(5): 1213-1223.

YOUNG B.E., STUART, S.N., CHANSON, J.S., COX, N.A. & BOUCHER, T.M. 2004. Disappearing Jewels: The Status of New World Amphibians. Natureserve, Arlington.

ZARACHO, V.H. & HERNANDO, A.B. 2011. The karyotype of *Adenomera diptyx* (Boettger 1885) (Anura, Leptodactylidae) from northeastern Argentina. Genet. Mol. Biol. 34(1):84–87.

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Appendix 1. List of vouchers collected in the municipality of Camapuã (Mato Grosso do Sul state, Brazil) and deposited at the zoological collection of Universidade Federal de Mato Grosso do Sul - UFMS.

Apêndice 1. Lista do material testemunho coletado no município de Camapuã (estado de Mato Grosso do Sul, Brasil) e depositados na coleção zoológica da Universidade Federal de Mato Grosso do Sul - UFMS.

Species	Collection number
Adenomera cf. *diptyx*	ZUFMS AMP02669
Dendropsophus jimi	ZUFMS AMP2659
Dendropsophus elianeae	ZUFMS AMP2660
Hypsiboas aff. *geographicus*	ZUFMS AMP2642 - 02646, 02652
Hypsiboas albopunctatus	ZUFMS AMP2665 - 2668
Leptodactylus furnarius	ZUFMS AMP2661 - 2664
Pseudopaludicola ternetzi	ZUFMS AMP2653 - 2657

Appendix 2. List of anuran sample tissue collected in the municipality of Camapuã (Mato Grosso do Sul state, Brazil) and deposited at the zoological collection of Universidade Federal de Mato Grosso do Sul - UFMS.

Apêndice 2. Lista de amostra de tecido de anuros coletada no município de Camapuã (estado de Mato Grosso do Sul, Brasil) e depositados na coleção zoológica da Universidade Federal de Mato Grosso do Sul - UFMS.

Species	Collection number
Pseudopaludicola ternetzi	ZUFMS AMP3408 - 3414
Pseudopaludicola cf. *saltica*	ZUFMS AMP3415 - 3416

Appendix 3. List of anuran vocalizations recorded in the municipality of Camapuã (Mato Grosso do Sul state, Brazil) and deposited at the zoological collection of Universidade Federal de Mato Grosso do Sul - UFMS.

Apêndice 3. Lista de vocalizações de anuros gravadas no município de Camapuã (estado de Mato Grosso do Sul, Brasil) e depositados na coleção zoológica da Universidade Federal de Mato Grosso do Sul - UFMS.

Species	Collection number
Hypsiboas punctatus	ZUFMS D0001
Leptodactylus furnarius	ZUFMS D0002
Pseudopaludicola ternetzi	ZUFMS D0003 - 5
Scinax fuscomarginatus	ZUFMS D0006