Article

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Bryophytes of the Parque Estadual da Serra do Brigadeiro, an Atlantic Forest Remnant in Southeastern Brazil[1]

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ABSTRACT – (Bryophytes of the Parque Estadual da Serra do Brigadeiro, an Atlantic Forest remnant in Southeastern Brazil). The objective was to present the floristic survey of the bryophytes of the Parque Estadual da Serra do Brigadeiro. It included an evaluation of the species richness, as well as information about the substrate preference of each species and its geographic distributions in Brazil. We found 208 taxa of bryophytes: one hornwort, 88 liverworts and 119 mosses. This richness represents ca. 26% of the bryoflora of Minas Gerais State and ca. 13% of that known for Brazil. Eighteen of the bryophytes species are endemic to Brazil, whereas 19 species are recorded for the first time in Minas Gerais. The bryoflora showed preference for tree bark (30%) and rock (23%) as substrates. Our data show that the Parque Estadual da Serra do Brigadeiro is an important area for the diversity conservation of Brazilian bryophytes and maintenance of endemic species of the country.
Keywords: conservation, liverworts, Minas Gerais State, mosses, substrate

RESUMO – (Briófitas do Parque Estadual da Serra do Brigadeiro, um remanescente de Mata Atlântica no Sudeste do Brasil). O objetivo foi apresentar o levantamento florístico das briófitas do Parque Estadual da Serra do Brigadeiro, incluindo uma avaliação da riqueza de espécies, bem como informações sobre a preferência de substrato de cada espécie e suas distribuições geográficas no Brasil. Encontramos 208 táxons de briófitas: um antócero, 88 hepáticas e 119 musgos. Essa riqueza representa 26% da brioflora do Estado de Minas Gerais e 13% do Brasil. Dezoito das espécies de briófitas são endêmicas do Brasil, enquanto 19 espécies são registradas pela primeira vez em Minas Gerais. A brioflora mostrou preferência pelo substrato casca de árvore (30%) e rocha (23%). Os dados obtidos mostram que o Parque Estadual da Serra do Brigadeiro é uma área importante para a conservação da diversidade de briófitas brasileiras e para a manutenção de espécies endêmicas do país.
Palavras-chaves: conservação, hepáticas, Estado de Minas Gerais, musgos, substrato

Introduction

Bryophytes are nonvascular plants characterized by a life cycle featuring alternating haploid and diploid generations, with the gametophyte as the main life form, which helps and feeds the unbranched, unisporangiate sporophyte (Vanderpoorter & Goffinet 2009). The monophyly of the three bryophyte groups and the Setaphyta clade of liverworts and mosses as the sister to Traqueophyta has been supported (Puttick *et al.* 2018), contrary to the view of three lineages of bryophytes like a paraphyletic group (Goffinet & Shaw 2009) and hornworts as the sister to vascular plants (Qiu *et al.* 2006).

These three groups are represented by ca. 18, 000 species worldwide (Goffinet & Shaw 2009). In Brazil, 1,578 taxa have been recorded (Flora do Brasil 2020, 2020), and the country has the highest rate of endemism (22%) (Flora do Brasil 2020, 2020).

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Bryophyte representativeness is especially high in the Atlantic forest, which harbors 87% of all taxa recorded for the country (Flora do Brasil 2020, 2020). This biome is recognized as a biodiversity *hotspot* with a high percentage of endemic species (Myers *et al.* 2000, Stehmann *et al.* 2009), including mosses and liverworts. Unfortunately, it is under intensive process of deforestation and destruction, and only ca. 28% of the native vegetation cover persists as isolated fragments in different stages of succession, with only 30% of the total vegetation cover found in protected areas, 9% of them are strictly protected and 21% of sustainable use (Rezende *et al.* 2018). Consequently, this bryoflora could be seriously threatened and many species could disappear without being known to science.

Several floristic surveys of bryophytes in Minas Gerais State were done in the Atlantic Forest, such as Parque Estadual de Ibitipoca (Luizi-Ponzo *et al.* 2013, Yano & Luizi-Ponzo 2014, Siviero & Luizi-Ponzo 2015), Serra Negra (Amorin *et al.* 2017), and Parque Nacional da Serra do Cipó (Yano & Peralta 2011a, Sousa & Câmara 2015). However, due the great size of the state, there are still large gaps in the knowledge of the brioflora of Minas Gerais State (Amorin 2013).

The Parque Estadual da Serra do Brigadeiro (PESB) is located in one of the areas of the Atlantic Forest that still comprises large tracts of continuous forest (Plano de Manejo PESB- Parque Estadual da Serra do Brigadeiro 2007). The Park has a variety of geographical, climatic and phytophysiological conditions, and, consequently, it harbors a high quality and quantity of microhabitats, with variation in the availability of nutrients (Benites *et al.* 2001), a key factor in the diversity patterns of bryophytes (Pócs 1982, Newmaster *et al.* 2005). For these reasons, the PESB harbors a diverse community of bryophytes with high numbers of endemic species, many of which have not been previously recorded for the state of Minas Gerais.

Despite its relevance, the bryoflora of the PESB is still poorly known. There are only three papers citing bryophytes collected in the PESB: Crum (1994), describing a new species, *Sphagnum leonii*, Leoni & Tinte (2004) listing 52 species that occur in the area, and Castro *et al.* (2011) listing the herbarium specimens.

In this paper, we present a detailed floristic survey of the bryophytes of the PESB, including an assessment of species richness, as well as information on substrate preference of each species, and its geographical distributions at the national level according to Flora do Brasil 2020 (2020).

Materials and methods

Study site - The Parque Estadual da Serra do Brigadeiro (PESB) is a protected area under state administration, located among the municipalities of Ervália, Fervedouro, Sericita, Araponga, Miradouro, Pedra Bonita, Muriaé and Divino, in the State Minas Gerais, Brazil. The Park covers an area of 14,985 ha between the geographical coordinates 20º33' to 21º00'S and 42º40' to 40º20'W (figure 1, map was generated using ArcGIS® software). The vegetation in the Park is composed of secondary fragments inserted in the area of Atlantic Forest biome (Caiafa & Silva 2005) and has two types of vegetal formations, according with IBGE (2012): (1) semideciduous forest from the altomontana formation and (2) high-altitude fields (campos de altitude).

Floristic surveys - Specimens were collected during four field expeditions between May 2017 and April 2018, along eight preexistent trails located in the northern, central and southern areas of the Park (approximate coordinates plotted in figure 1). Collecting effort was intended to cover the range of habitats and microhabitats (substrate type) available for bryophytes, like soil, trunks, lianas, shrubs, rocks, in both semideciduous forest and high-altitude fields, between 1000 to 1540 m of elevation, following Frahm's recommendations (2003). Specimens were deposited at VIC herbarium, with duplicates in SP (Acronyms follow Index Herbariorum, Thiers, 2020).

Bryophyte identification - For the specimen identification we used keys and specialized literature for to each family (Yano & Peralta 2011a, Frahm 1991, Sharp *et al.* 1994, Yano & Carvalho 1995, Gradstein, Churchill, *et al.* 2001, Gradstein & Costa 2003, Bordin & Yano 2013).

Our classification follows Söderström *et al.* (2016) for Anthocerotophyta and Marchantiophyta and Goffinet *et al.* (2009) for Bryophyta. The taxa are listed in alphabetical order by families, genera, and species, indicating endemic species and those recorded for the first time for Minas Gerais State. Distribution data was obtained from Flora do Brasil 2020 (2020), as well as from Santos *et al.* (2017), Carmo & Peralta (2016), Costa & Peralta (2015), Machado *et al.* (2015), Yano & Luizi-Ponzo (2014), Yano & Peralta (2011a), and Gradstein & Costa (2003).

Species classification according to substrate types follows Robbins (1952): (1) corticolous, species that grow on living trunks and branches; (2) epiphyllous, those that grow on leaves; (3) epixylic, on dead or decaying trunk; (4) rupicolous, on stones; and (5) terrestrial, on the ground.

Results

We collected and analyzed 514 specimens, corresponding to 208 species of bryophytes: one hornwort, 88 liverworts (20 families, 41 genera) and 119 mosses (32 families, 63 genera), (table 1). These taxa comprise 208 species, three varieties and one subspecies.

The best represented liverworts families were Lejeuneaceae, with 35 species (36%), Plagiochilaceae, with 10 (11%), and Lepidoziaceae, with six (6%), whereas the best represented moss families were Leucobryaceae, with 16 species (13%), Sematophyllaceae, with 12 (10%), and Pilotrichaceae, with nine (7%). The most representative genera in liverworts were *Plagiochila* and *Lejeunea*, with 10 species each; in mosses, the most speciose genera were *Campylopus*, with 10 species, and *Fissidens*, with nine, (table 1).

Table 1. List of bryophytes found in the Parque Estadual da Serra do Brigadeiro, Minas Gerais State, Brazil, with their substrate. Voucher information corresponds to the collecting series of Libia Mayerly Cifuentes (LMC). *: New record for Minas Gerais State. **: Endemic species. ***: New record for Minas Gerais State and Endemic species.

Taxa	Substrato	Voucher
Anthocerotophyta		
Anthocerotaceae		
Anthoceros punctatus L.	Soil	659
Bryophyta		
Bartramiaceae		
Breutelia tomentosa (Sw. ex Brid.) A. Jaeger	Soil	350
Leiomela bartramioides (Hook.) Paris	Rock/Tree bark	351
Philonotis sphaerocarpa (Hedw.) Brid.	Rock/Soil	479
Philonotis uncinata (Schwägr.) Brid.	Rock	514
Brachytheciaceae		
Rhynchostegium serrulatum (Hedw.) A. Jaeger	Soil/Tree bark	659
Squamidium brasiliense Broth.	Rock/Soil	704
Zelometeorium patens (Hook.) Manuel	Rock/Tree bark	410
Zelometeorium patulum (Hedw.) Manuel	Rock/Tree bark	759
Bryaceae		
***Brachymenium hornschuchianum* Mart.	Tree bark	484
Brachymenium patulum (Müll. Hal.) Schimp. ex Besch.	Tree bark	502
Bryum argenteum Broth.	Rock	479
Bryum cellulare Hook.	Rock	479
***Bryum subapiculatum*	Soil	477
Rhodobryum subverticillatum Broth.	Rock	352
Rosulabryum canariense (Brid.) Ochyra	Soil	495
Rosulabryum densifolium (Brid.) Ochyra	Rock/Soil	677
Calymperaceae		
Octoblepharum albidum Hedw.	Rock	491
***Syrrhopodon brasiliensis* W. D. Reese	Tree bark	554
Syrrhopodon gaudichaudii Mont.	Tree bark	536
Syrrhopodon incompletus Schwägr.	Decayed wood	690
Syrrhopodon leprieuri Mont.	Rock	446
Syrrhopodon prolifer Schwägr.	Decayed wood/Tree bark/Rock/Soil	552
Syrrhopodon tortilis Hampe	Rock	605
Cryphaeacea		
Schoenobryum concavifolium (Griff.) Gangulee	Tree bark	485
Daltoniaceae		
Calyptrochaeta setigera (Mitt.) W. R. Buck	Tree bark	594
Dicranaceae		
Holomitrium arboreum Mitt.	Soil	696
Holomitrium crispulum Mart.	Rock	504
****Leucoloma triforme* (Mitt.) A. Jaeger	Soil/Tree bark	559

continue

Table 1 (continuation)

Taxa	Substrato	Voucher
Entodontaceae		
Entodon argyreus (Besch.) Besch.	Rock	650
Fissidentaceae		
Fissidens asplenioides Hedw.	Rock	409
**Fissidens dissitifolius* Sull.	Tree bark	716
Fissidens elegans Brid.	Rock	580
Fissidens hornschuchii Mont.	Rock/Tree bark	725
Fissidens pellucidus Hornsch	Tree bark	760
Fissidens saprophilus Broth.	Tree bark	539
Fissidens scariosus Mitt.	Soil	507
Fissidens zollingeri Mont.	Rock	756
Hookeriaceae		
**Crossomitrium epiphyllum* (Mitt.) Müll. Hal.	Tree bark	646
**Crossomitrium saprophilum* Broth.	Rock	667
Hypnaceae		
Chryso-hypnum diminutivum (Hampe) W. R. Buck	Rock/Soil/Tree bark	492
Chryso-hypnum elegantulum (Hook.) Hampe	Rock	680
Mittenothamnium reptans (Hedw.) Cardot	Tree bark	424
Hypopterygiaceae		
Hypopterygium tamariscinum (Hedw.) Brid.	Tree bark	439
**Lopidium concinnum* (Hook.) Wilson	Rock/Tree bark	600
Lembophyllaceae		
Orthostichella pachygastrella (Müll. Hal. ex Ångstr.) B. H. Allen & Magill	Tree bark	428
Pilotrichella flexilis (Hedw.) Ångström	Tree bark	557
Leucobryaceae		
Campylopus aemulans (Hampe) A. Jaeger	Rock	393
Campylopus arctocarpus (Hornsch.) Mitt.	Soil	399
Campylopus filifolius (Hornsch.) Mitt. var. *humile*	Soil/Tree bark	397
Campylopus filifolius (Hornsch.) Mitt. var. *filifolius*	Tree bark	522
Campylopus gastroalaris (Müll.Hal.) Paris	Tree bark	540
Campylopus julaceus A. Jaeger	Rock	497
Campylopus lamellinervis (Müll.Hal.) Mitt.	Soil	482
Campylopus pilifer Brid.	Rock	570
Campylopus savannarum (Müll. Hal.) Mitt.	Tree bark	516
***Leucobryum clavatum* Hampe	Soil/Tree bark	372
Leucobryum crispum Müll. Hal.	Soil	559
Leucobryum laevifolium Broth.	Rock	576
Pilopogon guadalupensis (Brid.) J. -P. Frahm	Rock	375
Meteoriaceae		

continue

Table 1 (continuation)

Taxa	Substrato	Voucher
Papillaria callochlorosa Müll. Hal.	Tree bark	647
Mniaceae		
Plagiomnium rhynchophorum (Hook.) T.J.Kop.	Rock/Soil /Tree bark	353
Neckeraceae		
Neckera ehrenbergii Müll. Hal.	Tree bark	588
Neckeropsis disticha (Hedw.) Kindb.	Tree bark	642
**Porotrichodendron superbum* (Taylor) Broth.	Rock	657
Porotrichum lancifrons (Hampe) Mitt.	Rock	447
Porotrichum longirostre (Hook.) Mitt.	Rock/Tree bark	413
Orthodontiaceae		
Hymenodon aeruginosus (Hook. f. & Wilson) Müll. Hal.	Rock/Tree bark	564
Orthotrichaceae		
**Groutiella apiculata* (Hook.) H. A. Crum & Steere	Tree bark	354
Groutiella tomentosa (Hornsch.) Wijk & Margad.	Tree bark	355
Macrocoma tenuis subsp. *sullivantii* (Müll.Hal.) Vitt	Tree bark	437
Macromitrium microstomum (Hook. & Grev.) Schwägr.	Tree bark	485
Macromitrium punctatum (Hook. & Grev.) Brid.	Tree bark	487
Macromitrium richardii Schwägr.	Tree bark	549
Macromitrium podocarpi Müll. Hal.	Tree bark	641
Schlotheimia appressifolia (Hornsch.) Wijk & Margad.	Tree bark	640
Schlotheimia jamesonii (Arn.) Brid.	Tree bark	641
Phyllogoniaceae		
Phyllogonium viride Brid.	Rock/Tree bark	366
Pilotrichaceae		
Cyclodictyon albicans (Hedw.) Kuntze	Rock	590
Cyclodictyon limbatum (Hampe) Kuntze	Tree bark	501
***Lepidopilum caudicaule* (Müll.Hal.) Broth.	Rock/Tree bark	436
Lepidopilum muelleri (Hampe) Mitt.	Rock/Tree bark	762
Lepidopilum scabrisetum (Schwägr.) Steere	Rock	758
Thamniopsis incurva (Hornsch.) W. R. Buck	Soil/Decayed wood	561
Thamniopsis langsdorffii (Hook.) W. R. Buck	Rock/Tree bark	724
**Trachyxiphium aduncum* (Mitt.) W. R. Buck	Soil	562
Trachyxiphium saxicola (R. S. Williams) Vaz-Imbassahy & Costa	Rock/Tree bark	501
Polytrichaceae		
Pogonatum campylocarpum (Müll. Hal.) Mitt.	Soil	542
***Polytrichum angustifolium* Mitt.	Rock/Soil	357
Polytrichum commune L. ex Hedw.	Rock	391
Polytrichum juniperinum Willd. ex Hedw.	Rock	356
Pottiaceae		

continue

Table 1 (continuation)

Taxa	Substrato	Voucher
Hyophila involuta (Hook.) A. Jaeger	Rock	478
Tortella humilis (Hedw.) Jenn.	Rock	480
Prionodontaceae		
Prionodon densus (Hedw.) Müll. Hal.	Tree bark	543
Pylaisiadelphaceae		
Isopterygium subbrevisetum (Hampe) Broth.	Tree bark	708
Isopterygium tenerum (Sw.) Mitt.	Tree bark	706
**Pylaisiadelpha tenuirostris* (Bruch & Schimp.) W. R. Buck	Decayed wood	685
Wijkia flagellifera (Broth.) H. A. Crum	Tree bark	591
Racopilaceae		
Racopilum tomentosum (Hedw.) Brid.	Rock/Tree bark	434
Rhacocarpaceae		
***Rhacocarpus inermis* (Müll. Hal.) Lindb. var. *inermis*	Rock	639
Rhizogoniaceae		
Pyrrhobryum spiniforme (Hedw.) Mitt.	Decayed wood/Soil/Tree bark	718
Sematophyllaceae		
***Aptychopsis estrellae* (Hornsch.) Ångström	Tree bark	517
***Aptychopsis pyrrophylla* (Müll.Hal.) Wijk & Margad.	Rock/Decayed wood	692
***Aptychopsis subpungifolia* (Broth.) Broth.	Tree bark	527
Brittonodoxa subpinnata (Brid.) W. R. Buck, P. E. A. S. Câmara & Carv.-Silva	Rock/Tree bark	459
Microcalpe subsimplex (Hedw.) W. R. Buck	Rock/Soil/Tree bark	585
Sematophyllum pectinatum (Herzog) Schäf.-Verw.	Rock/Tree bark	510
Sematophyllum subdepressum (Hampe) Broth.	Rock/Tree bark	526
Sematophyllum swartzii (Schwägr.) W. H. Welch & H. A. Crum	Soil/Tree bark	529
Vitalia cuspidifera (Mitt.) P. E. A. S. Câmara et al.	Rock	732
Vitalia galipensis (Müll. Hal.) P. E. A. S. Câmara et al.	Decayed wood	717
Sphagnaceae		
***Sphagnum gracilescens* Müll. Hal.	Rock	373
Sphagnum perichaetiale Hampe	Rock	655
Sphagnum sparsum Hampe	Rock	569
Sphagnum subsecundum Nees	Soil	700
Stereophyllaceae		
Eulacophyllum cultelliforme (Sull.) W. R. Buck & Ireland	Tree bark	754
Thuidiaceae		
Pelekium schistocalyx (Müll.Hal.) A. Touw	Soil/Tree bark	638
***Thuidium bifidum* A. Soares & P. E. A. S. Câmara	Soil	671
Thuidium delicatulum (Hedw.) Schimp.	Soil/Tree bark	550
Thuidium tomentosum Schimp.	Rock/Soil/Tree bark	407
Marchantiophyta		

continue

Table 1 (continuation)

Taxa	Substrato	Voucher
Adelanthaceae		
Syzygiella rubricaulis (Nees) Grolle	Rock/Tree bark	546
Aneuraceae		
Aneura pinguis (L.) Dumort.	Decayed wood	565
Riccardia chamedryfolia (With.) Grolle	Tree bark	501
Riccardia digitiloba (Spruce ex Steph.) Pagán	Decayed wood	596
***Riccardia emarginata* (Steph.) Hell	Soil	568
Riccardia metzgeriiformis (Steph.) R. M. Schust.	Rock/Soil	658
***Riccardia regnellii* (Aongström.) Hell	Rock	465
Balantiopsidaceae		
Neesioscyphus bicuspidatus (Steph.) Grolle	Soil	669
Neesioscyphus argillaceus (Nees) Grolle	Soil	676
Calypogeiaceae		
Calypogeia peruviana Nees & Mont.	Soil	568
Cephaloziaceae		
***Fuscocephaloziopsis crassifolia* (Lindenb. & Gottsche) Váňa & L. Söderstr	Tree bark	558
Odontoschisma variabile (Lindenb. & Gottsche) Trevis.	Tree bark	558
**Cephaloziopsis intertexta* (Gottsche) R. M. Schust.	Rock	581
Dumortieraceae		
Dumortiera hirsuta (Sw.) Nees	Rock/Soil	420
Frullaniaceae		
Frullania brasiliensis Raddi	Tree bark	360
Frullania caulisequa (Nees) Nees	Tree bark	546
Frullania ericoides (Nees) Mont.	Tree bark	462
Frullania riojaneirensis (Raddi) Spruce	Tree bark	456
Jungermanniaceae		
Jungermannia amoena Lindenb. & Gottsche	Soil	669
Lejeuneaceae		
Acrolejeunea emergens (Mitt.) Steph.	Tree bark	473
Anoplolejeunea conferta (C. F. W. Meissn.) A. Evans	Tree bark	536
Bryopteris filicina (Sw.) Nees	Rock/Tree bark	378
Cheilolejeunea acutangula (Nees) Grolle	Tree bark	574
Cheilolejeunea clausa (Nees & Mont.) R. M. Schust.	Rock	710
Cheilolejeunea comans (Spruce) R. M. Schust.	Tree bark	699
Cheilolejeunea filiformis (Sw.) W. Ye, R. L. Zhu & Gradst.	Soil/Tree bark	464
Cheilolejeunea rigidula (Nees ex Mont.) R.M. Schust.	Rock	709
Drepanolejeunea anoplantha (Spruce) Steph.	Leaves	463
Drepanolejeunea granatensis (J. B. Jack & Steph.) Bischl.	Leaves	537
Frullanoides tristis (Steph.) van Slageren	Tree bark	457

continue

Table 1 (continuation)

Taxa	Substrato	Voucher
**Lejeunea bermudiana* (A. Evans) R.M.Schust.	Leaves	438
Lejeunea caulicalyx (Steph.) E. Reiner & Goda	Leaves	723
***Lejeunea cristulata* (Steph.) E. Reiner & Goda	Rock	715
Lejeunea deplanata Nees	Tree bark	276
Lejeunea flava (Sw.) Nees	Decayed wood	736
Lejeunea laetevirens Nees & Mont.	Rock/Tree bark	411
***Lejeunea oligoclada* Spruce	Leaves	438
Lejeunea setiloba Spruce	Leaves/Tree bark	531
Lopholejeunea nigricans (Lindenb.) Schiffn.	Tree bark	711
Marchesinia brachiata (Sw.) Schiffn.	Tree bark	492
Neurolejeunea breutelii (Gottsche) A. Evans	Rock	508
**Prionolejeunea aemula* (Gottsche) A. Evans	Leaves	416
**Prionolejeunea denticulata* (Weber) Schiffn.	Leaves	411
**Prionolejeunea mucronata* (Sande Lac.) Steph.	Leaves	409
Schiffneriolejeunea polycarpa (Nees) Gradst.	Tree bark	483
**Lejeunea asthenica* (Spruce)	Tree bark	404
Lejeunea pterigonia (Lehm. & Lindenb.) Mont.	Rock/Tree bark	726
**Lejeunea serpillifolioides* (Raddi) Gradst.	Rock	363
Lepidoziaceae		
Bazzania stolonifera (Sw.) Trevis.	Leaves	689
Kurzia brasiliensis (Steph.) Grolle	Rock	605
Lepidozia cupressina (Sw.) Lindenb.	Tree bark	606
Lepidozia inaequalis (Lehm. & Lindenb.) Lehm. & Lindenb.	Tree bark	537
Telaranea diacantha (Mont.) Engel & Merr.	Decayed wood/ Rock/ Soil/Tree bark	554
Telaranea nematodes (Gottsche ex Austin)	Rock	465
Lophocoleaceae		
Cryptolophocolea martiana (Nees)	Decayed wood/ Rock/ Soil/Tree bark	404
Lophocolea bidentata (L.) Dumort.	Decayed wood/ Rock/ Soil/Tree bark	501
Lophocolea muricata (Lehm.) Nees	Decayed wood/Tree bark	537
Marchantiaceae		
Marchantia chenopoda L.	Rock	419
Marchantia papillata Raddi	Rock/Soil	494
Metzgeriaceae		
Metzgeria albinea Spruce	Rock/Tree bark	369
Metzgeria conjugata Lindb.	Rock/Tree bark	750
Metzgeria fruticola Spruce	Rock	739
Metzgeria furcata (L.) Dumort.	Tree bark	644
**Metzgeria hegewaldii* Kuwah.	Tree bark	458
Monocleaceae		
Monoclea gottschei Lindb.	Rock	468

continue

Table 1 (continuation)

Taxa	Substrato	Voucher
Noterocladaceae		
Noteroclada confluens Taylor ex Hook. & Wilson	Soil	669
Pallaviciniaceae		
Pallavicinia lyellii (Hook.) S. F. Gray	Soil	672
Symphyogyna aspera Steph.	Rock/Soil	469
Symphyogyna brasiliensis (Nees) Nees & Mont.	Rock/Soil Rock	703
Symphyogyna podophylla (Thunb.) Mont. & Nees	Rock/Soil	421
Plagiochilaceae		
Plagiochila adianthoides (Sw.) Lindenb.	Rock	426
Plagiochila bifaria (Sw.) Lindenb.	Decayed wood/Tree bark	532
Plagiochila corrugata (Nees) Nees & Mont.	Rock/Tree bark	764
Plagiochila martiana (Nees) Lindenb.	Tree bark	518
Plagiochila patentissima Lindenb.	Rock/Tree bark	733
Plagiochila patula (Sw.) Lindenb.	Tree bark	601
Plagiochila rutilans Lindenb.	Rock/Tree bark	500
Plagiochila simplex (Sw.) Lindenb.	Rock	412
Plagiochila subplana Lindenb.	Rock	725
Porellaceae		
Porella brasiliensis (Raddi) Schiffn.	Rock/Tree bark	492
Porella reflexa (Lehm. & Lindenb.) Trevis.	Rock	712
Porella swartziana (Weber) Trevis.	Rock/Tree bark	430
Radulaceae		
Radula mammosa Spruce	Tree bark	536
Radula nudicaulis Steph.	Rock/Tree bark	444
Radula recubans Taylor	Rock/Tree bark	583
Radula sinuata Gottsche ex Steph.	Tree bark	539
Radula javanica Gottsche	Rock	721
Trichocoleaceae		
**Leiomitria flaccida* (Spruce) J. B. Jack & Steph.	Tree bark	367

Regarding substrate colonization, 70% of the species were found in only one type of substrate: tree bark (63 taxa), rocks (49), soil (20), decayed wood (six), and live leaves (nine). The remaining species were found in two to four types of substrates.

Eighteen of the bryophyte species are endemic to Brazil, including 13 species of mosses and five liverworts, whereas 19 species (10%) are recorded for the first time in the Minas Gerais State (Flora do Brasil 2020 (2020), Carmo & Peralta 2016, Costa & Peralta 2015, Machado *et al.* 2015, Yano & Luizi-Ponzo 2014, Yano & Peralta 2011a, Gradstein & Costa 2003) (table 1).

Discussion

Bryophyte species richness and Brazilian distribution - The high bryophyte species diversity in the mountain ecosystems of the Neotropics has been related to the large variety of microhabitats and conditions of constant humidity that facilitate the co-occurrence of numerous species (Frahm 2003, Gradstein *et al.* 2008). The bryophytes found in this survey of the PESB correspond to ca. 26% of the species estimated for the State of Minas Gerais and 13% of those known for Brazil (Flora do Brasil 2020, 2020). In our list, we added 189 species to those previously recorded by

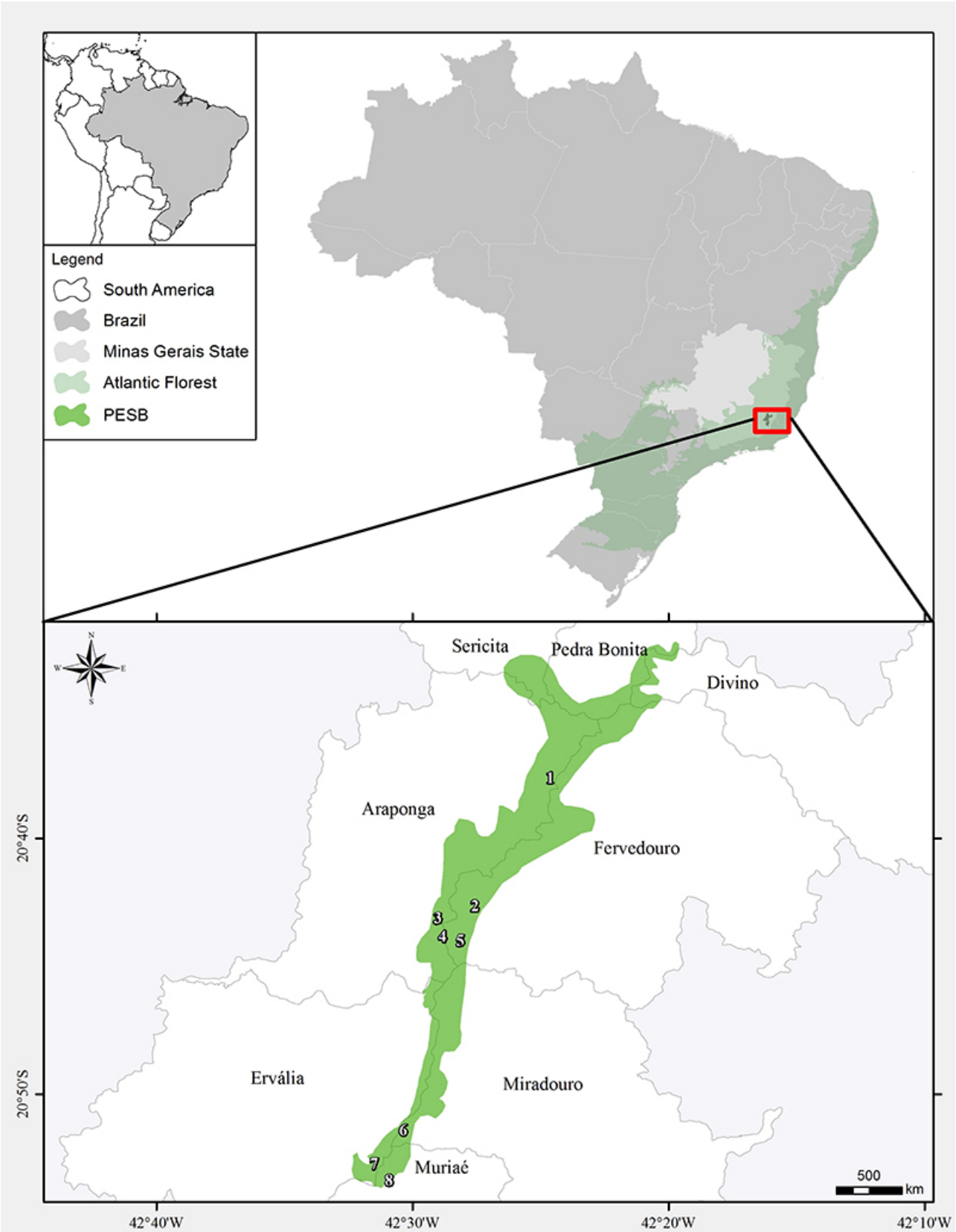

Figure 1. Location of Atlantic Forest domain in Brazil and sampling areas for bryophytes in the Parque Estadual da Serra do Brigadeiro in Minas Gerais State, Brazil. 1. Trilha do Laje do Ouro. 2. Trilha do Carvão. 3. Trilha do Pico do Grama. 4. Trilha da Lajinha. 5. Trilha da Pedra do Pato. 6. Trilha do Cruzeiro do Careço. 7. Trilha do Itajurú. 8. Trilha do Avião.

Leoni & Tinte (2004). The difference in species number is large, and the number of families and genera recorded are different, with 53 families and 105 genera versus 26 families and 40 genera listed in Leoni & Tinte (2004). In their list, these authors included the endemic species *Sphagnum leoni,* whose type locality is the PESB, and included also six other species that are doubtful records for Brazil.

Our results indicate a high diversity of bryophytes in the PESB. Yano & Peralta (2011a) found 237 species in the Parque Estadual da Serra do Cipó, Luizi-Ponzo *et al.* (2013) found 209 taxa in Parque Estadual de Ibitipoca, Amorim *et al.* (2017) recognized 92 species of the Serra Negra, and Carmo & Peralta (2016) recorded 289 species in Parque Nacional da Serra da Canastra.

Mosses presented a greater number of species than liverworts. This fact is common in high mountain ecosystems rather than in lowlands (Gradstein *et al.* 2001b) and this is consistent with results provided in other studies in high altitude areas (Yano & Peralta 2011a, 2011b, Luizi-Ponzo *et al.* 2013, Carmo & Peralta 2016). The predominance of mosses is explained by Costa *et al.* (2015) as a result of their life forms and the morphology of their gametophyte, which increases the ability to colonize open environments, such as rock outcrops, exposed soils, and banks; these microhabitats are abundant in the PESB, due to the wide altitudinal range of the area.

Lejeuneaceae was the best represented family in terms of species number, with 36% of the species. This comes as no surprise, as Lejeuneaceae is the largest family of liverworts in Brazil and in the tropics (Gradstein *et al.* 2001b, Gradstein & Costa 2003). Another well-represented family was Leucobryaceae (11%), a group reported by Yano & Peralta (2011a), Siviero & Luizi-Ponzo (2015) and Carmo & Peralta (2016) as having the greatest richness in high altitude areas in Minas Gerais State. The predominance of Leucobryaceae has been attributed to the acrocarpous growth habit of their gametophyte. Furthermore, they have hyalocysts cells in the leaves and alar cells at the basal angles of the leaves (*Campylopus*), which can store large amounts of water and thus can thrive in more exposed areas (Frahm 2003), a common habitat in the PESB.

On the other hand, 10% of the species found in the Park are endemic to Brazil (Flora do Brasil 2020 (2020), Costa & Peralta 2015). Some endemic species in the PESB are *Aptychopsis estrellae, Sphagnum gracilescens, Riccardia regnellii, Rhacocarpus inermis* var. *inermis, Polytrichum angustifolium* and *Bryum subapiculatum* (figure 2) (Flora do Brasil 2020 (2020), Costa & Peralta 2015, Machado *et al.* 2015, Yano & Luizi-Ponzo 2014, Gradstein & Costa 2003). For that reason, we assume that the PESB offers microhabitats of high quality and quantity, with moisture and nutrients available for these species; these variables have been pointed as determinants of diversity patterns in this group (Pócs 1982, Newmaster *et al.* 2005).

Substrate colonization - In the PEBS, most bryophytes showed substrate type preferences,with a greater number of species found in tree bark (63 taxa). This predominance could be related to heterogeneous conditions, such as the varied sizes of the phorophytes and the physical characteristics of bark -with more available colonization niches- (Bates 1992, Frahm 2003, Batista *et al.* 2018), combined with forest conditions of temperature, luminosity, and humidity (Batista & Santos 2016). In works done in the Atlantic Forest, Germano & Pôrto (2005), Sousa & Câmara (2015) and Siviero & Luizi-Ponzo (2015) also observed a greater number of corticicolous species and they also point to the reasons stated above.

The preference for substrate types has been attributed to the low humidity and to the need of occupying specialized microhabitats, to take advantage of their particular conditions (Batista *et al.* 2018). The annual average rainfall in the PEBS (1,300 mm/year) and it is characterized by a rainy period, during the months of November to March, which is the warmest, and by a dry period, from April to October (Plano de Manejo PESB- Parque Estadual da Serra do Brigadeiro 2007), so the preference for substrate types in bryophytes species of the PESB could be an important strategy for this climate conditions.

The frequency of species on rocky substrates (49 taxa) could be due to the abundant naked surfaces, mainly in the rocky outcrops and streams. In the Atlantic Forest numerous taxa grew on rocks and few species occurred on soil, probably as a result of the existence of a litter on the forest ground that makes difficult growth of the bryophytes (Santos & Costa 2008). In addition, a lower percentage of species growing in rocks and soil in the Atlantic Forest of northeastern Brazil was explained due to a minor heterogeneity in these substrates in contrast with tree bark (Batista *et al.* 2018).

On the other hand, epiphyllous species were scarce at our study site (nine taxa), and were represented only by liverworts: eight species of Lejeuneaceae and *Bazzania stolonifera* (table 1). The greatest representativeness of Lejeuneaceae in this substrate is a common condition in tropical forests (Pócs 1982, Siviero & Luizi-Ponzo 2015), because content the most specialized epiphyllous species among all the bryophytes, and these have vegetative and reproductive structures for water-storing and anchoring on the leaves (Pócs 1982). Another important attribute of the epiphyllous bryophytes is the heterogeneous occurrence pattern in the forest environment - they are strategically positioned in locations with specific microclimatic conditions (Alvarenga & Porto 2007). So, low occurrence of epiphyllous species in a general inventory like this one is highly probable, because we mainly sample the easily accessible places (near to pre-existent trails) and these are more readily impacted by different anthropic pressures, such as deforestation, wood extraction, unsustainable tourism (Plano de Manejo PESB - Parque Estadual da Serra do Brigadeiro 2007).

Figure 2. Some endemic species of Brazil found in the Parque Estadual da Serra do Brigadeiro in Minas Gerais State, Brazil. *Aptychopsis estrellae* (Hornsch.) Ångström, *Sphagnum gracilescens* Müll. Hal., *Riccardia regnellii* (Aongström.) Hell, *Rhacocarpus inermis* (Müll. Hal.) Lindb. var. *inermis*, *Polytrichum angustifolium* Mitt. and *Bryum subapiculatum* Hampe.

In the fragmented Brazilian Atlantic Forest, the opening of the canopy was considered a cause of reduction and local extinction of epiphyllous bryophyte communities, as it can alter humidity, temperature, and light conditions in the lower forest (Alvarenga & Porto 2007). Epiphyllous dependence on the microclimate conditions created by vegetation, and consequent susceptibility to environmental disturbances has been repeatedly pointed out (Gradstein 1997, Costa 1999, Alvarenga & Porto 2007, Alvarenga *et al.* 2009).

Then, it is advisable to do studies focused on the specific habitats that these plants occupy, such as humid and shady places within the forest (Gradstein *et al.* 2001), because epiphyllous are good indicators of the state of conservation of the area.

Conclusions

The data obtained in this study show that the Parque Estadual da Serra do Brigadeiro (PESB) is an important area for conservation of the diversity of Brazilian bryophytes and for the conservation and maintenance of species that are endemics, rare or have a moderate distribution in Brazil.

Our floristic survey of the bryophytes in the PESB contributes to the knowledge of the floristic diversity of the Park with the verification of their distribution, endemism and substrate types. It also contributes with the enrichment of the collection of bryophytes in the VIC Herbarium, where the samples are available for future studies on other aspects of Brazilian bryophytes.

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