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FOLIICOLOUS LICHENIZED FUNGI OF LOWLAND AMAZON FORESTS IN PANDO, BOLIVIA[1]

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Abstract. Foliicolous lichens are an important component of lowland tropical forests and are useful bioindicators of vegetation continuity or forest health. This study of these fungi in lowland Bolivian Amazon forests of Pando Department revealed the presence of 180 species, 101 of which are reported as new for Bolivia. The following 15 species are mentioned for the first time from South America: *Anisomeridium guttuliferum* Lücking, *Byssolecania pluriseptata* Breuss, *Caprettia confusa* Lücking & Sipman, *Chroodiscus submuralis* Lücking, *Coenogonium barbatum* Lücking, Aptroot & L. Umaña-Tenorio, *Echinoplaca tetrapla* (Zahlbr.) Lücking, *Gyalectidium laciniatum* Lücking, *G. pallidum* Herrera-Campos & Lücking, *Mazosia conica* Sérus., *Phylloblastia excavata* P. M. McCarthy, *Porina conica* R. Sant., *Porina subnucula* Lücking & Vězda, *Porina* aff. *subpallescens* Vězda, *Strigula minuta* Lücking and *Trichothelium intermedium* Lücking. The up-to-date list of foliicolous lichens of Bolivia now numbers 218 species, 52% more than known previously. The foliicolous lichen biota of Pando, a substantial part of the Bolivian Amazon, has clear affinities to neighboring countries due to the significant proportion of species typical for lowland and submontane humid forests in the Neotropics. Analyses of the lichen diversity in the area suggest that its species composition is positively correlated with the presence of specific forest types.

Key words: Biodiversity, distribution, foliicolous lichens, Neotropics, South America

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INTRODUCTION

The Amazon Basin preserves the largest continuous area of humid tropical forests and is still considered one of the world's most species-rich hotspots, but unreasonable natural resource management is leading to irreversible damage of its ecosystems (e.g., Davidson *et al*. 2012). The Bolivian Amazon is in the northern and northeastern parts of the country within the departments of Beni, La Paz, Pando and Santa Cruz; its different forest communities form a mosaic of vegetation which offers a variety of potential habitats for foliicolous lichens (Navarro & Maldonado 2002; Ibisch & Mérida 2004; Navarro & Ferreira 2007).

Pando Department is in the northernmost part of the Bolivian Amazon (9°38′–12°30′S, 69°35′–65°17′W), sharing borders with Brazil and Peru and covering 63,827 km^2 at 90–289 m a.s.l. (Fig. 1). Its mean annual temperature is *ca* 26°C. Mean annual rainfall in the central part of the department is 1500–1850 mm. In contrast, on the outskirts in the northeast (near Cobija) and northwest (near Nueva Esperanza) are very humid regions having 1900–3300 mm precipitation per year, with the maximum reaching 3600–5000 mm (Anonymous 1997; Navarro & Maldonado 2002; Ibisch & Mérida 2004; Navarro 2011; http://www.ine.gob.bo). The department has only one area protected at the national level: Reserva Nacional de Vida Silvestre Amazónica Manuripi in the southwest of the department.

Pando boasts a diverse system of vegetation including several types of riverine and terrestrial forests (Navarro & Maldonado 2002; Navarro 2003; Mostacedo *et al*. 2006), and is considered one of the most important biodiversity centers in Bolivia (Montambault 2002; Ibisch & Mérida 2004). In particular, its northeastern part in the

[1] This paper is dedicated to Professor Tamás Pócs, on the occasion of his 80th birthday.

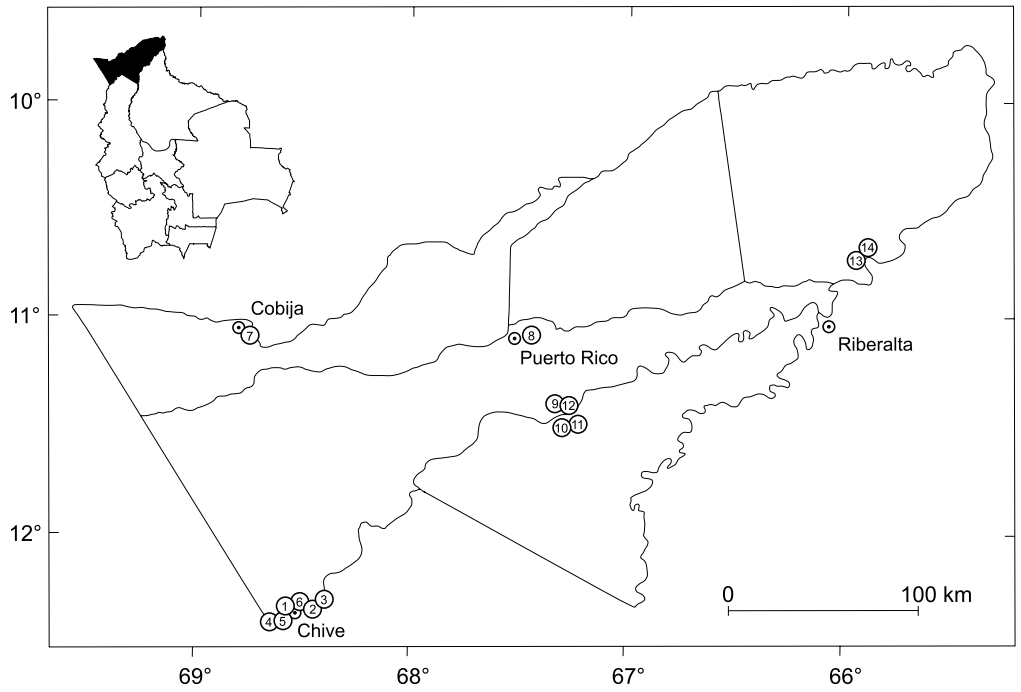

Fig. 1. Map of Pando showing lichen sampling locations.

Precambrian Shield region, which is covered by Tapajoz and Madeira vegetation, is ranked as the biologically richest and least disturbed forest areas in the whole Bolivian Amazon and has been strongly recommended for protection as a strict reserve (Montambault 2002; Ibisch & Mérida 2004; Navarro 2011).

Due to its geographical location and significant share of natural forest, Pando is an essential part of the Bolivian Amazon, but its lichen biota has received almost no attention so far (Flakus & Farkas 2013). The importance of this area is reinforced by a recent survey in an adjacent area of the Peruvian Amazon, which documented the second-highest number of *Graphidaceae* ever reported for a single site anywhere (Rivas Plata & Lücking 2013).

This paper on foliicolous lichens occurring in that area is intended to help fill a large information gap and improve our knowledge of the biodiversity and distribution of lichens in Bolivia. It provides many new national records, including species mentioned here for the first time from South America. Several undescribed species were found in the examined material. They need further attention and will be treated in forthcoming papers.

Material and methods

The data are based on specimens I collected in Bolivia during investigations there in 2006. At each studied locality I sampled the foliicolous lichens of an area of homogeneous forest vegetation measuring 50–100 m^2. The forest types at each locality were categorized according to the vegetation map of Bolivia by Navarro and Ferreira (2007).

The material was identified by standard methods. Morphology was observed with a Nikon SMZ800 stereomicroscope. Microscopy preparations were studied in water, a solution of potassium hydroxide, and for ascus structure in Lugol's iodine solution, using a Nikon Eclipse 80i (DIC) compound microscope. Thin-layer chromatography analyses were done according to Orange *et al*. (2001). Voucher specimens are deposited in KRAM (Kraków), LPB (La Paz) and my private collection.

To compare foliicolous lichen composition between sites, Jaccard's similarity index between each pair of

sites (Jaccard 1908) and the number of shared species were calculated, followed by non-metric multidimensional scaling ordination (NMDS) standardized for binary data using Jaccard's dissimilarity index as the distance measure, and subsequent auto-transformation (Minchin 1987). Additionally, hierarchical cluster analysis for binary data was run using the average linkage agglomeration method (Crawley 2013). Sites 3 and 5 were excluded from the analyses because of their low diversity. All statistical calculations were run with environment R ver. 3.0.2 (http://www.R-project.org) using the stats and vegan packages. To evaluate possible undersampling, the Chao 2 index estimating the total species richness in the area was calculated (Chao *et al*. 2009).

Localities are indicated in the species list and on the map (Fig. 1) by numbers corresponding to the list below, with forest symbols according to Navarro and Ferreira (2007) in parentheses. All specimens examined are from Pando Department, Bolivia.

List of localities

1. Prov. Manuripi, Reserva Nacional de Vida Silvestre Amazónica Manuripi, Chive, 12°23′47″S, 68°35′28″W, 179 m, 18 May 2006, anthropogenically disturbed terrestrial Amazon forest of northeast Pando (a20/a1aii);

2. Prov. Manuripi, Reserva Nacional de Vida Silvestre Amazónica Manuripi, Bajada near Chive by río Madre de Dios, 12°24′03″S, 68°26′45″W, 170 m, 19 May 2006, white-water-flooded Amazon forest (Várzea) (a29);

3. Prov. Manuripi, Reserva Nacional de Vida Silvestre Amazónica Manuripi, Metale near Chive by río Madre de Dios, 12°22′33″S, 68°25′21″W, 170 m, 19 May 2006, white-water-flooded Amazon forest (Várzea) (a29);

4. Prov. Manuripi, Reserva Nacional de Vida Silvestre Amazónica Manuripi, near Puerto Heath, 12°29′38″S, 68°37′28″W, 170 m, 20 May 2006, white-water-flooded Amazon forest (Várzea) (a29);

5. Prov. Manuripi, Reserva Nacional de Vida Silvestre Amazónica Manuripi, near Nueva España, 12°28′32″S, 68°35′33″W, 170 m, 20 May 2006, white-water-flooded Amazon forest (Várzea) (a29);

6. Prov. Manuripi, Reserva Nacional de Vida Silvestre Amazónica Manuripi, Chive, 12°23′19″S, 68°34′39″W, 157 m, 21 May 2006, anthropogenically disturbed terrestrial Amazon forest of northeast Pando (a20/a1aii);

7. Prov. Nicolas Suarez, Parque Ecologico Cobija, near Cobija, 11°02′16″S, 68°45′31″W, 191 m, 23 May 2006, anthropogenically disturbed white-water-flooded Pando Amazon forest (a20/a10);

8. Prov. Manuripi, Reserva Nacional de Vida Silvestre Amazónica Manuripi, Puerto Rico, 11°06′12″S, 67°31′14″W, 191 m, 25 May 2006, terrestrial Amazon forest of northeast Pando (a1aii);

9. Prov. Manuripi, Reserva Nacional de Vida Silvestre Amazónica Manuripi, Puerto Madre de Dios, 11°27′38″S, 67°15′56″W, 166 m, 26 May 2006, white-water-flooded Amazon forest (Várzea) (a29);

10. Prov. Madre de Dios, Reserva Nacional de Vida Silvestre Amazónica Manuripi, near Puerto Madre de Dios by río Madre de Manupare, 11°31′37″S, 67°17′29″W, 155 m, 27 May 2006, white-water-flooded Amazon forest (Várzea) (a29);

11. Prov. Madre de Dios, Reserva Nacional de Vida Silvestre Amazónica Manuripi, near Puerto Madre de Dios by río Madre de Manupare, 11°30′56″S, 67°16′07″W, 153 m, 27 May 2006, white-water-flooded Amazon forest (Várzea) (a29);

12. Prov. Manuripi, Reserva Nacional de Vida Silvestre Amazónica Manuripi, Puerto Madre de Dios, 11°27′38″S, 67°15′56″W, 166 m, 27 May 2006, white-water-flooded Amazon forest (Várzea) (a29);

13. Prov. Federico Roman, near Santa Cruzito, 10°43′03″S, 65°55′05″W, 149 m, 1 June 2006, black-water-flooded Amazon forest (Igapó) of east Pando (a6bii);

14. Prov. Federico Roman, near Santa Cruzito, 10°41′44″S, 65°54′54″W, 151 m, 1 June 2006, black-water-flooded Amazon forest (Igapó) of east Pando (a6bii).

Results and discussion

Biogeographic results

The first records of foliicolous lichens in Bolivia were given by Santesson (1952). More data were reported by Ferraro (2002), Lücking (2008), Flakus and Lücking (2008), Farkas (2010) and Flakus and Farkas (2013). Before this study, 117 foliicolous species were reported from the country. Only six species of foliicolous lichens were reported previously from Pando Department (Flakus & Farkas 2013), an important part of the Bolivian Amazon.

Based on recent collections of 180 species discovered in Pando (Table 1), including 101 records

new for the country, the latest list of foliicolous lichens of Bolivia includes 218 species, increasing the number of taxa by 52%. In view of Bolivia's high ecosystem diversity (Josse *et al*. 2003) and the large number of collections from various localities now being prepared (Flakus unpubl.), our current knowledge of its foliicolous lichen biota on the national scale must be far from complete.

Here I report fifteen species for the first time from South America. Previously they have been placed in three main biogeographic groups: (1) Neotropical species having a Central American distribution pattern, (2) Pantropical species known outside of continental South America, and (3) species known from few localities in the Paleotropics and/or Australia. The first group contains nine species recently described from extensively studied areas in Central America: *Anisomeridium guttuliferum* (previously known from Costa Rica), *Byssolecania pluriseptata* (Costa Rica), *Caprettia confusa* (Costa Rica), *Chroodiscus submuralis* (Costa Rica), *Coenogonium barbatum* (Costa Rica), *Gyalectidium laciniatum* (Costa Rica), *G. pallidum* (Mexico), *Strigula minuta* (Costa Rica) and *Trichothelium intermedium* (Mexico) (Santesson 1952; Ferraro *et al*. 2001; Herrera-Campos & Lücking 2002; Herrera-Campos *et al*. 2004; Rivas Plata *et al*. 2006; Breuss & Neuwirth 2007; Lücking 2008). The second group is represented by species known from scattered localities across the tropics in Central America, Australia and the Paleotropics, and includes *Echinoplaca tetrapla* (Costa Rica, Mexico, Thailand), *Mazosia conica* (Costa Rica, Mexico, Papua New Guinea) and *Porina conica* (Africa, Australasia, Asia) (Santesson 1952; Sipman 1993; Aptroot *et al*. 1997; Boonpragob *et al*. 1998; Lücking & Vězda 1998; Papong *et al*. 2007; Lücking 2008). The third group includes *Phylloblastia excavata* recently described from Australia (McCarthy 2010) and *Porina subnucula* known from two collections in tropical Africa and Australia (Lücking & Vězda 1998), as well as *P*. aff. *subpallescens* reported only from the *locus classicus* in Tanzania (Vězda 1975). The Bolivian specimen of *P. subpallescens* fits Vězda's original description but its photobiont had different, irregularly arranged angular-rounded cells, so it may represent another undescribed species. The specimen was very small and did not lend itself to description; I shall not to describe it until more collections are discovered.

ECOLOGICAL OBSERVATIONS

Foliicolous lichen diversity (Fig. 2) ranged from 10 to 72 species per studied site and was highest in undisturbed Igapó forest (site 13) in the Precambrian Shield area of eastern Pando (Fig. 3). The common foliicolous lichens, found in at least half localities, numbered only 18 species (10% of the total): *Anisomeridium foliicola*, *Arthonia accolens*, *Bacidina neotropica*, *Byssolecania hymenocarpa*, *Chroodiscus coccineus*, *Flavobathelium epiphyllum*, *Gyalectidium filicinum*, *G. pallidum*, *Lyromma ornatum*, *Mazosia dispersa*, *M. rotula*, *Phyllobathelium leguminosae*, *Porina alba*, *P. papillifera*, *Sporopodium leprieurii*, *Strigula maculata*, *S. phyllogena* and *Trichothelium pallescens*. In contrast, very rare species, found only in one or two localities, formed 53% of the local lichen biota and were represented by 96 species (Table 1).

The species composition in Pando is characteristic for Neotropical lowland humid Amazon forests (e.g., Lücking 1995, 1997, 1998, 2008; Lücking & Kalb 2000). The foliicolous lichen biota consists of 79 species (44%) previously classified by Lücking (1997, 2000) as indicators of typical lowland or lowland to submontane forest. Thirty of those (17%) represent the lowland element: *Bacidina pseudohyphophorifera*, *Bapalmuia nigrescens*, *B. palmularis*, *Byssolecania fumosonigricans*, *B. hymenocarpa*, *B. variabilis*, *B. amazonicum*, *Coenogonium dilucidum*, *C. siquirrense*, *C. subluteum*, *Cryptothecia filicina*, *Eugeniella psychotriae*, *Fellhanera muhlei*, *F. verrucifera*, *Lyromma palmae*, *Malmidea trailiana*, *Mazosia praemorsa*, *M. pseudobambusae*, *M. rubropunctata*, *M. tenuissima*, *M. tumidula*, *Phyllobathelium taxteri*, *Phyllogyalidea epiphylla*, *Porina atriceps*, *P. fusca*, *P. radiata*, *Sporopodium antonianum*, *Strigula janeirensis*, *Trichothelium pallescens* and *T. sipmanii*. The most common of the 49 species characteristic of lowland to submontane forest are

Fig. 2. Morphological diversity of foliicolous lichens in Pando. A – *Caleniopsis aggregata* (R. Sant.) Lücking, Sérus. & Vězda, B – *Chroodiscus coccineus* (Leight.) Müll. Arg., C – *Cryptothecia filicina* (Ellis & Everh.) Lücking, Thor, Aptroot & Kalb, D – *Eugeniella psychotriae* (Müll. Arg.) Lücking, Sérus. & Kalb, E – *Mazosia conica* Sérus., F – *Trichothelium argenteum* Lücking & L. I. Ferraro. Scale bars: A, D, E, F = 500 µm; B = 250 µm; C = 1000 µm.

Aderkomyces heterellus, *Anisomeridium foliicola*, *Arthonia accolens*, *Aulaxina minuta*, *Bacidina neotropica*, *Byssoloma minutissimum*, *B. tricholomum*, *Coenogonium hypophyllum*, *Fellhanera fuscatula*, *Mazosia dispersa*, *M. melanophtalma*, *M. paupercula*, *M. pilosa*, *M. rotula*, *Phyllobathelium leguminosae*, *Flavobathelium epiphyllum*, *Porina atrocoerulea*, *P. epiphylla*, *P. karnatakensis*,

Table 1. Foliicolous lichen taxa identified in Pando: * – new for Bolivia, ** – new for South America.

Species name	Locality number	Collection number
Aderkomyces heterellus (Stirt.) Lücking, Sérus. & Vězda	10, 13, 14	*6728*, *7289*, *7378*
Anisomeridium foliicola R. Sant. & Tibell	1, 2, 4, 6, 10, 11, 12, 13	*5905*, *5909*, *5921.2*, *5994*, *6001*, *6016.1*, *6050*, *6065*, *6075*, *6268*, *6272*, *6289*, *6415*, *6488.1*, *6724.1*, *6748*, *6757*, *6767.1*, *6776.2*, *6781*, *6867*, *7082*, *7199*
****Anisomeridium guttuliferum*** Lücking	2	*5978.1*, *5982*, *6023.1*, *6035.1*
Anisomeridium prolongatum Lücking	2	*5978.2*
Arthonia accolens Stirt.	1, 3, 5, 6, 10, 13, 14	*5886*, *6180*, *6186*, *6201*, *6353*, *6395*, *6416*, *6427*, *6452*, *6487*, *6492*, *6713*, *6741*, *6759*, *7222*, *7304*, *7318*, *7400*, *7403*, *7458*
****Arthonia aciniformis*** Stirt.	6, 9, 13, 14	*6412*, *6434.3*, *6470*, *6625.1*, *7138*, *7147*, *7348.1*
Arthonia cyanea Müll. Arg. var. ***cyanea*** f. ***cyanea***	5, 6	*6324*, *6328*, *6361*, *6384*, *6453*, *6500*
Arthonia leptosperma (Müll. Arg.) R. Sant.	2, 11, 13	*6007*, *6059*, *6794*, *6797.1*, *6798.1*, *6862*, *6863*, *6868*, *6888*, *6914*, *6923*, *7109*
****Arthonia orbygniae*** (H. B. P. Upadhyay) Matzer	14	*7426*, *7438.1*
****Arthonia palmulacea*** (Müll. Arg.) R. Sant.	14	*7452.1*
Aspidothelium fugiens (Müll. Arg.) R. Sant.	14	*7348*
Asterothyrium monosporum Müll. Arg.	9	*6650.3*
Asterothyrium rondoniense Bat. & H. Maia *ex* Henssen & Lücking	9, 12	*6612*, *6980*
Aulaxina microphana (Vain.) R. Sant.	9, 12	*5939*, *6078.2*, *7049*
****Aulaxina minuta*** R. Sant.	12, 13, 14	*6987*, *7044*, *7186.1*, *7419.1*, *7328*, *7337*, *7347.2*, *7462*
****Aulaxina submuralis*** Kalb & Vězda	2	*5947.1*
Bacidina apiahica (Müll. Arg.) Vězda	1, 2, 7, 13	*5860.2*, *6041*, *6549*, *7282*
****Bacidina hypophylla*** Lücking & Kalb	10, 14	*6710.1*, *7343.1*, *7460*
Bacidina neotropica Lücking	1, 2, 4, 7, 9, 11, 12, 13	*5867*, *5950*, *6236*, *6255*, *6267*, *6294.3*, *6501*, *6610.2*, *6632*, *6643*, *6673*, *6698*, *6828*, *6841.1*, *6844.1*, *6876*, *6878*, *6923.1*, *6992.1*, *7162*, *7189*, *7232*
Bacidina pallidocarnea (Müll. Arg.) Vězda	7, 8	*6470.2*, *6556*
****Bacidina pseudohyphophorifera*** (Lücking & Sérus.) Lücking	6, 13, 14	*6420*, *6428*, *7267*, *7443*
****Bapalmuia costaricensis*** Lücking & Kalb	1, 2, 7, 11	*5922*, *6045*, *6490*, *6947*
****Bapalmuia lineata*** Lücking & Kalb	2, 4, 7, 11, 13	*5940*, *5968*, *5996.1*, *6005*, *6034*, *6047*, *6051*, *6056.1*, *6068*, *6302*, *6536.1*, *6856*, *6887*, *6954*, *7203*
****Bapalmuia nigrescens*** (Müll. Arg.) M. Cáceres & Lücking	13	*7238.1*
****Bapalmuia palmularis*** (Müll. Arg.) Sérus.	11, 13, 14	*6963*, *7117*, *7122*, *7159*, *7261*, *7345*, *7404.2*
Byssolecania fumosonigricans (Müll. Arg.) R. Sant.	1, 11, 12, 13	*5911*, *5926.1*, *6788*, *6799*, *6841*, *6854*, *6889*, *6925*, *6948*, *7079*, *7151*
Byssolecania hymenocarpa (Vain.) Kalb, Vězda & Lücking	1, 2, 3, 4, 6, 7, 9, 10, 12, 14	*5852*, *5852.1*, *5861.1*, *5880*, *5953*, *5980*, *6000*, *6017*, *6023*, *6025*, *6032*, *6040*, *6058*, *6066*, *6073*, *6074*, *6078*, *6080*, *6199*, *6251*, *6282.1*, *6286*, *6306*, *6434.2*, *6490.3*, *6438*, *6446*, *6526*, *6528*, *6552.3*, *6643.1*, *6708.1*, *6731*, *6676.1*, *7033*, *7039*, *7072.1*, *7099*, *7457.1*

Table 1. *Continued*.

Species name	Locality number	Collection number
*****Byssolecania pluriseptata*** Breuss	11, 13	*6945*, *7159.1*, *7190*, *7225*
Byssolecania variabilis Vězda, Kalb & Lücking	2, 11	*5948*, *6019*, *6799.1*
****Byssoloma absconditum*** Farkas & Vězda	13	*7281*
****Byssoloma amazonicum*** Kalb & Vězda	14	*7410*, *7439*
Byssoloma chlorinum (Vain.) Zahlbr.	3, 6, 8, 10, 13, 14	*6170*, *6179*, *6190*, *6203*, *6377*, *6386*, *6399*, *6405.3*, *6410*, *6415.1*, *6425*, *6426*, *6485*, *6546.1*, *6587.1*, *6749*, *7186*, *7216*, *7334*, *7371*, *7424*
****Byssoloma citricola*** (Maubl.) Lücking, Sérus. & R. Sant.	1, 3, 6, 8	*5877*, *6175*, *6481*, *6588.2*
****Byssoloma humboldtianum*** Lücking & Kalb	14	*7340.2*, *7354.1*, *7420*
Byssoloma leucoblepharum (Nyl.) Vain.	6, 14	*6382*, *6418.1*, *6426.2*, *6429*, *6460.1*, *7457*
****Byssoloma minutissimum*** Kalb & Vězda	1, 7, 9, 11, 13, 14	*5887.1*, *6457.2*, *6513.1*, *6623*, *6839.1*, *7124*, *7150*, *7177*, *7240*, *7250*, *7262*, *7293*, *7350.1*
****Byssoloma tricholomum*** (Mont.) Zahlbr.	5, 6, 13, 14	*6336*, *6343*, *6354*, *6358*, *6429.2*, *7240*, *7274*, *7359*, *7411*, *7448*
Calenia phyllogena (Müll. Arg.) R. Sant.	2	*6054*
****Calenia thelotremella*** Vain.	1, 2	*5921*, *6030.1*
****Calenia triseptata*** Zahlbr.	2	*5931*, *5946*, *5955*, *5971*, *6009*, *6027*
****Caleniopsis aggregata*** (R. Sant.) Lücking, Sérus. & Vězda	2, 7	*5941*, *5960*, *5988*, *6037*, *6067*, *6483*
****Caleniopsis conspersa*** (Stirt.) Lücking, Sérus. & Vězda	14	*7409.1*, *7351*
****Caleniopsis laevigata*** (Müll. Arg.) Vězda & Poelt	13, 14	*7220.1*, *7346*, *7396.1*, *7419*
Calopadia foliicola (Fée) Vězda	1, 6, 8	*5874.1*, *6406.1*, *6421*, *6567*, *6586*, *6597*
Calopadia fusca (Müll. Arg.) Vězda	5	*6359*
Calopadia perpallida (Nyl.) Vězda	6	*6406*, *6482*, *6496*
Calopadia puiggarii (Müll. Arg.) Vězda	5	*6329*
*****Caprettia confusa*** Lücking & Sipman	2, 4, 9, 11, 12	*6003*, *6300*, *6303*, *6616*, *6633*, *6690*, *6921*, *6967*
****Chroodiscus australiensis*** Vězda & Lumbsch	14	*7382*, *7466*
Chroodiscus coccineus (Leight.) Müll. Arg.	1, 2, 4, 5, 6, 7, 9, 12, 13, 14	*5885*, *5931.2*, *5937*, *5949*, *6026.2*, *6079.1*, *6292*, *6327*, *6330*, *6339*, *6340*, *6341*, *6351*, *6356*, *6357*, *6364*, *6424*, *6430*, *6436*, *6437*, *6463.1*, *6484*, *6397*, *6520*, *6679*, *6684*, *6983*, *7036*, *7047*, *7156*, *7183*, *7291*, *7329*, *7349*, *7351*, *7355*, *7382.1*, *7392*, *7399*, *7412*, *7422*, *7425*, *7441*
*****Chroodiscus submuralis*** Lücking	10, 13, 14	*6758*, *7170*, *7398.1*
*****Coenogonium barbatum*** Lücking, Aptroot & L. Umaña-Tenorio	6	*6422.1*
****Coenogonium ciliatum*** Kalb & Lücking	13	*7103*, *7258.1*, *7283*
****Coenogonium dilucidum*** (Kremp.) Kalb & Lücking	9	*6685*
****Coenogonium fallaciosum*** (Müll. Arg.) Kalb & Lücking	13	*7105*
****Coenogonium flavoviride*** M. Cáceres & Lücking	6	*6489*
****Coenogonium geralense*** (Henn.) Lücking	6, 10, 11, 13	*6375*, *6405*, *6405.1*, *6428.1*, *6457.1*, *6472*, *6729*, *6804*, *7188*
****Coenogonium hypophyllum*** (Vězda) Kalb & Lücking	2, 4, 10, 13, 14	*5956*, *6275*, *6721*, *7200.1*, *7336*, *7460.1*
****Coenogonium interpositum*** Nyl.	14	*7332*, *7439.1*

Table 1. *Continued*.

Species name	Locality number	Collection number
**Coenogonium leprieurii* (Mont.) Nyl.	2, 10, 11, 13, 14	*6034.2*, *6746*, *6798*, *6933*, *7104*, *7126*, *7197*, *7258*, *7277*, *7284*, *7468*
**Coenogonium minimum* (Müll. Arg.) Lücking	11	*6816*
**Coenogonium siquirrense* (Lücking) Lücking	6, 13	*6405.1*, *7145*
Coenogonium subluteum (Rehm) Kalb & Lücking	1, 6, 7, 8, 11, 12	*5876.1*, *5912*, *6392*, *6519*, *6575*, *6576*, *6587*, *6595*, *6598*, *6600*, *6869*, *7067*
**Cryptothecia filicina* (Ellis & Everh.) Lücking, Thor, Aptroot & Kalb	13, 14	*7202*, *7202.1*, *7265*, *7271*, *7347*, *7361*, *7367*, *7374*, *7393*, *7395*, *7405*, *7395.1*
**Echinoplaca campanulata* Kalb & Vězda	8, 9	*6581*, *6642.1*, *6659.1*
Echinoplaca epiphylla Fée	3, 9	*6193*, *6682.2*
Echinoplaca leucotrichoides (Vain.) R. Sant.	2, 13	*5985*, *7226*
Echinoplaca pellicula (Müll. Arg.) R. Sant.	1, 2, 3, 6, 8	*5920.2*, *6033*, *6074.2*, *6181*, *6184*, *6416*, *6426*, *6468*, *6577*, *6581.1*
***Echinoplaca tetrapla* (Zahlbr.) Lücking	2	*5979.2*
**Eugeniella corallifera* (Lücking) Lücking, Sérus. & Kalb	13	*7187.1*
**Eugeniella leucocheila* (Tuck.) Lücking, Sérus. & Kalb	13, 14	*7171*, *7206*, *7206.1*, *7290*, *7324*, *7423*
**Eugeniella psychotriae* (Müll. Arg.) Lücking, Sérus. & Kalb	13, 14	*7207*, *7218*, *7219*, *7421.1*, *7430*, *7446*
**Fellhanera bouteillei* (Desm.) Vězda	9, 12	*6649*, *6972*
Fellhanera fuscatula (Müll. Arg.) Vězda	7, 9, 11, 13	*6474.1*, *6482.1*, *6674*, *6801.2*, *6920*, *6930*, *6948.1*, *7136*, *7140*, *7308*
**Fellhanera longispora* Lücking	7, 9	*6524*, *6525.1*, *6530.1*, *6630*, *6650*
**Fellhanera muhlei* Lücking	6	*6459.1*
**Fellhanera punctata* Lücking	13, 14	*7307*, *7406*
**Fellhanera semecarpi* (Vain.) Vězda	9	*6683.5*
Fellhanera stanhopeae (Müll. Arg.) Lücking	6, 9	*6459*, *6636*, *6651.4*, *6675.1*,
**Fellhanera verrucifera* Lücking	13, 14	*7251*, *7350*
**Flavobathelium epiphyllum* Lücking, Aptroot & Thor	1, 6, 9, 10, 11, 12, 13	*5904*, *5905.1*, *5908.1*, *5919.1*, *6401*, *6414.1*, *6488*, *6619*, *6624.2*, *6626.1*, *6670*, *6695*, *6709*, *6757.2*, *6760*, *6761*, *6766.1*, *6775*, *6869.2*, *7070.1*, *7237*, *7319*
Gyalectidium catenulatum (Cavalc. & A. A. Silva) L. I. Ferraro, Lücking & Sérus.	12	*6979*
Gyalectidium filicinum Müll. Arg.	1, 2, 4, 7, 9, 10, 12, 13	*5861.2*, *5903*, *5913*, *5917*, *5979.1*, *6027.1*, *6086*, *6237*, *6281.1*, *6295*, *6489.1*, *6514*, *6671.2*, *6712*, *6974*, *7124.1*, *7249*, *7272*
**Gyalectidium imperfectum* Vězda	6	*6409*, *6483*
***Gyalectidium laciniatum* Lücking	11, 12	*6836*, *7008*, *7040*
***Gyalectidium pallidum* Herrera-Campos & Lücking	1, 2, 4, 5, 11, 12, 13, 14	*5870*, *5891.3*, *5897*, *5900.1*, *6022*, *6237.1*, *6295.1*, *6308*, *6322*, *6323*, *6801.1*, *6805*, *6851*, *6968*, *6977*, *7018*, *7059*, *7089*, *7201*, *7210*, *7252*, *7303*, *7459*
**Lasioloma arachnoideum* (Kremp.) R. Sant.	6	*6495*
Lyromma coronatum Flakus & Farkas	1, 2	*5925.1*, *6018* (Flakus & Farkas 2013)
Lyromma dolicobelum Cavalc.	8, 13	*6570*, *7107*, *7111*, *7123*, *7127*, *7157*, *7160*, *7181*, *7191*, *7257* (Flakus & Farkas 2013)
Lyromma nectandrae Bat. & H. Maia	6, 11, 13	*6457*, *6802*, *7161*, *7193.1*, *7215*, *7260*, *7298* (Flakus & Farkas 2013)

Table 1. *Continued*.

Species name	Locality number	Collection number
Lyromma ornatum Lücking, Kalb & Sérus.	1, 2, 3, 6, 8, 11, 13, 14	*5882*, *5984*, *6019.1*, *6176*, *6407*, *6407.1*, *6455*, *6460*, *6554*, *6565*, *6865*, *7193*, *7314*, *7349.1* (Flakus & Farkas 2013)
Lyromma palmae (Calvac. & A. A. Silva) Lücking & Sérus.	2, 9, 12, 13	*5989.3*, *6662*, *6976*, *7046*, *7314.2* (Flakus & Farkas 2013)
Lyromma pilosum Lücking	1, 2, 7, 13	*5903.2*, *5975*, *6019.2*, *6440*, *6719* (Flakus & Farkas 2013)
**Malmidea trailiana* (Müll. Arg.) Kalb, Rivas Plata & Lumbsch	13	*7153*
***Mazosia conica* Sérus.	1, 2	*5861*, *5866*, *5873*, *5902*, *5977.1*
Mazosia dispersa (J. Hedrick) R. Sant.	1, 2, 5, 6, 7, 10, 14	*5872*, *5936*, *6039*, *6363*, *6438*, *6530*, *6779.1*, *7464.1*
Mazosia melanophtalma (Müll. Arg.) R. Sant.	1, 3, 4, 6, 10, 13	*5877.1*, *6196*, *6243*, *6250*, *6293*, *6486.1*, *6720.3*, *7194*
Mazosia paupercula (Müll. Arg.) R. Sant.	2, 4, 6	*6013.2*, *6282*, *6296*, *6434*, *6445*
Mazosia phyllosema (Nyl.) Zahlbr.	1, 8, 12, 13	*5889*, *6604*, *6998.1*, *7025*, *7317*
**Mazosia pilosa* Kalb & Vězda	6, 13, 14	*6417*, *6486.2*, *6389*, *7149*, *7333*
**Mazosia praemorsa* (Stirt.) R. Sant.	6, 10, 14	*6465*, *6708.2*, *6719.2*, *6739*, *6735*, *6742*, *6762*, *6777*, *7381.1*, *7415*
**Mazosia pseudobambusae* Kalb & Vězda	1	*5918*
Mazosia rotula (Mont.) A. Massal.	1, 2, 3, 4, 6, 12, 13	*5866.2*, *5895*, *5970*, *5996*, *5999*, *6034.3*, *6042.1*, *6173*, *6182*, *6203.1*, *6244.1*, *6310*, *6404*, *6486.3*, *7076*, *7312*
**Mazosia rubropunctata* R. Sant.	1, 3, 13, 14	*5902.3*, *6192*, *7110*, *7146*, *7248*, *7339.1*, *7391*, *7405.1*, *7436.1*, *7436.2*, *7464*
**Mazosia tenuissima* Lücking & Matzer	1, 4, 6, 13, 14	*5853*, *5866.1*, *5898*, *5906*, *6270.1*, *6286.1*, *6309*, *6312*, *6313*, *6493*, *7110.1*, *7166*, *7194.1*, *7302*, *7311*, *7464.2*, *7445.1*
**Mazosia tumidula* (Stirt.) Müll. Arg.	14	*7347.1*, *7391.1*, *7414*, *7442*
Microtheliopsis uleana Müll. Arg.	3, 4, 6	*6178*, *6254*, *6304.1*, *6415*
**Microtheliopsis uniseptata* Herrera-Campos & Lücking	1, 4, 11, 14	*5862*, *5881*, *5907*, *6259*, *6292.2*, *6305.2*, *6879.1*, *7382.1*
Opegrapha filicina Mont.	11, 13, 14	*6791*, *7176*, *7241*, *7268*, *7292*, *7330*, *7330.1*, *7385.1*, *7394*, *7417*
**Opegrapha serusiauxii* Lücking	14	*7341*, *7342*, *7389*, *7402*, *7461*
Phyllobathelium firmum (Stirt.) Vězda	10, 13	*6781.1*, *7323*, *7273*
Phyllobathelium leguminosae (Cavalac. & A. A. Silva) Lücking & Sérus.	1, 2, 4, 7, 9, 10, 12, 13	*5869.2*, *5998*, *6065.1*, *6278*, *6511.1*, *6527.1*, *6658*, *6663*, *6684.2*, *6700.1*, *6753*, *7057*, *7180*
Phyllobathelium thaxteri (Vain.) Zahlbr.	4	*6318*
Phylloblastia bielczykiae Flakus & Lücking	12	*6975.1*
***Phylloblastia excavata* P. M. McCarthy	9, 10	*6678*, *6684.1*, *6751*
**Phyllogyalidea epiphylla* (Vězda) Lücking & Aptroot	4, 7, 11	*6275.1*, *6281*, *6482*, *6833*
Porina alba (R. Sant.) Lücking	1, 2, 4, 6, 7, 10, 11, 12, 13	*5901*, *5976*, *5995.1*, *5998.1*, *6040.1*, *6069*, *6258*, *6290*, *6409*, *6411*, *6418*, *6451*, *6487.2*, *6513.4*, *6532*, *6542*, *6544.1*, *6550*, *6717.2*, *6720.1*, *6722.1*, *6734.3*, *6740.2*, *6755.4*, *6765*, *6769.2*, *6778*, *6797*, *6817*, *6823*, *6861*, *6876.1*, *6883*, *6914*, *6948.4*, *6951*, *6953*, *7006*, *7078.1*, *7113*, *7189.1*, *7223*, *7327*, *7239*, *7295*

Table 1. *Continued*.

Species name	Locality number	Collection number
[*]***Porina atriceps*** (Vain.) Vain.	10, 13	*6709.1*, *6740*, *6765.1*, *6769*, *7201.1*, *7234*
Porina atrocoerulea Müll. Arg.	1, 7, 11	*5868.1*, *6439*, *6478*, *6550.2*, *6552*, *6915*
[*]***Porina barbifera*** Lücking	6, 9	*6433*, *6497*, *6657*, *6661.2*
Porina boliviana Flakus & Lücking	7	*6553*
[**]***Porina conica*** R. Sant.	4	*6241*, *6284.2*
[*]***Porina conspersa*** Malme	9	*6673.2*
[*]***Porina distans*** Vězda & Vivant	11, 12	*6790*, *6807*, *6858.1*, *6945.3*, *6999*, *7075.1*
Porina epiphylla (Fée) Fée	1, 4, 11, 13	*5901.1*, *5923.1*, *6280.4*, *6821*, *6843*, *6855*, *7259*
[*]***Porina fulvella*** Müll. Arg.	13	*7121*
[*]***Porina fusca*** Lücking	13, 14	*7108*, *7118*, *7235*, *7238*, *7268*, *7330.3*
Porina karnatakensis Makhija, Adawadkar & Patw.	2, 7, 10, 12	*5983*, *6454*, *6755.3*, *6995*
[*]***Porina lucida*** R. Sant.	2, 4, 6, 10, 12	*5952*, *6252*, *6280*, *6411*, *6709.2*, *6717*, *6735.1*, *6743*, *6752*, *7061*
Porina nitidula Müll. Arg.	1, 6, 9, 11, 12	*5919*, *5924*, *6475*, *6610.1*, *6635*, *6834.1*, *7064*
Porina papillifera (Stirt.) F. Schill.	1, 2, 4, 6, 7, 11, 12	*5896*, *5933*, *6031*, *6249*, *6265*, *6414*, *6439.1*, *6446.2*, *6648.1*, *6482.3*, *6486.1*, *6487*, *6511.2*, *6871*, *7070*
Porina pseudoapplanata Lücking & M. Cáceres	1, 7, 8, 9	*5883.1*, *6441.1*, *6573*, *6555*, *6661.3*
[*]***Porina radiata*** Kalb, Lücking & Vězda	2, 4, 8, 12	*5995*, *6043*, *6277*, *6284.3*, *6304*, *6317*, *6564*, *7070.2*
Porina rubentior (Stirt.) Müll. Arg.	1, 2, 6, 10, 11, 12	*5868*, *5883*, *6058.1*, *6315*, *6402*, *6446*, *6720*, *6733.1*, *6740.1*, *6754.2*, *6771*, *6778.1*, *6810*, *6840.1*, *6890*, *6994*
Porina rubescens (Lücking) Hafellner & Kalb	4, 6, 7, 11, 12, 13	*6267.1*, *6433.1*, *6504*, *6813*, *6835*, *6849*, *6850*, *6885*, *6998*, *7247*
Porina rufula (Kremp.) Vain.	7, 10, 12, 14	*6463*, *6723.2*, *6726*, *7070.3*, *7401*
Porina subepiphylla Lücking & Vězda	2, 6, 10, 11, 12	*5978*, *5995.2*, *6010*, *6013.1*, *6077*, *6410.1*, *6755*, *6755.5*, *6874.1*, *6936*, *7001*
[*]***Porina subinterstes*** (Nyl.) Müll. Arg.	10, 12	*6723*, *7053*
[**]***Porina subnucula*** Lücking & Vězda	2, 6	*5934*, *5958*, *6036*, *6394*
[**]***Porina*** aff. ***subpallescens*** Vězda	6	*6430.2*
Porina tetracerae (Afzel. *ex* Ach.) Müll. Arg.	4, 11, 12	*6284*, *6858*, *6873.1*, *6881*, *6991*, *7000*, *7062.1*, *7069*
Porina tetramera (Malme) R. Sant.	1, 7, 11, 12	*5868.2*, *5892.1*, *6552.1*, *6800*, *6840*, *7012*, *7064.1*
[*]***Psoroglaena epiphylla*** Lücking	11	*6790.1*
[*]***Sporopodium antonianum*** Elix, Lumbsch & Lücking	2, 6, 7, 8, 9	*6078.1*, *6376*, *6381*, *6404*, *6417.1*, *6442*, *6450*, *6462.1*, *6495.1*, *6514.3*, *6579*, *6634*, *6666*, *6698.2*
[*]***Sporopodium aurantiacum*** (Müll. Arg.) Lücking	5, 6, 14	*6332*, *6381.1*, *6495.1*, *7338*
Sporopodium leprieurii Mont.	1, 2, 3, 4, 5, 6, 7, 9, 10, 12, 13, 14	*5925*, *6076*, *6171*, *6273*, *6344*, *6365*, *6400*, *6417*, *6459*, *6664.1*, *6669*, *6672.1*, *6733.2*, *6992*, *7087*, *7299.1*, *7432*
Strigula antillarum (Fée) Müll. Arg.	2	*5946.1*
[*]***Strigula janeirensis*** (Müll. Arg.) Lücking	1, 2, 4, 8, 12	*5863*, *5957*, *6253*, *6594*, *7077.1*
[*]***Strigula macrocarpa*** Vain.	1, 6, 7, 8	*5859.2*, *6464*, *6473*, *6499*, *6568*
[*]***Strigula maculata*** (Cooke & Massee) R. Sant.	1, 2, 4, 6, 7, 8, 11, 12, 13	*5860*, *5908*, *5920*, *5927*, *5951*, *5959*, *5990.1*, *6028*, *6044*, *6071*, *6246*, *6283*, *6283.1*, *6291*, *6407.1*, *6449*, *6591*, *6959*, *7003*, *7024*, *7071*, *7119*

Table 1. *Continued*.

Species name	Locality number	Collection number
*****Strigula minuta*** Lücking	1	*5859.1*
Strigula nemathora Mont.	2, 8, 11, 13, 14	*5929*, *6012*, *6052*, *6558*, *6590*, *6603*, *6853*, *6884*, *6959.1*, *6480*, *7116*, *7125*, *7227*, *7144.1*, *7158.1*, *7187*, *7201.2*, *7331*, *7436*
****Strigula nigrocarpa*** Lücking	8	*6583*
Strigula nitidula Mont.	2, 8	*6029*, *6601*
****Strigula obducta*** (Müll. Arg.) R. C. Harris	2, 4, 9, 11, 12	*5966*, *6257*, *6279*, *6610*, *6641*, *6650.2*, *6847*, *6869.1*, *6955*, *6960.1*, *6993*, *6995.1*, *7074*, *7080.1*
****Strigula phyllogena*** (Müll. Arg.) R. C. Harris	1, 2, 4, 7, 9, 11, 13	*5915*, *6077.3*, *6283.2*, *6535*, *6666.1*, *6859*, *7179*, *7236*
****Strigula platypoda*** (Müll. Arg.) R. C. Harris	4, 7	*6442.1*, *6545*, *6474*, *6492*, *6497*, *6513*, *6526.1*, *6536*, *6551*
****Strigula prasina*** Müll. Arg.	2, 10	*6016*, *6048*, *6721.1*
Strigula schizospora R. Sant.	2, 11, 14	*6008*, *6032.1*, *6924*, *7440*
Strigula smaragdula Fr.	2, 4, 6, 7, 8, 12	*5943*, *5974*, *5996.2*, *6291.1*, *6422*, *6460*, *6546.2*, *6592*, *7014*, *7042*
Strigula subtilissima (Fée) Müll. Arg.	7, 10	*6512.1*, *6529.1*, *6776*
****Strigula vulgaris*** (Müll. Arg.) Lücking	4, 11	*6247*, *6864*
Tapellaria intermedia Flakus & Lücking	1, 6	*5878*, *6456*
Tricharia longispora Kalb & Vězda	9	*6700*
Tricharia vainioi R. Sant.	1, 7, 9, 12, 13	*5875*, *5879.2*, *6493.1*, *6660*, *6689*, *7068*, *7366*
Trichothelium africanum Lücking	9	*6611.1*, *6637*
Trichothelium alboatrum Vain.	2	*5999.3*
Trichothelium annulatum (P. Karst.) R. Sant.	4, 6, 9, 12	*6249.1*, *6263*, *6433.2*, *6647.2*, *7058*
Trichothelium argenteum Lücking & L. I. Ferraro	6, 7, 9	*6440*, *6477*, *6456*, *6506*, *6648*, *6683*, *6693*
****Trichothelium bipindense*** F. Schill.	1, 6, 9, 11, 14	*5876*, *5879*, *5887*, *6403*, *6433.4*, *6461.2*, *6490*, *6611*, *6796*, *7341.2*, *7354*, *7383.1*
Trichothelium epiphyllum Müll. Arg.	1, 2, 13	*5851.1*, *5854.2*, *6020.1*, *6035*, *7242.1*, *7263*
*****Trichothelium intermedium*** Lücking	13	*7213*
****Trichothelium juruense*** (P. Henn.) F. Schill.	1, 6, 11, 13, 14	*5854.1*, *5914*, *6476*, *6946.2*, *6962*, *7148*, *7198.2*, *7383*
****Trichothelium minus*** Vain.	12	*6970*, *7067.1*
****Trichothelium minutum*** (Lücking) Lücking	13	*7174*
****Trichothelium pallescens*** (Müll. Arg.) F. Schill.	1, 2, 6, 7, 9, 12, 13	*5879.1*, *5981*, *5997*, *6026*, *6031.1*, *6433.3*, *6439*, *6453*, *6490.1*, *6518*, *6538*, *6622*, *6627*, *6639*, *6699.1*, *6988*, *7026*, *7086*, *7213*
****Trichothelium porinoides*** Vězda	6	*6388*
Trichothelium sipmanii Lücking	1, 6, 11, 13	*5867.2*, *6425*, *6430.1*, *6461*, *6835.1*, *7192*
Trichothelium subargenteum Flakus & Lücking	2, 4, 6, 13	*6026.1*, *6264*, *6433*, *7208.1*
****Trichothelium ulei*** (Henn.) Höhn.	13	*7129*, *7169*, *7198*

P. papillifera, *P. rubentior*, *P. rubescens*, *P. subepiphylla*, *Sporopodium leprieurii*, *Strigula obducta*, *Trichothelium argenteum* and *T. juraense*. Other species found on the study area belong to the lowland to submontane element (29 species, 16%), a group possessing a broad altitudinal distribution (13 species, 7%) according to Lücking (1997, 2000), or a group of taxa not evaluated previously, with unknown vertical distribution patterns (59 species, 33%).

Most of the Jaccard's similarity indexes were below 0.25 within group (Table 2), highlighting

Fig. 3. The site with the highest foliicolous lichen diversity in black-water-flooded Amazon forest (Igapó) of eastern Pando near Santa Cruzito.

the high beta diversity of foliicolous lichens in the study area. Non-metric multidimensional scaling (NMDS) ordination separated the species into three groups (Fig. 4). The resulting pattern was confirmed by hierarchical cluster analysis showing three different clusters (Fig. 5). The first one (A) is formed by site 8, the second one (B) by sites 1, 2, 4, 6, 7, 9, 11 and 12, and the last one (C) by sites 10, 13 and 14. To some extent the three groups are positively correlated with the forest types according to Navarro and Ferreira (2007).

Cluster A is represented only by one site with 20 species (11%) located in terrestrial Amazon forest of northeast Pando. Its characteristic species composition include lichens rarely noted at the rest of the sites: *Calopadia foliicola*, *Bacidina pallidocarnea*, *Echinoplaca campanulata*, *Lyromma dolicobelum*, *Porina pseudoapplanata*, *P. radiata*, *Strigula macrocarpa*, *S. nigrocarpa* and *S. nitidula*.

Clusters B and C form a separate group of riverine forests clearly separated from the first one. Cluster C combines sites in black-water-flooded Amazon forest (Igapó) of eastern Pando (Precambrian Shield region). Of the 100 species (56%) found in that forest, many are found exclusively in this vegetation type: *Arthonia obrygniae*, *A. palmulacea*, *Bacidina hypophylla*, *Byssoloma amazonicum*, *B. humboldtianum*, *Caleniopsis conspersa*, *C. laevigata*, *Chroodiscus australiensis*, *Cryptothecia filicina*, *Eugeniella leucocheila*, *E. psychotriae*, *Fellhanera punctata*, *F. verrucifera*, *Mazosia tumidula*, *Opegrapha serusiauxii*, *Porina fulvella*, *P. fusca*, *Trichothelium minutum* and *T. ulei*. Navarro and Ferreira (2007) classified site 10 as Várzea forest, but the lichen species

Table 2. Jaccard's similarity index (upper diagonal), number of species shared between study sites (lower diagonal) and number of species per site (diagonal).

Site No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	51	0.317	0.167	0.261	0.089	0.310	0.333	0.164	0.189	0.159	0.297	0.301	0.295	0.149
2	26	57	0.078	0.329	0.063	0.208	0.270	0.132	0.146	0.194	0.229	0.295	0.229	0.104
3	9	5	12	0.116	0.100	0.164	0.043	0.143	0.065	0.139	0.018	0.057	0.091	0.109
4	18	23	5	36	0.070	0.218	0.259	0.077	0.159	0.161	0.246	0.356	0.200	0.090
5	5	4	2	3	10	0.113	0.068	0.000	0.044	0.083	0.019	0.059	0.065	0.135
6	26	20	10	17	7	59	0.171	0.145	0.157	0.189	0.182	0.212	0.224	0.187
7	22	20	2	15	3	14	37	0.140	0.254	0.158	0.206	0.266	0.172	0.075
8	10	9	4	4	0	10	7	20	0.056	0.021	0.066	0.103	0.070	0.045
9	14	12	3	10	2	13	15	3	37	0.100	0.123	0.266	0.135	0.075
10	11	14	5	9	3	14	9	1	6	29	0.104	0.217	0.188	0.182
11	22	19	1	16	1	16	14	4	9	7	45	0.271	0.258	0.133
12	22	23	3	21	3	18	17	6	17	13	19	44	0.184	0.069
13	28	24	7	18	5	24	16	6	13	16	24	18	72	0.315
14	13	10	6	7	7	17	6	3	6	12	11	6	29	49

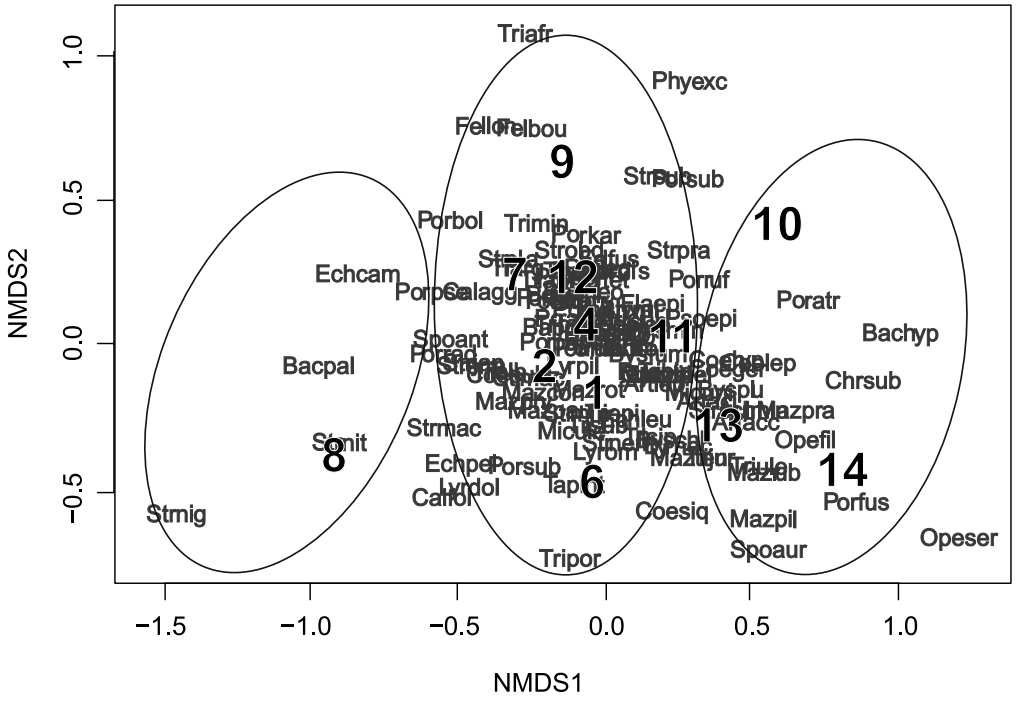

Fig. 4. Non-metric multidimensional scaling (NMDS) of the study sites based on foliicolous lichen composition using Jaccard's dissimilarity index as distance measure. Circle at left surrounds terrestrial forest, in the middle of which is white-water-flooded forest (Várzea); circle at right surrounds black-water-flooded forest (Igapó). Species symbols consist of the first three letters of the generic name and the first three of the epithet.

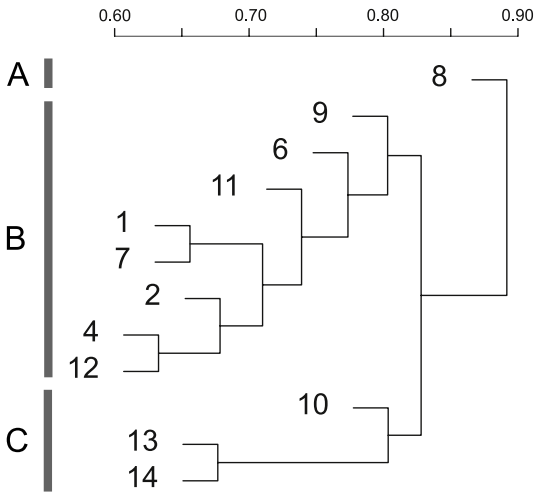

Fig. 5. Hierarchical cluster analysis of the study sites based on foliicolous lichen composition analysis from binary data using average linkage agglomeration. A – terrestrial forest, B – white-water-flooded forest (Várzea), C – black-water-flooded forest (Igapó).

composition most resembled that of sites 13 and 14; this, together with its location near a black-water river (río Madre de Manupare) suggests that the site is more probably Igapó forest.

Cluster B contains mainly white-water-flooded Amazon forests (Várzea) from western Pando and a few anthropogenically disturbed forests (sites 1, 6, 7). It contains 143 species: 116 (64%) from sites in Várzea forest and 27 (15%) from anthropogenically disturbed forests. The foliicolous lichen biota of Várzea forest shares many species in common with the other forest types but also contains some exclusive species such as *Asterothyrium rondoniense*, *Aulaxina microphana*, *Byssolecania variabilis*, *Caprettia confusa*, *Fellhanera bouteilei*, *Gyalectidium laciniatum*, *Porina distans*, *P. tetracerae*, *Strigula obducta* and *S. vulgaris*. The anthropogenically disturbed forests have few exclusive lichens.

The greater diversity of foliicolous lichens in Várzea forest (143 species) as compared with Igapó forest (100 species) might be explained by the higher diversity of vascular plants in the white-water-flooded forests than in black-water-flooded ones (Navarro & Maldonado 2002; Navarro 2003; Mostacedo *et al*. 2006), which provides more species potentially useful for lichens as a substrate. Fewer species (20) were observed in terrestrial forest (site 8). As commonly known, however, riverine forests (Várzea or Igapó) are much more homogenous floristically than terrestrial high forests (e.g., Mostacedo *et al*. 2006). The likely explanation for the disparity in numbers is undersampling; only a few sites in terrestrial forest were visited.

It is puzzling that the richest site in the study (with 72 species) is located in Igapó forest, which is considered to be the poorest in vascular plants. A possible explanation is its location in the Precambrian Shield region, the biologically richest and least-disturbed area of forest in the whole Bolivian Amazon, possibly preserving a greater variety of foliicolous lichens.

To evaluate possible undersampling, the Chao 2 estimator (Chao *et al*. 2009) was calculated for 558 species records from 14 sites. It estimated the potential total number of species in the studied area at *ca* 214 species. Thus we may have collected 84% of the species expected to be found in the area. The number of analyzed sites was not uniform across all types of forest, however, so these results should be taken as preliminary. To propose a reliable set of distribution patterns for the foliicolous lichens in the forest vegetation of Pando, more sites need to be investigated, especially those in terrestrial forests and in the Precambrian Shield region.

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