Bryophytes in fragments of Terra Firme forest on the great curve of the Xingu River, Pará state, Brazil[1]

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Abstract

Microclimatic conditions of tropical forest favour the high richness of bryophytes, which by being sensitive to environmental changes, are important indicators of habitat conditions. The aim of this study was to determine the richness and species composition of the bryophyte flora in fragments of terra firme forest on the great curve of the Xingu River, Pará state, Brazil. The collections were made in August and September 2012 in 14 fragments, in which were installed two plots per fragment, one at the edge and one inside, measuring 10 × 10 m each. The results showed 77 species in 45 genera and 18 families. *Lejeunea setiloba* Spruce and *Marchesinia brachiata* (Sw.) Schiffn. are new records for Pará state. The richness families in this study were the ones typically found in tropical forest surveys. A high richness of rare species in comparison to common ones, a pattern usually observed for plants in tropical forests was not reported in this study, probably due to historical fragmentation and disturbance in the area. The richness and species composition were determined mainly by the physiognomic characteristics of the studied forest fragments.

Keywords: brioflora, Amazonian flora, liverworts, mosses.

Briófitas em fragmentos florestais de terra firme na região da Volta Grande do Xingu, Pará, Brasil

Resumo

As condições microclimáticas das florestas tropicais favorecem elevada riqueza de briófitas, que por serem sensíveis às alterações ambientais, são importantes indicadoras das condições dos habitats. O objetivo deste trabalho foi determinar a riqueza e a composição florística da brioflora de fragmentos florestais de terra firme na região da Volta Grande do Xingu, Pará, Brasil. As coletas foram realizadas em Agosto e Setembro de 2012, em 14 fragmentos e em cada um destes foram plotadas duas parcelas, uma na borda e outra no interior, medindo 10 × 10 m (cada). Foram registradas 77 espécies, distribuídas em 45 gêneros e 18 famílias. *Lejeunea setiloba* Spruce e *Marchesinia brachiata* (Sw.) Schiffn. são novos registros para o Pará. As famílias mais ricas neste estudo foram aquelas tipicamente encontradas em levantamentos em florestas tropicais. A elevada riqueza de espécies raras em comparação às comuns, padrão comumente reportado para plantas em florestas tropicais, não foi observada, provavelmente devido ao histórico de fragmentação e distúrbios na área de estudo. A riqueza e a composição de espécies foram determinadas principalmente pelas características fisionômicas dos fragmentos estudados.

Palavras-chave: brioflora, flora da Amazônia, hepáticas, musgos.

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1. Introduction

In several regions of the world, bryophytes are an important component of vegetation (Glime, 2007). Large variations in landscapes and climates favour the richness and diversity of bryophytes (Gradstein et al., 2001), particularly in tropical forests (Gradstein and Pócs, 1989). In tropical regions their exuberance and diversity is especially noticed, increasing in altitudes above 1,500 m (Gradstein et al., 2001).

The Amazon and Atlantic Forest are the two most significant phytogeographic regions in terms of richness for bryophytes in Brazil (Santos et al., 2011). Even the Amazon being the largest extension of humid tropical forest characterized by a remarkable richness of species and high levels of endemism (Mittermeier et al., 1992), it is the second most important region for the bryoflora in the country. The higher diversity and endemism of bryophytes in Brazil is in the Atlantic forest, greatly due to its altitudinal and latitudinal range (Gradstein et al, 2001).

The landscape of the Amazon is very diverse and different forest types can be distinguished, among which stands out the terra firme forest that occupies about 90% of the Amazon territory (Pires, 1973; Pires and Prance, 1985; Gradstein and Costa, 2003). This forest type is characterized mostly by the floristic heterogeneity, with high richness and diversity, as well as high complexity regarding its composition, distribution and density of species (Oliveira and Mori, 1999; Ter Steege et al., 2000; Gama et al., 2005).

Studies on bryophytes in the state of Pará were performed in different forest formations and various parts of the state as in the surroundings of the Lake Tucuruí (Ilkiu-Borges et al., 2004; Garcia et al., 2014), Serra dos Carajás (Moraes and Lisboa, 2006), Caxiuanã (Alvarenga and Lisboa, 2009; Ilkiu-Borges et al., 2013), metropolitan region of Belém (Lisboa and Ilkiu-Borges, 1995; Moura et al., 2013), Marajó Island (Lisboa et al., 1999; Brito and Ilkiu-Borges, 2013) and northeastern Pará (Santos and Lisboa, 2008; Lisboa and Tavares, 2008; Tavares-Martins et al., 2014). In the southwestern state, it is recorded only the inventory held by Lisboa and Ilkiu-Borges (2001) in São Luiz do Tapajós, in the municipality of Itaituba.

Over the past 40 years, the region of the great curve of the Xingu River, located in the southwestern Pará, went through an intense process of occupation, which resulted in the change of its original forest cover and about 60% were converted into areas for family farms, pastures, among others (Mausel et al., 1993; Salomão et al., 2007). As a result, the forests in the region are quite fragmented and poorly known regarding its richness and composition, especially about bryophytes.

The aim of this study was to determine the richness and species composition of the bryophyte flora in fragments of terra firme forest on the great curve of the Xingu River, Pará state.

2. Material and Methods

2.1. Study area

The study area corresponds to the region called great curve of the Xingu River, in the lower course of the river (Figure 1), southwest of Pará (Salomão et al., 2007). The region includes areas classified as dense and open

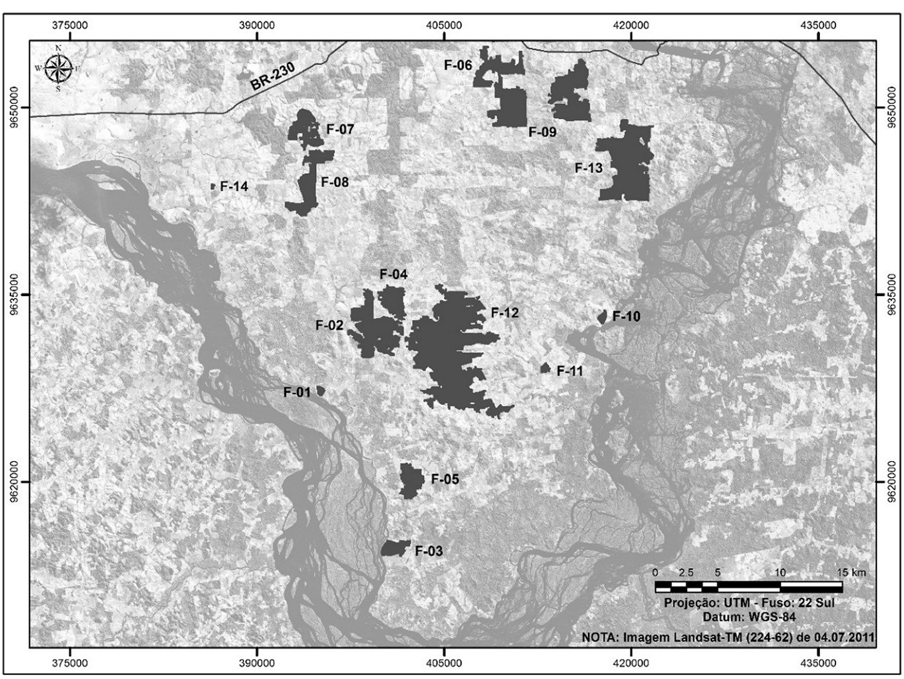

Figure 1. Location map of forest fragments in the region of Volta Grande do Xingu, Pará state, Brazil. Source: Marcelo Cordeiro Thalês (MPEG).

ombrophilous forest and alluvial vegetation, directly influenced by the hydrological system of the Xingu River, in addition to recent and old secondary forests (Salomão et al., 2007). The predominant climate is humid tropical, with an average temperature of 26 °C and annual rainfall of 2,289 mm. A short dry season occurs during the months of August and September (Cunha and Ferreira, 2012; INMET, 2012).

The 14 fragments studied are located on the right bank of the river, in Vitória do Xingu, which has the largest forest cover in the region (Salomão et al., 2007). The fragment dimensions range from 7.96 to 3,784.20 hectares and altitudes from 57 to 187 m (Figure 1).

The fragments show similar physiognomies, with few clearings and humid environments, and were characterised by large sized trees, such as the species *Theobroma speciosum* Willd. ex Spreng. (Malvaceae), *Inga spp.* (Fabaceae), *Pouteria spp.* (Sapotaceae), *Sterculia spp.* (Malvaceae), *Tachigali spp.* (Fabaceae), *Vouacapoua americana* Aubl. (Fabaceae), *Cenostigma tocantinum* Ducke (Fabaceae), *Bertholletia excelsa* Bonpl. (Lecythidaceae), *Alexa grandiflora* Ducke (Fabaceae), and *Schefflera morototoni* (Aubl.) Maguire et al. (Araliaceae). In the edges, the dossal is usually a more open and formed by fewer trees species.

2.2. Collection and taxonomic identification

The collections were made in August and September 2012, following the techniques described by Yano (1989). The selection of the 14 terra firme forest fragments was carried out with the aim of including the largest possible number of areas along the great curve of the Xingu River, taking as selection criteria the same physiognomies. In each fragment were established two plots, one on edge and other inside, measuring 10 × 10 m (each). This method was applied with the intention to engage a larger species composition within the fragments, since it is known that the edge have effect in floristic composition. Plot size was based on the subplots of Santos et al. (2011) and for the collection of material, each plot was subdivided into five corridors 2 × 10 m, where traversing each one, the material were collected on all types of substrates only reaching the understory.

In preparing the material for identification were adopted the usual techniques for bryophytes and the determination of taxa was performed with the aid of taxonomic keys and descriptions found in the specialised literature. The taxonomic classifications adopted were those of Goffinet et al. (2009) for the Bryophyta and Crandall-Stotler et al. (2009) for Marchantiophyta. The testimony material was incorporated in the João Murça Pires Herbarium (MG).

2.3. Data analysis

The richness, floristic composition, geographic distribution, the absolute frequency of the species were analyzed, and also calculated the similarity between fragments. The existence of significant differences in richness and in the guilds of tolerance of the species between fragments was also verified.

To verify sample sufficiency, a species accumulation curve was generated using the Mao Tau function (Colwell et al., 2004) with a confidence interval of 95%, for this was elaborate an matrix of presence/absence of species per fragment, subjected to analysis in EstimateS 8.2.0 program (Colwell, 2009).

The floristic composition was determined by the families, genera and species present in fragments and species richness described by the total of species inventoried in the study area.

The absolute frequency of the species was determined based on the number of occurrences (incidence/occurrence) of species in fragments. Three categories of frequency were defined, adapted from Silva and Pôrto (2007) and Garcia (2012): rare (one to five occurrences), common (six to 19 occurrences) and constant (20 or more occurrences).

A matrix of presence and absence of 77 species listed in 14 fragments was prepared and calculated the floristic similarity by the Jaccard coefficient, followed by a cluster analysis (Hair Junior et al., 2006) from the average linkage clustering method (UPGMA) using the MVSP 3.0 software.

To verify the existence of significant difference in species richness of bryophytes between fragments was applied a chi-squared test, which is the number of different species found in the sample from each fragment analyzed, calculated in the Biostat 5.0 software (Ayres et al., 2007).

In the analysis of tolerance guilds, species were classified according to their tolerance to sunlight in: sun epiphytes (Es), shade epiphytes (Esh) and generalists (Gen). This classification was based on the works of Richards (1984), Cornelissen and Ter Steege (1989), Gradstein et al. (2001), Alvarenga and Pôrto (2007), Gradstein and Ilkiu-Borges (2009), Silva and Pôrto (2009, 2013), Alvarenga et al. (2010), Oliveira et al. (2011) and Santos et al. (2011).

To check whether there is significant difference in the guilds of tolerance (Es, Esh and Gen) among different forest fragments was also used a chi-squared test.

3. Results

There were recorded 1,595 occurrences of bryophytes, totalling 77 species, belonging to 45 genera and 18 families (Table 1). The species accumulation curve (Figure 2) did not stabilise.

Liverwort were represented by 48 species (62%), 26 genera and six families, and therefore, with highest species richness compared to mosses (38%). Lejeuneaceae was the most representative family with 40 species (52%). Mosses accounted for 29 species (38%), 19 genera and 12 families, among which stood out Calymperaceae (7 spp.), Fissidentaceae (4 spp.), Pilotrichaceae (4 spp.), and Sematophyllaceae (4 spp.).

The richest genera among liverworts were *Lejeunea* (7 spp.), *Cheilolejeunea* (5 spp.) and *Ceratolejeunea* (4 spp.), and among mosses were *Fissidens* (4 spp.), *Calymperes* (3 spp.) and *Syrrhopodon* (3 spp.). The most occurring species were *Archilejeunea parviflora*, *Ceratolejeunea*

Table 1. Bryoflora of forest fragments of the region of Volta Grande do Xingu, Pará state, Brazil.

Species	Guild	Oc.	Fragments														Voucher
			F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	
BRYOPHYTA																	
Brachytheciaceae																	
Zelometeorium patulum (Hedw.) Manuel	Gen	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	AP63
Calymperaceae																	
Calymperes afzelii Sw.	Gen	4	-	-	-	-	-	1	-	-	-	1	1	1	-	-	AP464
C. erosum Müll. Hal.	Gen	41	3	2	8	2	5	4	4	1	1	4	2	2	-	3	AP188
C. palisotii Schwägr.	Gen	14	5	1	1	1	3	1	1	1	-	-	-	-	-	-	AP45
Octoblepharum albidum Hedw.	Gen	21	2	-	3	-	-	4	6	3	2	-	-	-	1	-	AP128
Syrrhopodon cryptocarpus Dozy & Molk.	Esh	23	5	3	-	1	4	3	-	2	4	-	1	-	-	-	AP14
S. incompletus Schwägr.	Esh	6	1	3	1	-	-	-	1	-	-	-	-	-	-	-	AP82
S. parasiticus (Brid.) Besch.	Es	11	-	1	2	-	-	3	1	1	1	-	1	-	1	-	AP246
Fissidentaceae																	
Fissidens guianensis Mont.	Esh	99	11	12	4	4	3	8	-	6	8	12	15	13	1	2	AP42
F. ineaqualis Mitt.	Esh	10	1	-	2	-	-	3	1	1	2	-	-	-	-	-	AP217
F. pellucidus Hornsch.	Esh	7	-	-	-	-	2	1	-	2	-	2	-	-	-	-	AP217
F. zollingeri Mont.	Gen	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	AP78
Hypnaceae																	
Chryso-hypnum diminutivum (Hampe) W. R. Buck	Es	4	-	1	1	-	-	2	-	-	-	-	-	-	-	-	AP113
Leucobryaceae																	
Leucobryum martianum (Hornsch.) Hampe ex. Müll. Hal.	Esh	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	AP177
Leucomiaceae																	
Leucomium strumosum (Hornsch.) Mitt.	Esh	25	1	5	-	2	-	1	-	-	5	-	2	7	2	-	AP474
Neckeraceae																	
Neckeropsis disticha (Hedw.) Kindb.	Gen	13	1	-	-	1	-	-	-	-	-	7	1	3	-	-	AP401
N. undulata (Hedw.) Reichardt	Gen	4	1	-	-	1	-	-	-	-	-	2	-	-	-	-	AP21
Pilotrichaeceae																	
Callicostella pallida (Hornsch.) Ångstr	Esh	52	2	6	2	6	1	2	-	2	4	2	9	6	3	7	AP96
Lepidopilum scabrisetum (Schwägr.) Steere	Esh	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	AP53
L. surinamense Müll. Hal	Esh	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	AP65
Pilotrichum evanescens (Müll.Hal.) Crosby	Esh	2	-	-	-	-	-	1	-	-	1	-	-	-	-	-	AP370

Gen = Generalist, Es = epiphytes of sun and Esh = epiphytes of shade; Occ. = Occurrence; F1 to F14 = forest fragments studied.
*First record for the state of Pará.

Table 1. Continued...

Species	Guild	Oc.	Fragments														Voucher
			F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	
Pylaisiadelphaceae																	
Isopterygium tenerum (Sw.) Mitt.	Gen	52	6	3	3	1	1	7	5	1	10	-	1	-	8	6	AP14
Taxithelium planum (Brid.) Mitt.	Gen	43	1	1	-	3	1	2	-	2	3	12	3	2	6	7	AP239
Sematophyllaceae																	
Acroporium estrellae (Müll.Hal.) W. R. Buck & Schäf.-Verw.	Esh	2	1	-	-	-	1	-	-	-	-	-	-	-	-	-	AP208
Sematophyllum subsimplex (Hedw.) Mitt.	Gen	36	2	1	-	-	3	5	17	-	3	-	1	-	1	3	AP239
Trichosteleum papillosum (Hornsch.) A. Jaeger	Gen	12	-	2	-	1	2	2	-	-	1	1	1	-	1	1	AP208
Trichosteleum subdemissum (Besch.) A. Jaeger	Es	6	1	-	-	-	-	1	2	1	-	1	-	-	-	-	AP340
Stereophyllaceae																	
Pilosium chlorophyllum (Hornsch.) Müll. Hal.	Gen	59	4	5	5	4	9	6	10	6	1	-	1	4	4	-	AP16
Thuidiaceae																	
Pelekium scabroSouthum (Mitt.) Touw	Es	49	4	8	1	7	2	1	-	-	3	11	4	5	1	2	AP65
MARCHANTIOPHYTA																	
Calypogeiaceae																	
Calypogeia miquelli Mont.		1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	AP284
Frullaniaceae																	
Frullania apiculata (Reinw *et al.*) Dumortier	Es	2	-	-	1	-	-	-	-	1	-	-	-	-	-	-	AP115
Lejeuneaceae																	
Acrolejeunea torulosa (Lehm. & Lindenb.) Schiffn.	Es	4	-	-	-	-	-	-	-	4	-	-	-	-	-	-	AP323
Archilejeunea auberiana (Mont.) A. Evans	Es	5	-	-	-	-	-	-	-	-	-	3	2	-	-	-	AP408
A. parviflora (Nees) Schiffn.	Esh	88	14	13	2	6	3	1	-	6	2	12	13	14	2	-	AP11
Caudalejeunea lehmanniana (Gottsche) A. Evans	Gen	2	-	-	1	-	-	-	-	-	-	-	-	-	1	-	AP538
Ceratolejeunea coarina (Gottsche) Schiffn.	Gen	91	13	9	10	2	5	8	7	4	11	2	7	6	5	2	AP96
C. cornuta (Lindenb.) Steph.	Gen	11	1	-	-	1	-	4	2	1	1	-	-	-	1	-	AP225
C. cubensis (Mont.) Schiffn.	Gen	42	6	5	6	1	2	4	2	3	6	3	-	3	1	-	AP89

Gen = Generalist, Es = epiphytes of sun and Esh = epiphytes of shade; Occ. = Occurrence; F1 to F14 = forest fragments studied.
*First record for the state of Pará.

Table 1. Continued...

Species	Guild	Oc.	Fragments														Voucher
			F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	
C. minuta Dauphin	Es	6	-	-	1	-	1	1	-	1	2	-	-	-	-	-	AP359
Cheilolejeunea adnata (Kunze) Grolle	Gen	18	1	2	9	-	2	-	1	2	-	-	-	1	-	-	AP43
C. aneogyna (Spruce) A. Evans	Gen	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	AP311
C. comans (Spruce) R. M. Schust.	Gen	5	-	-	-	1	1	-	-	3	-	-	-	-	-	-	AP321
C. oncophylla (Ångstr.) Grolle & E. Reiner	Gen	21	2	2	3	-	5	2	3	2	1	-	-	-	-	1	AP82
C. rigidula (Mont.) R. M. Schust.	Gen	10	1	1	3	-	3	1	-	1	-	-	-	-	-	-	AP180
Cololejeunea camilli (Lehm.) A. Evans	Gen	59	4	-	7	9	12	7	-	-	7	4	4	4	1	-	AP253
C. contractiloba A.Evans	Esh	3	1	1	-	-	1	-	-	-	-	-	-	-	-	-	AP38
C. subcardiocarpa Tixier	Gen	53	5	1	5	-	-	9	11	5	4	2	2	-	1	8	AP107
Diplasiolejeunea brunnea Steph.	Es	10	-	5	-	-	-	-	-	-	2	-	2	-	1	-	AP48
Drepanolejeunea polyrhiza (Nees) Grolle & R.-L. Zhu	Es	6	-	6	-	-	-	-	-	-	-	-	-	-	-	-	AP66
Harpalejeunea oxyphylla (Nees & Mont.) Steph.	Es	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	AP93
Lejeunea adpressa Nees	Gen	23	2	1	1	1	1	1	1	1	3	3	-	1	3	4	AP33
L. caulicalyx (Steph.) E. Reiner & Goda	Gen	30	5	5	1	2	1	1	1	1	2	1	5	-	3	2	AP07
L. cerina (Lehm. & Lindenb.) Gottsche	Gen	3	-	-	-	-	-	-	-	-	-	-	1	2	-	-	AP500
L. huctumalcensis Lindenb. & Gottsche	Gen	7	-	-	-	-	-	1	-	1	3	-	-	-	1	1	AP369
L. laetevirens Nees & Mont.	Gen	4	-	-	-	1	-	-	1	-	-	-	1	1	-	-	AP462
**L. setiloba* Spruce	Esh	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	AP216
L. tapajosensis Spruce	Gen	33	1	-	1	2	3	3	-	6	-	9	1	1	6	-	AP38
Leptolejeunea elliptica (Lehm. & Lindenb.) Schiffn.	Es	3	-	-	-	-	-	-	-	-	1	-	-	-	2	-	AP364
Lopholejeunea subfusca (Nees) Schiffn.	Es	12	-	4	-	-	1	-	2	2	2	-	1	-	-	-	AP82
**Marchesinia brachiata* (Sw.) Schiffn.	Es	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	AP477
Mastigolejeunea auriculata (Wilson) Schiffn.	Esh	3	-	-	-	1	2	-	-	-	-	-	-	-	-	-	AP180
Pictolejeunea picta (Gottsche ex Steph.) Grolle	Esh	5	-	3	1	-	-	1	-	-	-	-	-	-	-	-	AP144

Gen = Generalist, Es = epiphytes of sun and Esh = epiphytes of shade; Occ. = Occurrence; F1 to F14 = forest fragments studied.
*First record for the state of Pará.

Table 1. Continued...

Species	Guild	Oc.	Fragments														Voucher
			F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	
Prionolejeunea denticulata (Weber) Schiffn.	Gen	6	1	2	1	-	-	-	-	1	1	-	-	-	-	-	AP144
P. muricatoserrulata (Spruce) Steph.	Esh	15	3	-	1	-	1	2	-	2	-	-	-	5	1	-	AP42
Rectolejeunea berteroana (Gottsche ex Steph.) A. Evans	Gen	17	1	2	2	2	-	-	1	2	2	-	-	-	5	-	AP87
Stictolejeunea balfourii (Mitt) E. W. Jones	Gen	15	-	3	1	1	1	2	-	-	3	-	2	1	1	-	AP63
S. squamata (Willd. ex Weber) Schiffn.	Gen	89	11	6	7	8	5	4	-	6	11	5	12	6	3	5	AP96
Symbiezidium barbiflorum (Lindenb. & Gottsche) A. Evans	Gen	7	1	-	1	1	-	-	-	-	-	1	-	2	1	-	AP93
S. transversale (Sw.) Trevis	Es	31	-	2	4	7	4	-	-	-	-	4	1	8	1	-	AP144
Taxilejeunea obtusangula (Spruce) A. Evans	Gen	12	1	3	1	2	-	-	-	-	1	1	1	1	1	-	AP58
Xylolejeunea crenata (Nees & Mont.) X.-L. He & Grolle	Esh	22	1	1	-	-	2	2	10	2	1	-	-	-	1	2	AP239
Lophocoleaceae																	
Chiloscyphus liebmannianus (Gottsche) J.J.Engel & R.M.Schust.	Esh	7	2	1	1	-	1	2	-	-	-	-	-	-	-	-	AP16
Plagiochilaceae																	
Plagiochila disticha (Lehm. & Lindenb.) Lindenb.	Esh	74	9	3	9	3	1	7	-	1	13	2	12	13	1	-	AP15
P. montagnei Ness	Esh	41	5	2	3	8	2	1	-	-	3	6	4	3	4	-	AP08
P. subplana Lindenb.	Esh	52	9	9	3	2	1	1	-	2	6	1	5	8	5	-	AP23
Radulaceae																	
Radula flaccida Lindenb. & Gottsche	Gen	40	13	1	11	1	1	-	-	-	7	1	1	-	4	-	AP27
R. javanica Gottsche	Es	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	AP384
Total		1595	165	153	131	96	100	124	91	90	144	116	120	124	85	56	

Gen = Generalist, Es = epiphytes of sun and Esh = epiphytes of shade; Occ. = Occurrence; F1 to F14 = forest fragments studied. *First record for the state of Pará.

coarina, *Cololejeunea camilli*, *C. subcardiocarpa*, *Stictolejeunea squamata*, *Plagiochila disticha*, *P. subplana*, *Fissidens guianensis*, *Calymperes erosum*, *Callicostella pallida*, *Isopterygium tenerum*, *Pilosium chlorophyllum*, and *Pelekium scabrosulum*.

Regarding the frequency of the species, 27 (35%) were classified as rare, 23 (30%) common, and 27 (35%) constant. Among the species classified as rare, the following species stood out by occurring once in this study, *Calypogeia miquelii*, *Cheilolejeunea aneogyna*, *Harpalejeunea oxyphylla*, *Lejeunea setiloba*, *Marchesinia brachiata*, *Radula javanica*, *Leucobryum martianum*, *Lepidopilum scabrisetum*, and *L. surinamense*.

In the similarity analysis (Figure 3), F7 and F14 showed the lowest degree of similarity to the further fragments, which resulted in their location at different branches. They also presented the lowest species richness, compared to all other studied fragments. In F7 were found bryophytes colonizing pieces of plastics in the area of the fragment edge.

The cladogram of similarity also showed the formation of two big groups of fragments, one containing four fragments (F4, F10, F12, and F11) and the other more heterogeneous, consisting of eight fragments (F1, F3, F2, F6, F9, F13, F5 and F8). In the first group, F4 and F10 were more similar than F11 and F12. In the second group, F5 and F8 were less similar than the grouping formed by F1, F3 and F2, and F6, F9 and F13.

The chi-squared test indicated the existence of significant differences (p = 0. 0151) in the number of species of bryophytes among the studied areas (Figure 4).

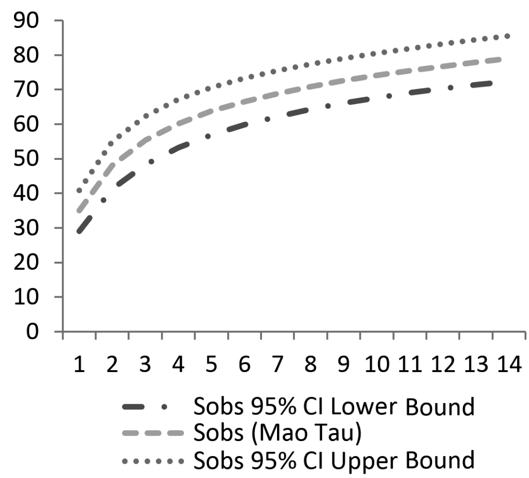

Figure 2. Species accumulation curve generated for the 14 fragments analysed in the region of Volta Grande do Xingu, Pará state, Brazil.

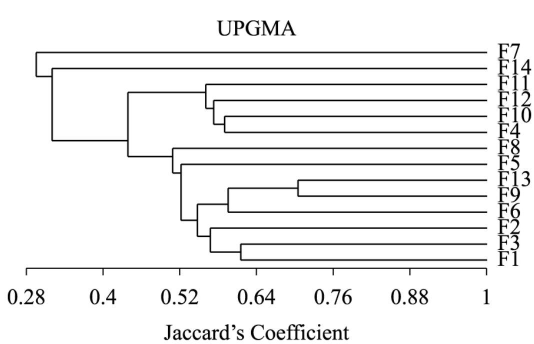

Figure 3. Floristic similarity between fragments in the region of Volta Grande do Xingu, Pará state, Brazil.

The listed species were generalists in their majority (48%), followed by shade epiphytes (30%) and sun epiphytes (21%), one species has not been classified.

In the result of chi-square applied to the guilds of tolerance (Table 2), no significant differences were observed (p = 0.9907) between the categories analyzed.

4. Discussion

The species richness found in the study area (77 spp.) included two species to the list of bryophytes reported by Costa (2014) for the Pará State, which happens to be of 333 species. In the study area, the species accumulation curve was not stabilized, but according to Schilling and Batista (2008) the use of this method in tropical forest is controversial, due to the high richness inherent to this environment. In accordance with Zartman and Nascimento (2006) and Zartman and Shaw (2006), the fragmentation causes loss of richness and diversity of bryophytes. We believe that the sampling on the great curve of the Xingu River was sufficient to represent the bryoflora of the area, since it is not possible to appoint the necessary sampling effort to achieve the richness of an area (Vanzolini, 1992), and because the richness found corresponds to 23.3% of the bryoflora reported for Pará state.

Lejeuneaceae was the most representative family in this study and this is in agreement with other surveys carried out in the Amazon (Gradstein and Costa, 2003; Ilkiu-Borges et al., 2004, 2009; Lisboa and Tavares, 2008; Alvarenga and Lisboa, 2009; Moura et al., 2013; Brito and Ilkiu-Borges, 2013; Tavares-Martins et al., 2014). The results confirmed it as one of the richest families in

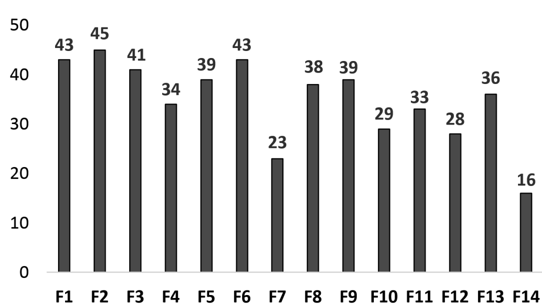

Figure 4. Species richness of bryophytes in different forest fragments studied in the region of Volta Grande do Xingu, Pará state, Brazil.

Table 2. Distribution of the number of different species of bryophytes by the guilds in the studied fragments in the region of Volta Grande do Xingu, Pará state, Brazil, according to the categories: generalist, epiphytes of sun and shade.

GUILD	FRAGMENTS													
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14
Gen	26	23	23	23	20	22	16	22	22	17	19	17	22	12
Es	2	7	7	2	4	5	3	6	6	5	6	3	5	1
Esh	15	15	11	9	15	16	3	10	11	7	8	8	9	3
TOTAL	43	45	41	34	39	43	22	38	39	29	33	28	36	16

the Neotropics, representing approximately 70% of the liverwort in tropical forests (Gradstein et al., 2001).

The higher richness of Calymperaceae, Fissidentaceae, Pilotrichaceae, and Sematophyllaceae was expected and can be explained by their high incidence among the richest families in the Neotropics (Gradstein et al., 2001). Fissidentaceae is mainly found in tropical regions, but its richness decreases with higher latitude (Pursell, 2007).

The genera *Lejeunea*, *Cheilolejeunea*, *Ceratolejeunea*, *Fissidens*, *Calymperes* and *Syrrhopodon* are often the most representative in Pará (Santos and Lisboa, 2008; Moraes and Lisboa, 2009; Brito and Ilkiu-Borges, 2013; Moura et al., 2013), and therefore this result was also predictable.

Among the most occurring species, *Calymperes erosum* is considered quite tolerant, and may be potentially indicative of disturbed habitats (Santos and Lisboa, 2008), other species such as *Octoblepharum albidum*, *Taxitelium planum*, *Sematophyllum subsimplex* and *Calymperes palisotii* which also occurred in the region of the great curve of the Xingu River were considered as indicators of disturbed habitats by Lisboa and Ilkiu-Borges (1995).

Studies in tropical forests pointed to a greater richness of rare species (Silva and Pôrto, 2007; Garcia, 2012). Therefore, the equal rates of rare and constant species is unusual and indicates a change in the establishment of bryophytes community in the region of the great curve of the Xingu River. The strategies of dispersal and establishment of bryophytes are associated with spatial patterns of local richness and environmental conditions (favorable and stable), thus, many species have small populations and heavily dependent on interactions with neighboring populations (Husband and Barrett, 1996; Glime, 2007; Mota de Oliveira et al., 2009).

In this study, the mosses *Leucobryum martianum, Lepidopilum surinamense* and *L. scabrisetum* as well as the liverworts *Cheilolejeunea aneogyna, Harpalejeunea oxyphylla* and *Radula javanica* were considered rare.

Leucobryum martianum, Lepidopilum surinamense and *L. scabrisetum* are characteristic epiphytes of humid tropical forest (Lisboa and Ilkiu-Borges, 1996; Santos and Lisboa, 2008; Moraes and Lisboa, 2009; Moura et al., 2013), and the later one seems to be confined to this type of environment (Florschütz-de Waard, 1986). In Pará, only *L. surinamense* was found in canga vegetation, an open and dry environment (Moraes and Lisboa, 2006). *Leucobryum martianum* was also considered abundant in the Amazon, forming large mats on the floor of terra firme forest (Yano, 1992),

Cheilolejeunea aneogyna, Harpalejeunea oxyphylla and *Radula javanica* are common species in lowland tropical forest, and the two former species can also be found in submontane forest (Gradstein and Costa, 2003). In Pará, *Cheilolejeunea aneogyna* was registered in both primary and secondary forests (Garcia et al., 2014; Moura et al., 2013; Tavares-Martins et al., 2014). Tavares-Martins et al. (2014) registered *H. oxyphylla* and *R. javanica* exclusively in canopy of terra firme forest and emphasized that these species are typical of open environments.

According to Söderström and During (2005), there are various types of species rarity and a species can be rare in different scales. Since the species above mentioned were collected in different areas and environments of the Pará state, also being considered common, the rarity of these species in the study area can be related to the fragmentation and the isolation of the fragment, which decrease the rates of species colonization (Zartman and Shaw, 2006).

The less similar fragments, F7 and F14, were located very close to the access roads. Although not visible during the fragment selection for this study, the canopy of the two fragments was more open in relation to the others, as well as possessing lower tree species richness and signs of disturbance inside, such as cut trees and plastic waste.

The conservation status of the fragments was the factor that exerted the greatest influence on the similarity between areas in the region of the great curve of the Xingu River. The fragments F9 and F13 were those who had a higher degree of similarity, followed by F3 and F1 and by F10 and F4. These showed structures with similar canopies (more closed), without signs of disturbance inside and greater presence of tree species.

The species composition was also influenced by the conservation status of the fragments, because as stated Zartman (2003) and Zartman and Nascimento (2006), the maintenance of communities depends on neighboring populations, which may be present in near fragments.

The fragments with the higher species richness were F1, F2, F3, and F6, which possibly generated the significant difference observed. They shared physiognomic characteristics, present enclosed canopy and few clearings and, therefore, were more humid. According to Oliveira et al. (2011), the best physionomically structured fragments harbor a rich bryoflora, because they have a higher number of trees, with larger diameters and height, which are important characteristics for their maintenance. The low-light environments and with more humidity are, according to Richards (1984), the favorable microclimate for the maintenance of the bryoflora.

Regarding to the light tolerance guilds, the result was similar to that found by Silva and Pôrto (2009, 2010, 2013) and Santos et al. (2011), conducted in lowland forests in Atlantic Forest. In a study conducted in submontane forest, in Bolivia, Acebey et al. (2003) realized that generalist species are apparently indifferent to forest destruction, while those with smaller niches (experts) seem to be less likely to survive the deforestation, as observed in this study where there was predominance of generalists. However, the large proportion of specialist (sun/share epiphytes), indicates that the fragments still have conditions for their establishment, mainly by their physiognomic conditions.

The species can vary greatly in their susceptibility to fragmentation due to their different dispersion abilities, persistence and establishment in fragmented landscapes (Kolb and Diekmann, 2004).

The fragments studied in the region of the great curve of the Xingu River revealed a rich bryoflora, which represents approximately 25% of species registered in the state of Pará (318 spp.), especially considering the fact that this study included only one type of forest formation. The results showed that predominant families were like those typically found in surveys in tropical forests, but the standard of rarity found here did not follow the pattern observed for both bryophytes and other groups of plants in tropical forests, probably due to historical fragmentation and disturbance in the area. The richness and species composition were determined mainly by the physiognomic characteristics of the studied areas.

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