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Bryoflora of the municipalities of Soure and Cachoeira do Arari, on Marajó Island, in the state of Pará, Brazil[1]

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ABSTRACT

This study aims to investigate the richness and ecological aspects (ecosystem and substrate) of mosses and liverworts at two municipalities on Marajó Island, in the state of Pará, Brazil. The study area (6615 km^2) encompasses the municipalities of Soure and Cachoeira do Arari. Bryophytes were collected from the 10th to the 16th of January, 2007, during random visits along existing trails or during the forging of new trails, from all possible types of vegetation, regardless of the type of substrate. The ecosystems visited in the study area were *capoeira* (secondary vegetation, growing on land that has been burned or cleared), *teso* (vegetation growing on areas of land at an elevation slightly higher than the water line during flood season), floodplain forest, mangrove forests, *cerrado* (savanna) and natural grasslands (pure and mixed). In total, 11 families, 30 genera, and 67 species were recorded, of which 39 represented new records for the island. *Cololejeunea panamensis* G. Dauphin & Pocs represented a new record for South America; *Microlejeunea subulistipa* Steph. represented a new record for the northern region of Brazil, and *Cololejeunea verwimpii* Tixier and *Mastigolejeunea innovans* (Spruce) Steph. represented new records for the state of Pará.

Key words: Bryophyta, Marchantiophyta, Bryophytes, Amazon, neotropics

Introduction

Insular environments can contain a subset of continental flora (Tan & Pócs 2000). Therefore, floristic studies on islands are important to determine how and which species are distributed in these locations. Yano & Peralta (2008) analyzed studies of bryophytes on islands in the state of São Paulo and noted that the composition of species found on the islands does not seem to differ from that of those found on the continent. However, the authors stress the importance of conducting taxonomic and ecological studies to understand the population dynamics of bryophytes in island environments.

Marajó Island is a continental, fluvial-marine island of approximately 48,000 km^2 located at the mouth of the Amazon River in the state of Pará, and is geopolitically subdivided into 12 municipalities (Cruz 1987): Afuá, Anajás, Breves, Cachoeira do Arari, Chaves, Curralinho, Muaná, Ponta de Pedras, Salvaterra, Santa Cruz do Arari, São Sebastião da Boa Vista and Soure.

On Marajó Island, exploitative activities such as mining and overgrazing are quite common (Ferreira *et al.* 2001). The island's vegetation is used for various purposes, such as those of the construction and furniture industries (Amaral *et al.* 2007). However, overexploitation results in habitat degradation and the suppression of vegetation at levels that threaten biodiversity in the Amazon (MMA 2004). For bryophytes, one of the predicted changes is the loss of specific groups, such as epiphytic bryophytes (Gradstein 1992). The recommendations made by the Conservation Action Plan for Bryophytes (Plano de Ação para Conservação das Briófitas) include increasing inventories to determine the richness and types of habitats in various tropical regions (Hallingbäck & Hodgetts 2000).

The first studies on the bryophytes of Marajó Island were conducted in the 1990s and combined records collected in four municipalities: Salvaterra, Afuá, Anajás and Chaves. Most of those studies, however, dealt only with mosses, with the exception of that conducted by Lisboa *et al.* (1993) in Salvaterra, which included liverwort records (related to a total of 12 species, belonging to five families). Lisboa & Maciel (1994) studied the bryophytes in the municipality of Afuá, where 31 species of mosses (of 15 families) were reported. In the city of Chaves, Lisboa *et al.* (1998) identified 18 species (of nine families), and in Anajás, Lisboa *et al.* (1999) cataloged 34 mosses (of 17 families).

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Recent studies have included mosses as well as liverworts. L. P. Macedo conducted a study in 2009 involving bryophytes found on palm trees in the municipalities of Soure and Cachoeira do Arari (unpublished data). That study identified 21 species (13 mosses and eight liverworts). In addition, D. N. Fagundes and E. T. Garcia, also in 2009, identified 26 species (15 mosses and 11 liverworts) from the Bacurizal Reserve in the municipality of Salvaterra (Fagundes & Garcia, personal communication).

Marajó Island bryophytes are known on the basis of studies of the bryoflora from six of the 12 municipalities on the island, and liverworts have been recorded in only half of the municipalities studied. Therefore, it appears that knowledge about Marajó bryoflora remains incipient, particularly as it regards liverworts. In addition, the ongoing deforestation resulting from ranching and mining in this region might have caused habitat loss and consequently the disappearance of species yet unknown, lending an urgent quality to the need for a survey of bryoflora in the region. The aim of this work is to investigate the richness and ecological aspects (ecosystem and substrate) of mosses and liverworts in selected municipalities on Marajó Island.

Material and methods

The study area (6615 km^2) includes the municipalities of Soure and Cachoeira do Arari (Fig. 1). The region is classified as aving a humid, equatorial climate (Amaral *et al.* 2007; Cruz 1987). The vegetation comprises floodplain forests, grasslands, *teso* (vegetation growing on areas of land at an elevation slightly higher than the water line during flood season), mangrove forests and many areas of secondary vegetation (Capobianco *et al.* 2001). The altitude ranges from 4 to 20 m above sea level (Cruz 1987). Bryophytes were collected from the 10th to the 16th of January, 2007, during random visits along existing trails or during the forging new trails, from all possible types of vegetation, regardless of the type of substrate.

The environments visited in the study area (Tab. 1) were classified on the basis of Pires & Prance (1985) and Amaral *et al.* (2007; 2008), being broadly characterized by the collectors as *capoeira* (secondary vegetation, or vegetation that grows on land previously burned or cleared), resulting from human activity, such as family agriculture, logging and artificial pastures; *teso*, an environment characterized by *Desmoncus* spp., *Bactris maraja* Mart., *Euterpe oleracea* Mart. and *Guadua* spp., in black soil; floodplain forests, defined as ecosystems that border fast-moving rivers or muddy river basins; mangrove forests, composed of narrow strips of coastal vegetation and subject to flooding; (5) *cerrado*, or savanna, physiognomically similar to that found in central Brazil but with different soil and climate.

There are also natural grasslands, known as pure grasslands and mixed grasslands (6). In the pure grasslands on Marajó Island, the landscape matches the description of pure grassland savanna. In such grasslands, the herbaceous layer, which resembles a mosaic, forms copses or even forest islands dozens of hectares in size or interspersed with groups of palm trees. The soil is sandy-loamy and blackened, but there are large areas (patches) of white sand. However, in the mixed, or shrubby-arboreal, grasslands, the landscape features small copses and forest islands of varying size and shape; the environment contains many isolated trees or large groups of trees; and the soil is dark, being either sandy or a mixture of sandy and loamy.

The collection and preservation of samples followed the methodology described by Lisboa (1993). The species were identified on the basis of the bibliography cited here, such as Bischler *et al.* (1963), Buck (2003), Dauphin (2003), Florschütz (1964), Gradstein (1994), Gradstein & Costa (2003), Gradstein & Ilkiu-Borges (2009), Ilkiu-Borges & Lisboa (2002a; 2004a; 2004b), Ireland & Buck (1994), Lisboa (1993), Reese (1993), Reiner-Drehwald (1994; 2009), Schuster (1980), Tixier (1991), Van Slageren (1985) and Zartman & Ilkiu-Borges (2007). The classification systems adopted were that of Crandall-Stotler *et al.* (2009) for Marchantiophyta and that of Goffinet *et al.* (2009) for Bryophyta. For each species, aspects of their ecology (ecosystem and substrate), material selected and worldwide distribution pattern were characterized as per Costa *et al.* (2007), Costa *et al.* (2010), Reiner-Drehwald (2009), Florschütz (1964), Gradstein (1994), Gradstein & Costa (2003), Ireland & Buck (1994), Pursell (2007), Reese (1993), Santos & Costa (2010), Sharp *et al.* (1994), Tropicos (2011), Valente & Pôrto (2006) and Yano (2006; 2008).

The species were classified according to the substrate on which they were found (Robbins 1952). Species that occurred on living leaves were classified as epiphylls , and those collected from termites mounds (termitaria) were treated as a class apart, because they do not fit into any of the previously defined categories. The collected samples were preserved and deposited in the Emílio Goeldi Paraense Museum Herbarium, located in the city of Belém.

Results and discussion

In Soure and Cachoeira do Arari, we recorded 1275 occurrences of bryophytes across 67 species, 30 genera and 11 families (Tab. 1). We analyzed 617 samples containing bryophytes. However, only a representative sample of each species will be presented as the selected material.

Mosses were represented by 25 species in 13 genera and eight families, of which the two most representative were Fissidentaceae (seven species) and Calymperaceae (six species). These families are among the most common in tropical America (Gradstein *et al.* 2001). Fissidentaceae is found mainly in the tropical regions of the globe (Pursell 2007; Gradstein *et al.* 2001), and Calymperaceae is one of the richest and most abundant families in lowland forests of the neotropics (Gradstein *et al.* 2001).

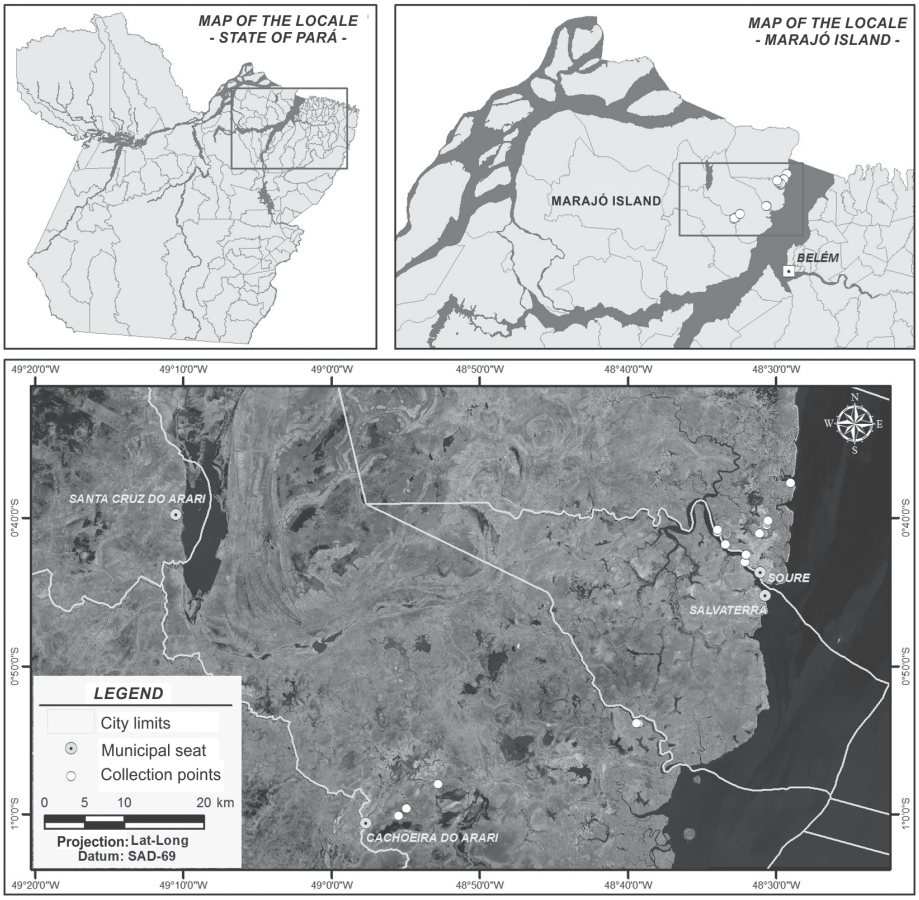

Figure 1. Map of Marajó Island, highlighting the municipal seats of Soure and Cachoeira do Arari, as well as the collection points.

Of the liverworts, we recorded 42 species in 17 genera and three families. This group had higher species richness (63%) when compared with mosses (37%). Among families of liverworts, as expected, Lejeuneaceae showed the highest richness (39 species, 93% of the diversity of the group in the area). The most representative genera also belonged to Lejeuneaceae, including *Cheilolejeunea* (Spruce) Schiffn. (seven species), as well as *Cololejeunea* (Spruce) Schiffn. and *Lejeunea* Lib. (five species each).

Of the species recorded, 6% represented new records: *Cololejeunea verwimpii* and *Mastigolejeunea innovans,* collected here for the first time in the state of Pará; *Microlejeunea subulistipa,* a new record for northern Brazil; and *Cololejeunea panamensis,* a new record for South America and recorded here for the second time since the species was first described (Brito & Ilkiu-Borges 2012). We also documented new records for six liverwort genera *(Mastigolejeunea, Plagiochila, Prionolejeunea, Rectolejeunea, Stictolejeunea* and *Symbiezidium)* and two moss genera *(Entodontopsis* and *Pterogonidium).*

Of the species recorded in Soure and Cachoeira do Arari, 94% have a wide distribution in Brazil, occurring in three or more phytogeographic domains. As for worldwide distribution, the predominant distribution was neotropical (60%), followed by pantropical (24%), and the tropics of Africa and the Americas (6%), only 3% occurring in tropical and subtropical America. Only one species, *Taxithelium planum*, showed wide distribution. The species *Trichosteleum papillosum* has only been recorded in South America. *Microlejeunea subulistipa* and *Archilejeunea crispistipula* have restricted distribution in Brazil (Tab. 1). Similar results for the predominance of neotropical species distribution were found in several studies conducted in Brazil, such as that conducted by Costa & Santos (2010) in the Atlantic Forest of Rio de Janeiro, as well as those conducted by Osakada & Lisboa (2004), Alvarenga *et al.* (2007, 2008) and Tavares (2009) in the Amazon Rainforest within the state of Pará.

Among the species studied, *Archilejeunea crispistipula* and *Microlejeunea acutifolia* are exclusive to the Amazon phytogeographic domain and *Microlejeunea subulistipa,* previously found only in the Atlantic Forest, had expanded its distribution, with disjunct distributions in the Amazon and Atlantic Forest. Similar patterns were found by Santos & Costa (2010) while studying the phytogeography of liverworts in the Atlantic Forest. It is believed that during the formation of the Atlantic Forest there were periods of contact with other vegetation formations, such as the Amazon and Andean Forests (Leitão-Filho 1987; Rizzini 1997).

Table 1. List of bryophytes distributed in the ecosystems and substrates of the municipalities of Soure and Cachoeira do Arari, Marajó Island, Brazil, and worldwide distribution pattern of each species.

PHYLUM / Family / Species	No. Rec.		Ecosystems									Species per substrate										Selected Material	Worldwide Distribution
			Soure					Cachoeira do Arari				Soure				Cachoeira do Arari							
	Soure	Cachoeira do Arari	Sv	Ts	Fl	Ma	Sa	Fl	Ma	Pg	Mg	Co	Ex	Te	Tm	Co	Ex	Ep	Te	Tm	Ru		
BRYOPHYTA																							
Bryaceae																							
Bryum coronatum Schwägr.	-	1									1									1		Cachoeira do Arari, Ikiu--Borges *et al.* 3400 (MG).	Pantropical
Calymperaceae																							
Calymperes afzelii Sw.	38	12	21	11			6	1	3		8	33	5			8	3		1			Soure, Ilkiu-Borges *et al.* 3033 (MG).	Pantropical
C. erosum Müll. Hal.	16	2	4	12				1			1	15			1	1				1		Soure, Ilkiu-Borges *et al.* 3112 (MG).	Pantropical
C. lonchophyllum Schwägr.	-	5						5								4	1					Cachoeira do Arari, Santos *et al.* 339 (MG).	Pantropical
C. palisotii Schwägr.	89	40	23	54		4	8	2			27	82	7			34	5		1			Soure, Ilkiu-Borges *et al.* 3144 (MG).	Pantropical
Octoblepharum albidum Hedw.	27	24	12	5	10					14	10	19	6		2	20	2		1	1		Soure, Ilkiu-Borges *et al.* 3065 (MG).	Pantropical
Syrrhopodon cryptocarpos Dozy & Molk.	5	-	3				2					5										Soure, Ilkiu-Borges *et al.* 3091 (MG).	Tropics of Africa and the Americas
Fissidentaceae																							
Fissidens elegans Brid.	-	5									5					1			3	1		Cachoeira do Arari, Santos *et al.* 454 (MG).	Neotropical
F. guianensis Mont.	8	14	2	1			5	14				7			1	10	3				1	Soure, Ilkiu-Borges *et al.* 3094 (MG).	Neotropical
F. inaequalis Mitt.	1	3			1			3						1			1			1	1	Soure, Santos *et al.* 223 (MG).	Neotropical
F. intromarginatus (Hampe) A. Jaeg.	-	1									1								1			Cachoeira do Arari, Santos *et al.* 433 (MG).	Neotropical

Continues

Table 1. Continuation.

PHYLUM / Family / Species	No. Rec.		Ecosystems									Species per substrate										Selected Material	Worldwide Distribution
			Soure					Cachoeira do Arari				Soure				Cachoeira do Arari							
	Soure	Cachoeira do Arari	Sv	Ts	Fl	Ma	Sa	Fl	Ma	Pg	Mg	Co	Ex	Te	Tm	Co	Ex	Ep	Te	Tm	Ru		
F. pellucidus Hornsch.	2	3	1		1			3						1	1	2				1		Soure, Santos *et al.* 176 (MG).	Neotropical
F. submarginatus Bruch	-	6									6					2			4			Cachoeira do Arari, Ilkiu-Borges *et al.* 3383 (MG).	Neotropical
F. zollingeri Mont.	-	3									3					3						Cachoeira do Arari, Santos *et al.* 431 (MG).	Pantropical
Leucobryaceae																							
Campylopus surinamensis Müll. Hal.	-	1									1								1			Cachoeira do Arari, Santos *et al.* 402 (MG).	Tropical & Subtropical Americas
Pilotrichaceae																							
Callicostella pallida (Hornsch.) Ångström.	-	6						5		1						2	3		1			Cachoeira do Arari, Santos *et al.* 328 (MG).	Neotropical
Pylaisiadelphaceae																							
Isopterygium subbrevisetum (Hampe) Broth.	-	13						7		6						8	4		1			Cachoeira do Arari, Ilkiu-Borges *et al* 3261 (MG).	Neotropical
I. tenerum (Sw.) Mitt.	-	3								3						3						Cachoeira do Arari, Ilkiu-Borges *et al.* 3316 (MG).	Neotropical
Pterogonidium pulchellum (Hook.) Müll. Hal.	-	33						1		23	9					18	12		2	1		Cachoeira do Arari, Ilkiu-Borges *et al.* 3375 (MG).	Neotropical
Taxithelium planum (Brid.) Mitt.	1	38		1				27		4	7		1			27	10				1	Soure, Santos *et al.* 219 (MG).	Wide
Sematophyllaceae																							
Sematophyllum subpinnatum (Brid.) Britton	-	7								4	3					7						Cachoeira do Arari, Ilkiu-Borges *et al.* 3416 (MG).	Pantropical
Sematophyllum subsimplex (Hedw.) Mitt.	59	16	45	12	2			7		2	7	43	15		1	11	5					Cachoeira do Arari, Santos *et al.* 428 (MG).	Tropics of Africa and the Americas

Continues

Table 1. Continuation.

PHYLUM / Family / Species	No. Rec.		Ecosystems									Species per substrate										Selected Material	Worldwide Distribution
			Soure					Cachoeira do Arari				Soure				Cachoeira do Arari							
	Soure	Cachoeira do Arari	Sv	Ts	Fl	Ma	Sa	Fl	Ma	Pg	Mg	Co	Ex	Te	Tm	Co	Ex	Ep	Te	Tm	Ru		
Trichosteleum papillosum (Hornsch.) A. Jaeg.	5	5	3	1			1	4		1		4	1			3	2					Soure, Ilkiu-Borges *et al.* 3095 (MG).	South America
T. subdemissum (Besch.) A. Jaeg.	2	2	1				1	2				2				1	1					Cachoeira do Arari, Santos *et al.* 360 (MG).	Tropics of Africa and the Americas
Stereophyllaceae																							
Entodontopsis leucostega (Brid.) Buck & Ireland	5			1			4					4	1									Soure, Ilkiu-Borges *et al.* 3219 (MG	Pantropical
MARCHANTIOPHYTA																							
Frullaniaceae																							
Frullania apiculata (Reinw., Blume & Nees) Dumort	3	1		2	1						1	3				1						Soure, Santos *et al.* 218 (MG).	Pantropical
F. gibbosa Nees	5	2			5					2		4	1			2						Soure, Ilkiu-Borges *et al.* 3169 (MG).	Neotropical
Lejeuneaceae																							
Acrolejeunea emergens (Mitt.) Steph.	17	33	1	7	8		1			16	17	16	1			30	3					Cachoeira do Arari, Ilkiu-Borges *et al.* 3379 (MG).	Pantropical
A. torulosa (Lehm. & Lindenb.) Schiffn.	1	16			1					1	15	1				15	1					Cachoeira do Arari, Ilkiu-Borges *et al.* 3443 (MG).	Neotropical
Archilejeunea auberiana (Mont.) A. Evans	-	1								1						1						Cachoeira do Arari, Santos *et al.* 3415 (MG).	Neotropical
A. crispistipula (Spruce) Steph.	-	16								15	1					14	2					Cachoeira do Arari, Ilkiu-Borges *et al.* 3368 (MG).	Brazil
A. fuscescens (Hampe ex Lehm.) Fulford	-	20						1		19						14	5		1			Cachoeira do Arari, Ilkiu-Borges *et al.* 3263 (MG).	Neotropical
A. parviflora (Nees) Schiffn.	-	5						5								3	1	1				Cachoeira do Arari, Ilkiu-Borges *et al.* 3230 (MG).	Neotropical

Continues

Table 1. Continuation.

PHYLUM / Family / Species	No. Rec.		Ecosystems									Species per substrate										Selected Material	Worldwide Distribution
			Soure					Cachoeira do Arari				Soure				Cachoeira do Arari							
	Soure	Cachoeira do Arari	Sv	Ts	Fl	Ma	Sa	Fl	Ma	Pg	Mg	Co	Ex	Te	Tm	Co	Ex	Ep	Te	Tm	Ru		
Ceratolejeunea cornuta (Lindenb.) Steph.	-	22						9		3	10					18	3				1	Cachoeira do Arari, Ilkiu-Borges *et al.* 3265 (MG).	Neotropical
C. cubensis (Mont.) Schiffn.	-	6						6								6						Cachoeira do Arari, Ilkiu-Borges *et al.* 3235 (MG).	Neotropical
C. laetefusca (Austin) Schust.	-	3								3						2	1					Cachoeira do Arari, Ilkiu-Borges *et al.* 3369 (MG).	Neotropical
Cheilolejeunea adnata (Kunze) Grolle		3									3					2	1					Cachoeira do Arari, Santos *et al.* 453 (MG).	Neotropical
C. comans (Spruce) Schust.	8	8		4		4				8		8				8						Soure, Ilkiu-Borges *et al.* 3209 (MG).	Neotropical
C. discoidea (Lehm. & Lindenb.) Kachr. & Schust.	15	26	6	4	5			7		4	15	13	2			23	3					Soure, Santos *et al.* 166 (MG).	Neotropical
C. holostipa (Spruce) Grolle & R.-L.Zhu	_	1						1								1						Cachoeira do Arari, Santos *et al.* 344 (MG).	Neotropical
C. oncophylla (Ångström.) Grolle & E. Reiner	41	42	13	21	5	1	1	6		8	28	37	4			37	5					Soure, Ilkiu-Borges *et al.* 3088 (MG).	Neotropical
C. rigidula (Mont.) Schust.	74	19	25	30	1	17	1	13			6	73	1			17	2					Cachoeira do Arari, Ilkiu-Borges *et al.* 3272 (MG).	Tropics of Africa and the Americas
Cheilolejeunea sp.	-	5								2	3					5						Cachoeira do Arari, Ilkiu-Borges *et al.* 3326 (MG).	Cachoeira do Arari
Cololejeunea cardiocarpa (Mont.) A. Evans	-	2								2						2						Cachoeira do Arari, Ilkiu-Borges *et al.* 3310 (MG).	Pantropical
C. diaphana A. Evans	-	1								1							1					Cachoeira do Arari, Santos *et al.* 295 (MG).	Pantropical
C. minutissima subsp. m*yriocarpa* (Nees & Mont.) Schust.	-	15								15						12	3					Cachoeira do Arari, Santos *et al.* 382 (MG).	Pantropical
C. panamensis G. Dauphin & Pócs	9	-	3	6								9										Soure, Ilkiu-Borges *et al.* 3059 (MG).	Neotropical

Continues

Table 1. Continuation.

PHYLUM / Family / Species	No. Rec.		Ecosystems									Species per substrate										Selected Material	Worldwide Distribution
			Soure					Cachoeira do Arari				Soure				Cachoeira do Arari							
	Soure	Cachoeira do Arari	Sv	Ts	Fl	Ma	Sa	Fl	Ma	Pg	Mg	Co	Ex	Te	Tm	Co	Ex	Ep	Te	Tm	Ru		
C. verwimpii Tixier	23	4	6	17				1		2	1	21	2			1		3				Soure, Ilkiu-Borges *et al.* 3058 (MG).	Neotropical
Frullanoides corticalis Lehm. & Lindenb.) Slageren	56	3		49	5		2	1			2	56				2		1				Soure, Ilkiu-Borges *et al.* 3141 (MG).	Neotropical
Lejeunea adpressa Nees	1	1		1				1				1				1						Cachoeira do Arari, Ilkiu-Borges *et al.* 3235 (MG).	Subtropical & Tropical Americas
L. caulicalyx (Steph.) E. Reiner & Goda	-	4								1	3					1	2			1		Cachoeira do Arari, Ilkiu-Borges *et al.* 3346 (MG).	Neotropical
L. laetevirens Nees & Mont.	72	26	4	63	4		1	8		11	7	69	3			20		6				Soure, Ilkiu-Borges *et al.* 3062 (MG).	Neotropical
L. phyllobola Nees & Mont.	1	21		1				16		4	1	1				18	3					Cachoeira do Arari, Santos *et al.* 340 (MG).	Neotropical
L. trinitensis Lindenb.	-	1								1						1						Cachoeira do Arari, Ilkiu-Borges *et al.* 3447 (MG).	Neotropical
Leptolejeunea elliptica (Lehm. & Lindenb.) Schiffn	-	11								11						2		9				Cachoeira do Arari, Ilkiu-Borges *et al.* 3360 (MG).	Neotropical
Lopholejeunea subfusca (Nees) Schiffn.	5	41		5				14		17	10	5				40	1					Soure, Ilkiu-Borges *et al.* 3147 (MG).	Pantropical
Mastigolejeunea auriculata (Wilson) Schiffn.	_	1									1					1						Cachoeira do Arari, Ilkiu-Borges *et al.* 3441 (MG).	Pantropical
M. innovans (Spruce) Steph.	_	6									6					4	1			1		Cachoeira do Arari, Santos *et al.* 453 (MG).	Neotropical
Microlejeunea acutifolia Steph.	2	-	2									2										Soure, Ilkiu-Borges *et al.* 3032 (MG).	Neotropical
M. bullata (Taylor) Steph.	24	2	9	13	2						2	21	3				2					Soure, Ilkiu-Borges *et al.* 3052 (MG).	Neotropical
M. epiphylla Bischl.	5	4	2	3						1	3	5				3	1					Cachoeira do Arari, Ilkiu-Borges *et al.* 3392 (MG).	Neotropical

Continues

Table 1. Continuation.

PHYLUM / Family / Species	No. Rec.		Ecosystems									Species per substrate										Selected Material	Worldwide Distribution
			Soure					Cachoeira do Arari				Soure				Cachoeira do Arari							
	Soure	Cachoeira do Arari	Sv	Ts	Fl	Ma	Sa	Fl	Ma	Pg	Mg	Co	Ex	Te	Tm	Co	Ex	Ep	Te	Tm	Ru		
M. subulistipa Steph.	-	3								3						1	2					Cachoeira do Arari, Santos *et al.* 437 (MG).	Brazil
Prionolejeunea denticulata (Nees) Schiffn.	-	1						1								1						Cachoeira do Arari, Santos *et al.* 355 (MG).	Neotropical
Rectolejeunea berteroana (Gottsche ex Steph.) A. Evans	-	1						1								1						Cachoeira do Arari, Santos *et al.* 359 (MG).	Neotropical
Stictolejeunea squamata (Willd. ex Weber) Schiffn.	-	1						1								1						Cachoeira do Arari, Santos *et al.* 346 (MG).	Neotropical
Symbiezidium transversale (Sw.) Trevis.	-	2						2								2						Cachoeira do Arari, Santos *et al.* 418 (MG).	Neotropical
Plagiochilaceae																							
Plagiochila montagnei Nees	-	32						17		9	6					29	3					Cachoeira do Arari, Ilkiu-Borges *et al.* 3244 (MG).	Neotropical
Total records	620	655	186	324	51	26	33	193	3	229	230	559	53	2	6	507	98	20	17	9	4		
Total species	31	64	20	24	14	4	12	33	1	35	35	28	15	2	5	57	33	5	11	9	4		

No. Rec. – number of records; Sv – secondary vegetation; Ts – *teso* (vegetation growing on areas of land at an elevation slightly higher than the water line during flood season); Fl – floodplain; Ma – mangrove forest; Sa – savanna; Pg – pure grassland; Mg – mixed grassland; Co – Corticicolous; Ex – epixylous; Ep – epiphyllous; Te – terrestrial; Tm – termite mound; Ru – rupicolous.

Studies on patterns of geographic distribution are mentioned by Fiaschi & Pirani (2009), who state that those patterns, for vascular plants in Brazil, are generally in agreement with the main geomorphological domains and related types of vegetation. However, due to their forms of dispersion, bryophytes have a wider distribution than spermatophytes (Watson 1974; Tan & Pócs 2000).

There was an observable difference in species richness between the ecosystems studied. In Soure, 31 species were recorded, including 13 belonging to the Bryophyta division and 18 belonging to Marchantiophyta. As shown in Tab. 1, the bryoflora in Cachoeira do Arari was richer in terms of species (63 species) when compared with Bryophyta (23 species) and Marchantiophyta (40 species). This result might not have been influenced by sampling difference, because the bryoflora present in Soure and Cachoeira do Arari was estimated on the basis of 620 and 655 samples, respectively. Regarding the groups studied in these municipalities, Soure produced the majority of Bryophyta records (258, compared with 243 in Cachoeira), while Cachoeira do Arari was predominant in Marchantiophyta (412 vs. 362), as can be seen in Fig. 2.

Fig. 3 illustrates the ratio between the most frequently occurring species, which represent 28% of species cited in this work. Some of them are among the most commonly cited in the literature concerned with the study of bryoflora in the Lower Amazon and the coast of Pará, such as: *Sematophyllum subsimplex* (Santos & Lisboa 2003; 2008; Sousa & Lisboa 2005; Moraes & Lisboa 2006; Ilkiu-Borges *et al.* 2009), *Octoblepharum albidum* albidum (Moraes & Lisboa 2009; Santos & Lisboa 2003; 2008; Ilkiu-Borges et al. 2009), *Taxithelium planum* (Santos & Lisboa 2003; Sousa & Lisboa 2005), *Calymperes palisotii* (Lisboa *et al* 1998; Lisboa & Tavares 2008; Santos & Lisboa 2003; 2008; Ilkiu-Borges *et al.* 2009), *Cheilolejeunea rigidula* (Lisboa & Tavares *2008), Archilejeunea fuscescens* (Ilkiu-Borges & Lisboa 2002a) and *Ceratolejeunea cornuta* (Ilkiu-Borges & Lisboa 2002a). These species have a wide distribution pattern (Tab. 1), as well as broad ecological amplitude. Consequently, this result was expected, given that the vegetation of the region has been altered considerably.

Soure presented five types of ecosystems and Cachoeira do Arari presented four types (Tab. 1). A variation in species composition was recorded within these municipalities. In the first, 13% of the reported species were unique, compared with 57% in the second. These results reflect the difference in species richness and the predominance of mosses and liverworts found in each municipality, which is probably associated with microclimatic variations (mainly humidity) and abiotic variations in the various ecosystems studied. The majority of unique species were collected in Cachoeira do Arari, in the more forested grassland areas, and this might have influenced the richness as well as the quality of these species, i.e., favoring species with narrower ecological niches and therefore less tolerant to environmental changes.

Regarding the number of records in particular ecosystems, this followed the same pattern as species richness. Thus, the ecosystems in which the highest numbers of records were observed were mixed and pure grasslands (459), followed by *teso* (324), floodplain forest (244) and secondary vegetation (186). Regarding the number of species, the mixed and pure grasslands also predominated, with 35 species each, followed by floodplains (47 species), *teso* (24 species) and secondary vegetation (20 species).

Of the species recorded in this study, 18 (27%) were observed only in the pure and mixed grasslands of Cachoeira do Arari. Thirteen species (33%) were restricted to floodplain forests. In the study conducted by Ilkiu-Borges & Lisboa (2002a), the floodplain ecosystem also showed high species richness (48 species) and the greatest number of records (416).

The areas of secondary vegetation, despite having a large number of species (20 species), had only one unique species, *Microlejeunea acutifolia.* A similar result was found by Ilkiu-Borges & Lisboa (2002a). In a study conducted in municipalities of northeastern Pará, Santos & Lisboa (2003) observed that secondary vegetation was one of the environments that presented the highest numbers of records (131) and species (35). In a subsequent study, also conducted in northeastern Pará (Santos & Lisboa 2008), the authors again observed that secondary vegetation presented high numbers of records (336) and species richness (31), as in the present study.

The species *Cheilolejeunea oncophylla, Cheilolejeunea rigidula, Lejeunea laetevirens, Calymperes afzelii, C. palisotii, C. erosum, Octoblepharum albidum, Sematophyllum subsimplex, Fissidens guianensis, Trichosteleum papillosum, Acrolejeunea emergens, Cheilolejeunea discoidea, Cololejeunea verwimpii, Frullanoides corticalis, Lopholejeunea subfusca* and *Microlejeunea bullata* were collected in four to seven ecosystems, corresponding to 24% of the species collected and, therefore, representing the most common species in the study area.

The species *Bryum coronatum*, *Campylopus surinamensis*, *Fissidens intromarginatus*, *Prionolejeunea denticulata*, *Rectolejeunea berteroana* and *Stictolejeunea squamata* occurred only once in the area, corresponding to 9% of the species recorded in this study, and were found only in Cachoeira do Arari (Tab. 1).

Among colonization substrates of bryophytes, living tree trunks had higher representation (84%) as it relates to number of records. This can be explained by the fact that in tropical forests it is the most available substrate, taking the form of trees, saplings, shrubs, seedlings and lianas (Gradstein 1995). Decaying tree trunks were the second most used substrate (12%). These results corroborate those of Richards (1984), which indicated live trunks followed by decaying trunks as the substrates most used by bryophytes in tropical forests, as they are the most abundant in these types of forests. These results are also in agreement with

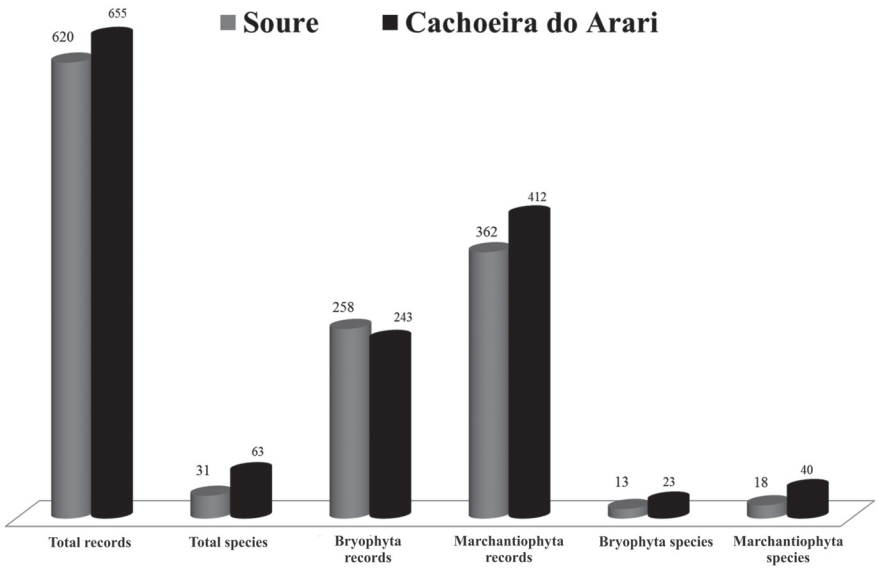

Figure 2. Number of records and of species in the municipalities of Soure and Cachoeira do Arari, Marajó Island, Brazil.

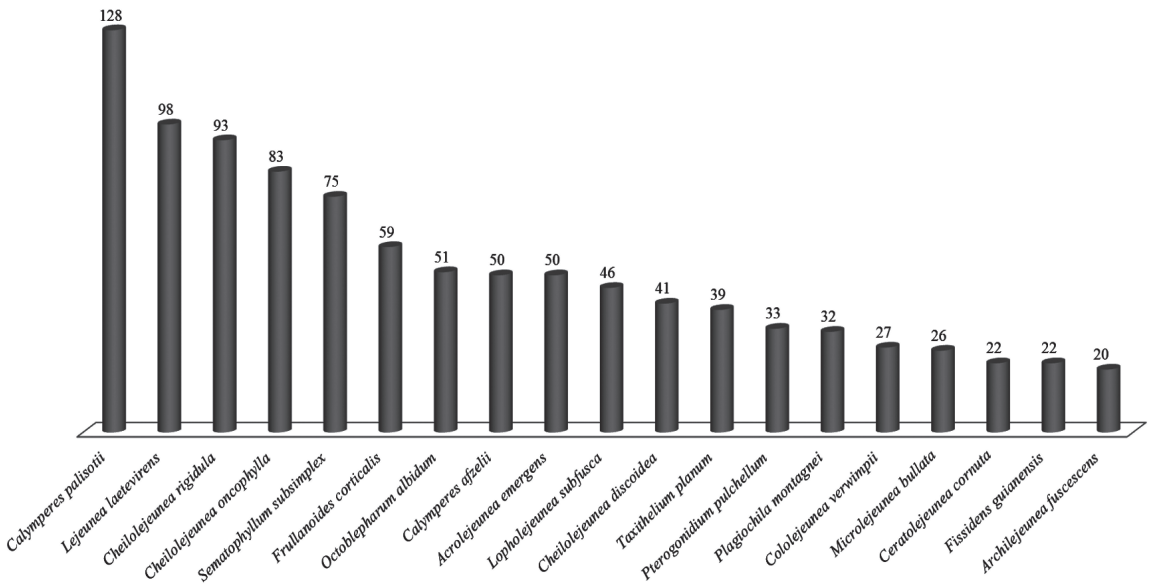

Figure 3. Species with highest number of records in the municipalities of Soure and Cachoeira do Arari, Marajó Island, Brazil.

those of other bryofloristic studies conducted in the state of Pará (Lisboa *et al.* 1998; 1999; Santos & Lisboa 2008; Ilkiu-Borges *et al.* 2009).

Living and decaying trunks were colonized by 85 and 48 species, respectively (Fig. 4). Gradstein (1995) argues that even subtle differences in water supply, nutrients, light and inclination of the substrate affect the ability of bryophytes to establish themselves and, therefore, tree bases, trunks and ascending branches often harbor different species.

There were 20 occurrences of bryophytes on living leaves, representing five species of Lejeuneaceae. This is explained by Gradstein (1995), who stated that over 90% of epiphyllous liverworts belong to Lejeuneaceae. Of the species encountered, *Leptolejeunea elliptica, Lejeunea laetevirens* and *Cololejeunea verwimpii* had the highest number of records, whereas *Frullanoides corticalis* and *Archilejeunea parviflora* were collected only once from this substrate. However, all of these species were collected on other types

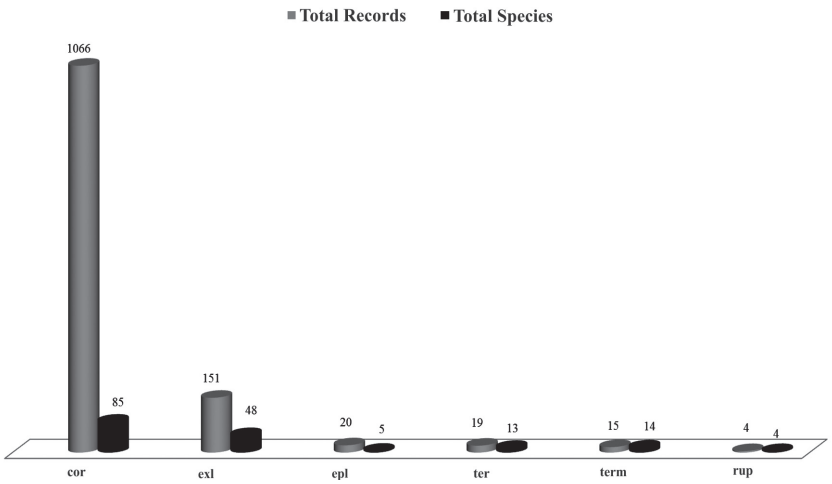

Figure 4. Total records and species by substrate in the municipalities of Soure and Cachoeira do Arari, Marajó Island, Brazil.

Table 2. Comparison of species richness across studies of bryophytes on Marajó Island, Brazil.

PHYLUM							
Family							
Species	1	2	3	4	5	6	7
BRYOPHYTA							
Bartramiaceae							
Philonotis sp.	-	x	-	-	-	-	-
P. uncinata var. *glaucescens* (Hornsch.) Florsch.	-	-	-	x	-	-	-
Brachytheciaceae							
Zelometeorium patulum (Hedw.) Manuel	-	x	-	x	-	-	-
Bryaceae							
Bryum apiculatum Schwägr.	-	-	x	x	-	-	-
B. capillare Hedw.	-	-	x	-	-	-	-
B. coronatum Schwägr.****	-	-	-	-	-	-	x
Calymperaceae							
C. afzelii Sw.	-	x	-	x	X	x	x
C. erosum Müll. Hal.	x	x	x	x	X	x	x
C. guildingii Hook. & Grev.	x	-	-	-	-	x	
C. levyanum Besch.	-	x	-	-	-	-	-
C. *lonchophyllum* Schwägr.	-	-	-	x	-	-	x
C. nicaraguense Renauld & Cardot	x	x	-	-	-	-	-
C. pallidum Mitt.	-	-	-	-	X	-	x
C. palisotii Schwägr.	x	x	x	x	X	x	x
Leucophanes molleri Müll. Hal.	-	-	-	x	-	-	-
Octoblepharum albidum Hedw.	x	x	x	-	X	x	x
O. albidum var *violascens* Müll. Hal.	-	-	-	x	-	x	-
O. cylindricum Schimp. ex Mont.	-	-	-	-	X	-	-
O. pulvinatum (Dozy & Molk.) Mitt.	-	x	-	x	X	-	-
Syrrhopodon cryptocarpus Dozy & Molk.	x	-	-	-	X	-	x

Continues

Table 2. Continuation.

PHYLUM / Family / Species	1	2	3	4	5	6	7
S. ligulatus Mont.	x	-	-	-	X	x	-
S. rigidus Hook. & Grev.	x	-	-	-		-	-
S. incompletus Schwägr.	-	-	-	x	X	-	-
S. incompletus Schwägr. var. *incompletus*	x	x	-	-	-	x	-
S. incompletus Schwag var. *luridus* (Paris & Broth.) Florsch.	-	x	-	-	-	-	-
S. leprieurii Mont.	-	-	-	x	-	-	-
Fissidentaceae							
Fissidens elegans Brid.	-	-	-	x	-	-	x
F. flaccidus Mitt.	-	-	-	-	-	x	-
F. guianensis Mont.	-	x	-	-	-	-	x
F. inaequalis Mitt.****	-	-	-	-	-	-	x
F. intromarginatus (Hampe) A. Jaeg.****	-	-	-	-	-	-	x
F. pellucidus Hornsch.****	-	-	-	-	-	-	x
F. prionodes Mont.	-	x	x	-	-	-	-
F. submarginatus Bruch****	-	-	-	-	-	-	x
F. zollingeri Mont.****	-	-	-	-	-	-	x
Hookeriaceae							
Crossomitrium patrisiae (Brid.) Müll. Hal.	-	-	-	x	-	-	-
Hypnaceae							
Chryso-hypnum diminutivum (Hampe) W.R. Buck	-	-	x	-	-	-	-
Ectropothecium leptochaeton (Schwägr.) W.R. Buck	-	x	-	-	-	-	-
Vesicularia vesicularis (Schwägr.) Broth.	-	-	-	x	-	-	-
Vesicularia vesicularis var. *rutilans* (Brid.) W.R. Buck	-	-	-	x	-	-	-
Leucobryaceae							
Campylopus surinamensis Müll. Hal.	-	-	-	-	x	-	x
Leucobryum albidum (Brid. *ex* P. Beauv.) Lindenb.	-	-	-	x	-	-	-
L. martianum (Hornsch.) Hampe ex Müll. Hal.	-	-	-	x	-	-	-
Leucomiaceae							
Leucomium strumosum (Hornsch.) Mitt.	-	-	-	x	-	-	-
Neckeraceae							
Neckeropsis undulata (Hedw.) Reichardt	-	x	-	x	-	-	-
Orthotrichaceae							
Groutiella tomentosa (Hornsch.) Wijk & Margad.	-	x	-	-	-	-	-
Pilotrichaceae							
Callicostella pallida (Hornsch.) Ångström.	-	x	x	-	-	-	x
Lepidopilum scabrisetum (Schwägr.) Steere.	-	-	-	x	-	-	-
L. surinamense Müll. Hal.	-	x	-	x	-	-	-
Pilotrichum bipinnatum (Schwägr.) Brid.	-	-	-	x	-	-	-
P. evanescens (Müll. Hal.) Crosby	-	-	-	x	-	-	-
Pottiaceae							
Barbula agraria Hedw.	-	x	x	-	-	-	-
Hyophila involuta (Hook.) A. Jaeg.	-	x	x	-	-	-	-
Splachnobryum obtusum (Brid.) Müll. Hal.	-	-	-	x	-	-	-
Pterobryaceae							
Henicodium geniculatum (Mitt.) W.R. Buck	-	-	-	x	-	-	-
Orthostichopsis tetragona (Sw. *ex* Hedw.) Broth.	-	x	-	-	-	-	-
Pireella pohlii (Schwägr.) Cardot	-	x	-	-	-	-	-

Continues

Table 2. Continuation.

PHYLUM Family Species	1	2	3	4	5	6	7
Pylaisiadelphaceae							
Isopterygium subbrevisetum (Hampe) Broth.	-	-	-	x	-	-	x
I. tenerum (Sw.) Mitt.	-	x	x	-	-	-	x
Pterogonidium pulchellum (Hook.) Müll. Hal.****	-	-	-	-	-	-	x
Taxithelium planum (Brid.) Mitt.	-	x	x	x	x	x	x
T. pluripuctatum (Renauld & Cardot) Broth.	-	-	x	-	-	-	-
Sematophyllaceae							
Acroporium estrellae (Müll. Hal.) Buck & Schaf.-Verw.	-	-	x	-	-	-	-
Meiothecium boryanum (Müll. Hal.) Mitt.	-	-	-	x	-	-	-
M. revolubile Mitt.	-	x	-	-	-	-	-
Sematophyllum adnatum (Michx.) E. G. Britton	-	x	-	-	-	-	-
S. subpinnatum (Brid.) Britton	-	-	x	x	-	-	x
S. subsimplex (Hedw.) Mitt.	x	x	x	x	x	x	x
Sematophyllum sp.		x	-	-	-	-	-
Trichosteleum fluviale (Mitt.) Broth.	-	x	x	-	-	-	-
T. guianae (Müll. Hal.) Broth.	-	x	-	-	-	-	-
T. papillosum (Hornsch.) A. Jaeg.****							x
T. sentosum (Sull.) A. Jaeg.	-	-	-	x	-	-	-
T. subdemissum (Besch.) A. Jaeg.	x	-	-	-	-	x	x
Stereophyllaceae							
Entodontopsis leucostega (Brid.) W.R. Buck & Ireland****	-	-	-	-	-	-	x
Pilosium chlorophyllum (Hornsch.) Müll. Hal.	-	-	-	x	-	-	-
Stereophyllum radicolosum (Hook.) Mitt.	-	x	-	-	-	-	-
Thuidiaceae							
Cyrto-hypnum involvens (Hedw.) W.R. Buck & Crum	-	-	x	x	-	-	-
C. schistostocalyx (Müll. Hal.) Buck & Crum	-	x	-	-	-	-	-
MARCHANTIOPHYTA							
Frullaniaceae							
Frullania apiculata (Reinw., Blume & Nees) Dumort.****	-	-	-	-	-	-	x
F. gibbosa Nees	-	-	-	-	x	-	x
F. riojaneirensis (Raddi) Spruce	-	-	-	-	x	-	-
Lejeuneaceae							
Acrolejeunea emergens (Mitt.) Steph.****	-	-	-	-	-	-	x
A. torulosa (Lehm. & Lindenb.) Schiffn.	-	-	-	-	-	x	x
Archilejeunea auberiana (Mont.) A. Evans****	-	-	-	-	-	-	x
A. crispistipula (Spruce) Steph.****	-	-	-	-	-	-	x
A. fuscescens (Hampe *ex* Lehm.) Fulford****	-	-	-	-	-	-	x
A. parviflora (Nees) Schiffn.****	-	-	-	-	-	-	x
Ceratolejeunea cornuta (Lindenb.) Steph.	-	-	-	-	x	x	x
C. cubensis (Mont.) Schiffn.****	-	-	-	-	-	-	x
C. laetefusca (Austin) Schust.****	-	-	-	-	-	-	x
C. rubiginosa Steph.	-	-	-	-	-	x	-

Continues

Table 2. Continuation.

PHYLUM / Family / Species	1	2	3	4	5	6	7
Cheilolejeunea adnata (Kunze) Grolle	-	-	-	-	x	-	x
C. comans (Spruce) Schust.****	-	-	-	-	-	-	x
C. discoidea (Lehm. & Lindenb.) Kachr. & Schust.****	-	-	-	-	-	-	x
*C. holostip*a (Spruce) Grolle & R.-L.Zhu****	-	-	-	-	-	-	x
C. oncophylla (Ångström.) Grolle & Reiner, M. E.	-	-	-	-	x	x	x
C. rigidula (Mont.) Schust.	-	-	-	-	x	x	x
C. trifaria (Reinw., Blume & Nees) Mizut.	-	-	-	-	-	x	-
Cheilolejeunea sp.****	-	-	-	-	-	-	x
Cololejeunea cardiocarpa (Mont.) A. Evans	-	-	-	-	x	-	x
C. diaphana A. Evans****	-	-	-	-	-	-	x
C. minutissima subsp. *myriocarpa* (Nees & Mont.) Schust.****	-	-	-	-	-	-	x
C. panamensis G. Dauphin & Pócs*	-	-	-	-	-	-	x
C. subcardiocarpa Tixier	-	-	-	-	-	x	-
C. verwimpii Tixier***	-	-	-	-	-	-	x
Frullanoides corticalis (Lehm. & Lindenb.) Slageren	-	-	-	-	x	x	x
Lejeunea adpressa Nees****	-	-	-	-	-	-	x
L. caulicalyx (Steph.) Reiner, M. E. & Goda****	-	-	-	-	-	-	x
L. laetevirens Nees & Mont.	x	-	-	-	x	x	x
L. phyllobola Nees & Mont.****	-	-	-	-	-	-	x
L. trinitensis Lindenb.****	-	-	-	-	-	-	x
Leptolejeunea elliptica (Lehm. & Lindenb.) Schiffn.****	-	-	-	-	-	-	x
Lopholejeunea subfusca (Nees) Schiffn.	-	-	-	-	-	x	x
Mastigolejeunea auriculata (Wilson) Schiffn.****	-	-	-	-	-	-	x
M. innovans (Spruce) Steph.***	-	-	-	-	-	-	x
Microlejeunea acutifolia Steph.****	-	-	-	-	-	-	x
M. bullata (Taylor) Steph.	-	-	-	-	x	-	x
M. epiphylla Bischl.	-	-	-	-	-	x	x
M. subulistipa Steph.**	-	-	-	-	-	-	x
Prionolejeunea denticulata (Nees) Schiffn.****	-	-	-	-	-	-	x
Rectolejeunea berteroana (Gottsche *ex* Steph.) A. Evans****	-	-	-	-	-	-	x
Stictolejeunea squamata (Willd. *ex* Weber) Schiffn.****	-	-	-	-	-	-	x
Symbiezidium transversale (Sw.) Trevis.****	-	-	-	-	-	-	x
Plagiochilaceae							
Plagiochila montagnei Nees****	-	-	-	-	-	-	x
Total: 125 taxa	12	32	18	34	23	23	67

Columns: 1. – Lisboa *et al.* (1993); 2. – Lisboa & Maciel (1994); 3. – Lisboa *et al.* (1998); 4. – Lisboa *et al.* (1999); 5. – Macedo (personal communication, 2009); 6. – Fagundes & Garcia (2009 pers. comm.); 7. – this work.
*New record for South America; **New record for northern Brazil; ***New record for the state of Pará; ****New record for Marajó Island.

of substrates and can therefore be classified as facultative epiphylls (Cornelissen & Ter Steege 1989).

Of the 19 occurences found on the ground, there were 13 species. According to Richards (1984), terrestrial bryophytes in tropical forests are more abundant at high altitudes. Among the 15 records of bryophytes on termite mounds, there were 14 species. This type of substrate is common in studies of bryophytes in the Amazon, such as those conducted by Lisboa (1993), Ilkiu-Borges & Lisboa (2002a), Santos & Lisboa (2003), Souza & Lisboa (2005), and Ilkiu-Borges *et al.* (2009).

Bryophytes found on rocks (rupicolous bryophytes) accounted for four records and four species. The limited number of rupicolous species is attributable to the limited availability of rocky substrate in the area.

In previous studies of the bryoflora of Marajó Island (Lisboa & Maciel 1994; Lisboa *et al.* 1993, 1998, 1999) and in two more recent studies (Macedo, personal communication, 2009; Fagundes & Garcia, personal communication, 2009), 89 species of bryophytes were recorded for this area. The present study has added 39 species (31

liverworts and eight mosses) to that total (Tab. 2).. The disparity between the number of newly recorded liverwort species and that of newly recorded moss species is a consequence of the fact that many of the previous studies included only mosses.

As shown in Tab. 2, the species richness observed in the present study (67 species) was higher than in other studies conducted on Marajó Island. This might be attributable to the large sample size of the present study (617 samples collected vs. 63-122 samples collected in previous studies), as well as to the fact that we included all types of ecosystems (vs. single ecosystems in previous studies).

The species *Calymperes palisotii*, *C. erosum* and *Sematophyllum subsimplex* were recorded in all studies conducted on Marajó Island (Lisboa *et al.* 1993; Lisboa & Maciel 1994; Lisboa *et al.* 1998; 1999; Macedo, personal communication, 2009; Fagundes & Garcia, personal communication, 2009). *Octoblepharum albidum, Taxithelium planum* and *Calymperes afzelii* were collected in most of those studies. *Syrrhopodon cryptocarpos* was cited by Lisboa *et al.* (1993), by L.P. Macedo (personal communication, 2009), and in the present work. These species, in fact, are generalist species.

The present study led to the creation of 39 new records for Marajó Island. Consequently, the bryoflora in this area now accounts for 36% of the species found in the state of Pará. The great richness of the Soure and Cachoeira do Arari regions reveals the importance of the study of local flora, which create new records and thus broaden our knowledge of said flora, given that these regions harbor large numbers of species. In areas such as Marajó, which has been designated as a priority A region, or area of extreme importance for preservation (Capobianco *et al.* 2001), there is a need for ecosystem conservation, which will certainly slow the loss of habitat and consequently the depletion of flora.

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