BRYOPHYTE DIVERSITY AND NEW SPECIES OCCURENCES FROM CARAUARI IN SOUTHWESTERN AMAZONAS, BRAZIL

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ABSTRACT

This study reports the bryophyte community of a forest area of the Jaraqui River, a tributary of the Juruá River, in the municipality of Carauari, Amazonas state. During the study, 184 specimens were studied and a total of 43 species were identified. Of these, 24 are mosses and 19 are liverworts, distributed in 32 genera and 16 families. The families with the most taxa were Lejeuneaceae, with fourteen species in fourteen genera, Sematophyllaceae with five species in three genera, followed by Calymperaceae with four species in two genera. Of the species recorded, two are new occurrences for Brazil, *Brittonodoxa allinckxiorum* (Brid.) W.R. Buck, P.E.A.S. Câmara & Carv.-Silva and *Callicostella colombica* R.S. Williams, as well as two for the Amazonas state, *Crossomitrium epiphyllum* (Mitt.) Müll. Hal.and *Taxithelium juruense* (Broth.) Broth. In addition, we highlight the distribution and conservation status of the species *Otolejeunea schnellii* (Tixier) R.L. Zhu & M.L. So, recorded in the northern Brazilian Amazon and Chocó region of western Colombia, and *Taxithelium juruensis* reported only for the Juruá basin in the state of Acre, Brazil. It can be concluded that more floristic studies, even on a small scale, are of fundamental importance in order to understand the distribution and conservation status of bryophytes in tropical regions.
Keywords: Floristics, Juruá River, species distribution

RESUMO

Este estudo descreve a comunidade de briófitas de uma área florestal do rio Jaraqui, um afluente do rio Juruá, no município de Carauari, estado do Amazonas. Durante o estudo, 184 espécimes foram estudados identificando um total de 43 espécies. Destas, 24 são musgos e 19 são hepáticas, distribuídas em 32 gêneros e 16 famílias. As famílias com maior taxa são Lejeuneaceae com quatorze espécies em quatorze gêneros, Sematophyllaceae com cinco espécies em três gêneros, seguida de Calymperaceae com quatro espécies em dois gêneros. Destacam-se no estudo duas novas ocorrências para o Brasil, neste caso, *Brittonodoxa allinckxiorum* (Brid.) W.R. Buck, P.E.A.S. Câmara & Carv.-Silva e *Callicostella colombica* R.S. Williams, além de duas para o estado do Amazonas, *Crossomitrium epiphyllum* e *Taxithelium juruense* (Broth.) Broth. Além destacamos a distribuição e estado de conservação da espécie *Otolejeunea schnellii* (Tixier) R.L. Zhu & M.L. So, com coletas apenas no norte de Amazônia brasileira e na região do Choco na Colômbia, e *T. juruensis* relatado apenas para bacia do Juruá no estado do Acre, Brasil. Pode-se concluir que mais estudos florísticos, mesmo que em pequena escala, são de fundamental importância para entender a distribuição e estado de conservação de briófitas de regiões tropicais.

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Palavras-chave: Florística, Rio Juruá, distribuição de espécies

INTRODUCTION

The Amazon Rainforest presents highly heterogeneous ecosystems with diverse plant communities (Lindenmayer & Likens, 2010; Magnusson et al., 2013; Cardoso et al., 2017), and bryophytes (e.g., mosses, liverworts and hornworts) have high diversity and endemism in the Amazon rainforest, which makes it the second most diverse biome in Brazil for bryophytes after the Atlantic Forest. (Costa & Peralta, 2015; Flora do Brasil, 2020). Floristic surveys of bryophytes have gained greater interest as they are important in order to understand regional diversity patterns and extinction risk of local species (Söderstörm, 2008; Souza & Lisboa, 2006; Martinell & Moraes, 2013). However, a large number of areas remain unexplored, and surveys of these will add new species to the regional flora or extend the distribution range of other species.

The use of a network of study plots has permitted a large sample across the Amazon (Oliveira & Steege, 2013). In order to fill biodiversity gaps, in recent years, expeditions to remote areas have greatly expanded knowledge about the flora of mountainous regions (Costa et al., 2017, 2020; Costa, 2017; Sierra et al., 2019) and also in humid forests along a tributary of the Rio Negro (Sierra et al., 2018; Zartman et al., 2019). However, in the state of Amazonas, collection efforts are often associated with areas close to cities and highways that allow more logistically viable expeditions (Hopkins, 2007; Lindenmayer & Likens, 2010; Magnusson et al., 2013). Bryophytes are no exception, where most collections come from areas close to the city of Manaus (Lisbon, 1976; Griffin III, 1979; Yano, 1992; Zartman & Ackerman, 2002; Zartman & Ilkiu Borges, 2007).

The southwestern region of the state of Amazonas has been little explored floristically speaking, and the low number of collections for this area indicates a large knowledge gap for all plant groups (Hopkins, 2007; Cardoso et al., 2017). The region known as the middle Juruá occupies an area of 70,752 km^2, which represents 4.5% of the total area of the state of Amazonas (1,570,746 km^2). The Juruá River, due to its sinuosity, makes it one of the most extensive rivers in the Amazon basin (Del-Rio et al., 2020). The length of the river makes this region logistically difficult for large botanical expeditions (Hopkins, 2019), which represent a limiting factor when trying to represent the flora of the region (Hopkins, 2007; Lindenmayer & Likens, 2010; Magnusson et al., 2013). However, new approaches should be considered in order to advance current botanical studies in the vast Amazon region.

In this context, in an academic collaboration with students from the Amazonas State University, in the city of Carauari, and graduate students from the Instituto Nacional de Pesquisas da Amazonia in Manaus, we characterized the bryoflora of a remote area in the southwestern region of the state of Amazonas. The bryophyte samples were collected from an area in the Bacaba community near Cararuari, Amazonas, Brazil. These were reviewed to generate a species list that represents the first bryophyte records for this region.

MATERIAL AND METHODS

Area of study

The study was carried out in the region of the middle Juruá River in an area of *terra firme* forest in the Bacaba community (06° 18’ 25.83” S, 68° 10’ 28.73” W), which comprised mature forest, wetlands and areas of secondary forest (*capoeira*).

According to the climate classification of Köppen, the region has a tropical rainy climate (Vianello, 2000), with an average annual rainfall of 2,500 mm. The temperature ranges from 24 ºC to 35 ºC, and humidity is around 90% for most of the year. The rainy season is from November to April and is followed by a dry season, with less than 60 mm^3

of rain in the driest month. During the rainy period, the Juruá River increases its height up to 11 m with the seasonal rains.

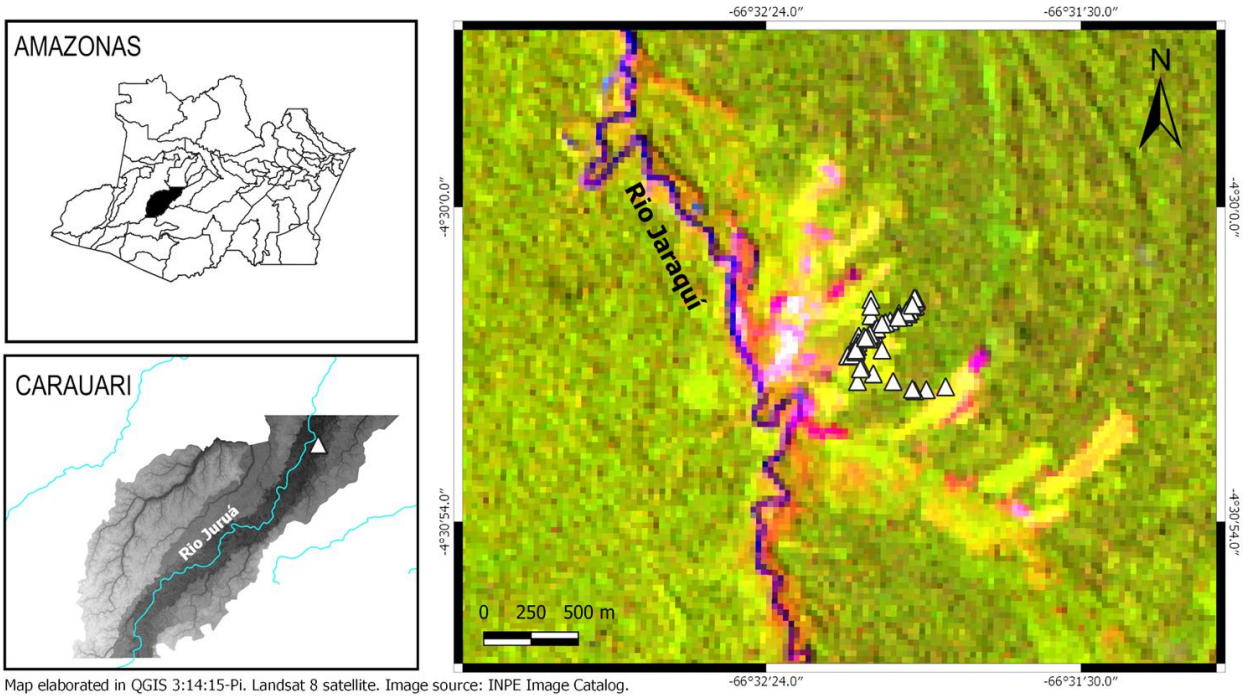

Figure 1. Geographic location of the collection area. The middle Juruá River near the Bacaba community located in the municipality of Carauari, southwest of the state of Amazonas, Brazil.

Data collection

During two surveys in March and August of 2018, bryophytes were collected following the methodology described by Lisboa (1993) in all briocenological groups along the trail in the study area (epiphyte, epiphyll, epixyle and terricolous). All exsiccates were deposited in the herbarium of the Instituto Nacional de Pesquisas da Amazonia (INPA), with duplicates in the private herbarium of the Universidade do Estado do Amazonas. The samples were studied with the aid of a stereoscope (Stemi DV4, Zeiss) and an optical microscope (Primo Star, Zeiss). All samples were identified and classified at genus and species level using bryophyte monographs and floras (Gradstein & Costa, 2003; Zartman & Ilkiu-Borges, 2007, Flora do Brasil, 2020).

RESULTS AND DISCUSSION

One hundred and eighty-four specimens were collected in the *terra firme* forest area in the community of Bacaba in the municipality of Carauari. This total included 43 species (24 mosses and 19 liverworts), which are distributed in 32 genera and 16 families (Table 1). The most diverse family is Lejeuneaceae with fourteen species in fourteen genera. Sematophyllaceae is the second most diverse family with five species in three genera, followed by Calymperaceae with four species in two genera. Among the species collected, we highlight two new occurrences for Brazil, namely *Brittonodoxa allinckxiorum* (W.R. Buck) W.R. Buck, P.E.A.S. Câmara & Carv.-Silva and *Callicostella colombica* R.S. Williams, while the species *Crossomitrium epiphyllum* (Mitt.) Müll. Hal. and *Taxithelium juruense* (Broth.) Broth. represent new reports for the state of Amazonas.

Table 1. Bryophyte species, voucher number, collection substrate information. **new occurrence for Brazil, *new occurrence for the state of Amazonas.

TAXON	VOUCHER	BRIOCENOLOGICAL GROUPS
Bryophyta (Mosses)		
Calymperaceae		
Calymperes erosum Müll. Hal.	Nascimento FA 163	Epiphyte
Syrropodon cryptocarpus Dozy & Molk.	Nascimento FA 142	Epiphyte
Syrrhopodon hornschuchii Mart.	Nascimento FA 75	Epiphyte
Syrrhopodon incompletus Schwägr. var. *incompletes*	Nascimento FA 126	Epiphyte
Fissidentaceae		
Fissidens elegans Brid.	Nascimento FA 43, 76, 85, 110	Terricolous
Hypnaceae		
Isopterygium tenerum (Sw.) Mitt.	Nascimento FA 10	Epiphyte
Hookeriaceae		
Crossomitrium patrisiae (Brind.) Müll. Hal.	Nascimento FA 23	Epiphyte
**Crossomitrium epiphyllum* (Mitt.) Müll. Hal.	Nascimento FA 21, 35, 42	Epiphyte
Leucobryaceae		
Leucobryum martianum (Hornsch.) Hampe ex Müll. Hal.	Nascimento FA 10, 29, 32, 119, 124, 141	Epiphyte
Leucobryum crispum Müll. Hal.	Nascimento FA 36, 96, 97, 124	Epiphyte
Neckeraceae		
Neckeropsis undulata (Hedw.) Reichardt	Nascimento FA 164	Epiphyte
Octoblepharaceae		
Octoblepharum albidum Hedw.	Nascimento FA 1, 11, 22, 50, 120, 128, 129 142, 152, 152	Epiphyte
Octoblepharum cocuiense Mitt.	Nascimento FA 88, 164	Epiphyte
Octoblepharum pulvinatum (Dozy & Molk.) Mitt.	Nascimento FA 45, 99	Epixyle
Pilotrichaceae		
Callicostella pallida (Hornsch) Angström	Nascimento FA 9, 30, 154	Epixyle
***Callicostella colombica* R.S. Williams	Nascimento FA 30, 154	Epixyle
Pilotrichum bipinnatum (Schwägr.) Brid.	Nascimento FA 99, 107, 108 115, 132	Epixyle
Sematophyllaceae		
***Brittonodoxa allinckxiorum* (W.R.Buck) W.R.Buck, P.E.A.S. Câmara & Carv.-Silva	Nascimento FA 103, 160, 259	Epixyle
Brittonodoxa subpinnata (Brid.) W.R. Buck, P.E.A.S. Câmara & Carv.-Silva	Nascimento FA 134, 156, 159	Epixyle
Microcalpe subsimplex (Hedw.) W.R. Buck	Nascimento FA 18, 38, 40, 49, 54, 69, 89, 101, 118, 126, 130, 157, 158	Epiphyte
Taxithelium pluripunctatum (Renauld & Cardot) Broth.	Nascimento FA 2, 21, 52, 93, 135, 162	Epixyle

**Stereophylaceae* *Taxithelium juruense* (Broth.) Broth.	Nascimento FA 41, 92, 165	Epixyle
Stereophylaceae		
Eulacophyllum cultelliforme (Sull.) W.R. Buck & Ireland	Nascimento FA 70, 121, 122, 134	Epiphyte
Thuidiaceae		
Pelekium scabrosulum (Mitt.) A. Touw	Nascimento FA 113	Epiphyte
Marchantiophyta (Liverworts)		
Calypogeiaceae		
Calypogeia peruviana Nees & Mont.	Nascimento FA 167	Corticola, epixyle
Frullaniaceae		
Frullania caulisequa (Nees) Nees in Gottsche et al.	Nascimento FA 106, 167	Epixyle
Lejeuneaceae		
Acrolejeunea torulosa (Lehm. & Lindenb.) Schiffn.	Nascimento FA 46, 54, 138	Epixyle
Archilejeunea fuscescens (Hampe ex Lehm.) Fulford	Nascimento FA 59	Epixyle
Cheilolejeunea adnata (Kunze ex Lehm.) Grolle	Nascimento FA 38	Epixyle
Cololejeunea obliqua (Nees & Mont.) Schiffn	Nascimento FA 5, 167	Epixyle
Cyclolejeunea peruviana (Lehm. & Lindenb.) A. Evans	Nascimento FA 4, 5, 11, 12, 34, 39, 44, 53, 62, 63, 69, 72, 79, 95, 100, 105, 131, 140, 141, 145	Epixyle
Drepanolejeunea polyrhiza (Nees) Grolle & R.L. Zhu	Nascimento FA 39	Epixyle
Lejeunea immersa Spruce	Nascimento FA 84	Epixyle
Metalejeunea cucullata (Reinw. et al.) Grolle	Nascimento FA 55, 78, 137	Epixyle
Odontolejeunea lunulata (Weber) Schiffn.	Nascimento FA 3, 5, 15, 59, 65, 66, 68, 73, 74, 75, 83, 112, 114, 123, 139, 142, 144, 148, 150, 162	Epiphyte, epixyle
Otolejeunea schnellii (Tixier) R.L. Zhu & M.L. So	Nascimento FA 81, 82, 92	Epixyle
Prionolejeunea denticulata (Weber) Schiffn.	Nascimento FA 14	Epixyle
Stictolejeunea squamata (Willd. ex Weber) Schiffn.	Nascimento FA 92	Epixyle
Thysananthus amazonicus (Spruce) Schiffn.	Nascimento FA 93, 164	Epixyle
Xylolejeunea crenata (Nees & Mont.) X.L. He & Grolle	Nascimento FA 14, 19, 24	Epixyle
Lepidoziaceae		
Bazzania hookeri (Lindenb.) Trevis	Nascimento FA 67, 111	Epixyle
Micropterygium trachyphyllum Reimers	Nascimento FA 125	Epixyle
Plagiochilaceae		
Plagiochila disticha (Lehm. & Lindenb.) Lindenb.	Nascimento FA 17, 116, 136	Epixyle

The southwestern region of the Amazon Rainforest, in addition to being little investigated compared to the northern region (Costa, 2000; Sobreira, 2019), is at high risk

due to the increase in deforestation in recent decades. Although our sampling recorded one third of the total number of species observed in other areas in the Amazon (Griffin III, 1979; Oliveira & Steege, 2013; Sierra et al., 2018), it represents the first floristic list of a specific area for the southwestern region of the state of Amazonas. Among the 43 species registered, 8% of them represent new occurrences for the Amazon and 4% new occurrences for Brazil. The families Calymperaceae and Lejeuneaceae are the most abundant and diverse in the Amazon region (Costa & Peralta, 2015). However, the diversity recorded here does not reach the estimated number for these families, which means that we still need to triple the intensity of collections in this area, as recommended by Hopkins (2019).

The Juruá region has a little-known flora and there is the possibility of discovering taxonomic novelties for the bryoflora of tropical forests. For example, here we expand the distribution of two species, *Brittonodoxa allinckxiorum* and *Callicostella colombica*, which until now had not been reported in Brazil. They were previously known to occur in tropical forests in South America (British Guiana, French Guiana, Colombia, Venezuela, and Peru). Based on label information and the speciesLink system, the occurrence of these species was already expected for the Brazilian Amazon. For this reason, floristic studies are important for defining the conservation status and distribution of these species that have few recorded collections. The other novelty for the state Amazonas was *Crossomitrium epiphyllum,* which is widely distributed across the Neotropics and occurs in other Brazilian states including the Pará state. An extensive review of the specimens previously identified as *Taxithelium juruense* (Câmara, 2011) indicate that this is an endemic species with restricted distribution. Câmara (2011) concludes that the only specimens that correspond to *T. juruense* are restricted to the Juruá Basin in the state of Acre. We found this species in three samples growing on decomposing trees in mature forest near a tributary of the Juruá River in the state of Amazonas. For now, this species is restricted to the Juruá River basin, which makes it a rare and threatened species. Another rare species recorded here, *Otolejeunea schnellii*, is distributed in the northern part of the Amazonas state (Zartman & Ilkiu-Borges, 2007, Sierra et al., 2018, Flora do Brasil, 2020) and the Chocó region in Colombia (Benavides & Sastre-de Jesús, 2011). All records of this species indicate that *O. schnellii* is restricted to mature forest and should be considered as a threatened species (Benavides & Sastre-de Jesús, 2011).

CONCLUSION

Our study expands the area of occurrence of several species and adds to the efforts to better understand the real conservation status of tropical bryophytes (Gradstein & Costa, 2003). The study of bryophyte collections from a small area of the Juruá basin, in the southwestern part of the Amazonas state, has resulted in distribution records, as well as species known for few collections.

The Amazon Rainforest is still an area in which it is logistically difficult to carry out extended fieldwork in order to collect botanical samples in remote areas. Adding to this, major research institutions are often restricted to the main capital city of each Amazonian state. However, a network of campuses of the Amazonas State University have been created in several cities in the interior of Amazonas, Brazil since the year 2002, which trains students from this university to collect and identify plants and might represent a key step for advancing and filling the biodiversity knowledge gap of neglected areas in the Amazon Rainforest (Coelho et al., 2020). In addition, this could create a greater interest in the Amazonian biodiversity in students of all levels, and the conservation of the local flora, since programs on the campuses in the interior of the Amazonas state seek to form new educational personnel for regional state schools and federal institutes.

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