

Bryophyte communities in an Atlantic forest remnant, state of Pernambuco, Brazil

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Abstract – The floristic composition, richness, and growth forms of bryophyte communities were studied at the Reserva Ecológica de Gurjaú (08°10'00"–08°15'00"S; 35°02'30"–35°05'00"W), an Atlantic forest remnant in the state of Pernambuco, Brazil. The main microhabitats – soil (plane and inclined), leaves (glabrous and pubescent), rocks, dead trunks (on reduced, intermediate and advanced decomposition levels), and live trunks – were examined. The data were evaluated using multivariate statistical analysis. The corticolous bryophyte flora was the most diverse (33% of the species), followed by the epixylic flora (23%). These communities are fairly similar sharing 75% of their species, whereas the terricolous community is composed of a more distinct group of species. Liverwort diversity exceed that of mosses in epiphyllous (23:1) and corticolous (2:1) communities, whereas the reverse was true in the terricolous communities (1:3). The epixylic communities did not show specificity in relation to degrees of decomposition of dead trunks, or significant specific richness differences between these levels. From the seven growth forms recognized, the mat form prevailed. Community distribution patterns and their respective growth forms were similar to those observed in other humid tropical forests, although with lower specific richness values. A progressive deforestation process resulting in the conversion of forest fragments into degraded habitats can explain this.

Atlantic forest / Brazil / bryophyte communities / bryophyte ecology / growth forms / multivariate analysis

Résumé – Les communautés de bryophytes sur sol, rochers, feuilles, troncs vivants et troncs en décomposition ont été étudiées dans la Réserve Écologique de Gurjaú, un reliquat de Forêt Atlantique, dans l'État de Pernambuco, Brésil. Les données ont fait l'objet de traitements statistiques et d'analyses multivariées. La communauté corticole apparaît comme la plus riche (33% des espèces), suivie par l'épixyle (23%). Ces communautés sont assez semblables (75%), tandis que la communauté terricole forme un groupe isolé. Les hépatiques sont plus nombreuses que les mousses au sein des épiphyllées (23:1) et des corticoles (2:1) ; l'inverse a été observé chez les terricoles (1:3). Aucune exclusivité par rapport à la décomposition des troncs n'a été remarquée chez les épixyles. Huit formes de croissance ont été reconnues, la trame étant la plus fréquente. Les communautés étudiées ont une répartition semblable à celles des forêts tropicales humides, bien que la richesse d'espèce et de formes de croissance soient moins expressives, ce qui est peut être dû au fort état de fragmentation de la Réserve, entraînant une pauvreté de la bryoflore.

Bryoflore / communautés de bryophytes / forêt tropicale / formes de croissances / microhabitats

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INTRODUCTION

The characterization of bryophyte communities has been investigated in humid tropical forest environments, especially in the last decades, when researchers began in depth studies of the neotropical region. Microhabitats and species' growth forms are the most studied aspects, and publications by Gams (1932), Richards (1932, 1984), Pócs (1982), Gradstein & Pócs (1989), Gradstein (1997), Uniyal (1999), and Gradstein *et al.* (2001) are of particular importance for conservation. Similarly, in Brazil, recent publications about bryophytes have analyzed bryophyte communities especially in relation to their microhabitats and growth form. While studying the bryophyte flora of an Amazonian savanna, Lisboa (1976) observed that the corticolous and terricolous microhabitats harbored the greatest diversity, although few species were exclusively limited to one type of substrate. Pôrto (1992) obtained similar results, and found greater species richness in corticolous and epixylic communities in both habitats, in Atlantic Forest lowland (*ca* 100 m) and sub-montane remnants (*ca* 1000 m). The diversity of growth form types was particularly higher in the sub-montane forest due to greater exposure to lower temperatures and high atmospheric humidity because of fog and clouds (Frahm, 1987).

In a study on the floristics and ecology of bryophytes from coastal ecosystems of the state of São Paulo, Visnadi (1998) also verified the predominance of corticolous communities, except in coastal environments, where terricolous communities dominated.

Bastos (1999), studying restinga vegetation in the state of Bahia, observed the predominance of epiphytes from the families Frullaniaceae and Lejeuneaceae on smooth bark and from the families Calymperaceae and Leucobryaceae on rough bark. The epixylic and epiphytic communities were similar in terms of species composition, whereas terricolous communities were dominated by acrocarpous mosses from the families Bryaceae, Leucobryaceae, Archidiaceae, and Dicranaceae. Except for *Frullania ericoides* (Nees) Mont., which occurred solely on stems of *Eschweilera ovata* (Cambess) Mart. (Lecythydaceae), no species epiphytic or epixylic species exhibited a specificity for the phorophyte species.

Michel (2001) studied epiphytic liverworts of *Araucaria angustifolia* (Bert.) Kuntze, in the state of Rio Grande do Sul, finding greater richness in the undisturbed localities, such as forest interiors, and at trunk bases (below 0.5 m).

Finally, Oliveira & Silva *et al.* (2002) studied the bryophytes of preserved Atlantic forest remnants in the state of Rio de Janeiro and observed that mosses and liverworts showed similar behaviors when colonizing rocks, live trunks, and decomposing trunks, although most species were generalists.

Based on a previous bryophyte survey in an Atlantic forest remnant of Pernambuco (Germano & Pôrto, 2004, 2005), the aim of this study was to characterize bryophyte communities in relation to their floristic composition, richness and growth forms.

STUDY AREA

This study was conducted in the Reserva Ecológica de Gurjaú (Gurjaú Ecologic Reserve) (08°10'00"-08°15'00" S and 35°02'30"-35°05'00" W), the largest

Atlantic forest remnant of southern Pernambuco. Recently, this area was considered a conservation priority due to its extreme biological importance (Brasil – MMA, 2002).

The climate is tropical type AS', with a rainy autumn-winter season, according to Köppen's classification (Andrade & Lins, 1984). Mean annual temperature and precipitation are 25.5°C and 2.450 mm, respectively. The landscape ranges between 80-150 m. Soil is characterized as an association of red yellow laterite with clay texture and red yellow podzolic (Jacomine *et al.*, 1972).

MATERIAL AND METHODS

Bryophytes were sampled in ten sites in the Reserva Ecológica de Gurjaú. The main occurrence substrates were analyzed and 10 cm² samples were removed randomly:

- leaves: five of the older or more diverse leaves were collected from each phorophyte (tree or bush), and the leaf surface was analyzed (pubescent or glabrous) following Gradstein *et al.* (1996);
- soil: plane soil (forest interior and borders) and inclined soil (hillsides) were sampled;
- rocks: were analyzed in the forest interior and borders;
- live trunks: samples were collected from the base up to 2 m high, from phorophytes with a perimeter > 50 cm;
- dead trunks: samples of trunks (circumference > 50cm) were collected, classified in three dead trunk decomposition levels (reduced, intermediate, and advanced) based on cortex texture and wood softness, following the methodology of McCulloch *apud* Södertröm (1987) with adaptations by Germano & Pôrto (1997).

A georeferenced database was created (Laboratório Biologia de Briófitas – Bryophyte Biology Laboratory of the Federal University of Pernambuco) containing taxonomic identification and information on growth form and substrate occurrence of Reserva Ecológica de Gurjaú's bryophytes.

Based on the microhabitats in which they occur, the following communities are considered: leaf – epiphyllous, soil – terricolous, rocks – saxicolous, live trunks – corticolous, and dead trunks – epixylic.

The type of growth form was determined for each species following Mägdefrau (1982), with Richards' (1984) modifications.

The χ^2 test was used to evaluate the significance of bryophyte richness between communities and between the three levels of decomposition of the dead trunks. To quantify compositional relationships among community types, multivariate analysis were conducted using a computer program (NTSys 1.8) based on the Sørensen index and the cophenetic correlation coefficient > 0.7 (Rohlf, 1993; Visnadi & Vital, 2001).

In the frequency and similarity analysis, only species with > 5 occurrences were included. Species were classified according to the following parameters: exclusive = present in only one type of substrate; semi-exclusive = occurring in ≥ 50% of the same substrate, and generalist < 50%.

RESULTS

The community distribution pattern in the Reserva de Gurjaú shows great richness of corticolous and epixylic communities; the saxicolous, epiphyllous, and terricolous communities had lower representational values and that were close to each other (Fig. 1).

There was a significantly greater specific richness of liverworts over mosses in two of the microhabitats analyzed (*i.e.*, corticolous and epiphyllous) whereas the reverse pattern characterizes soil communities (Table 1). On live trunks, dead trunks, and rocks, Lejeuneaceae, Calymperaceae, and Sematophyllaceae were the dominant families (Fig. 2). Most species share microhabitats and few show exclusivity.

Most corticolous species share other substrates and are considered generalists, except for *S. ligulatus* (Fig. 2).

Dead trunks come next in the bryophyte preference list. The epixylic communities were rich in pleurocarpous mosses. Most species were generalists and only the liverwort *Lejeunea quinqueumbonata* Spruce was exclusive of dead trunks (Fig. 3).

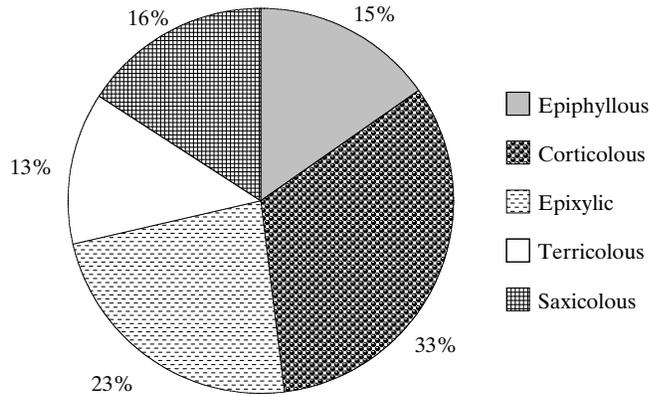


Fig. 1. Specific richness of bryophyte communities by microhabitat in the Reserva Ecológica de Gurjaú – Pernambuco, Brazil.

Tab. 1 – Specific richness of bryophyte classes per community in the microhabitats where they occurred in the Reserva Ecológica de Gurjaú – Pernambuco, Brazil.

	<i>Epiphyllous</i>	<i>Corticolous</i>	<i>Epixylic</i>	<i>Terricolous</i>	<i>Saxicolous</i>
Liverworts	23	35	19	4	13
Hornworts	0	0	0	1	0
Mosses	1	17	18	15	12
Total	24	52	37	20	25

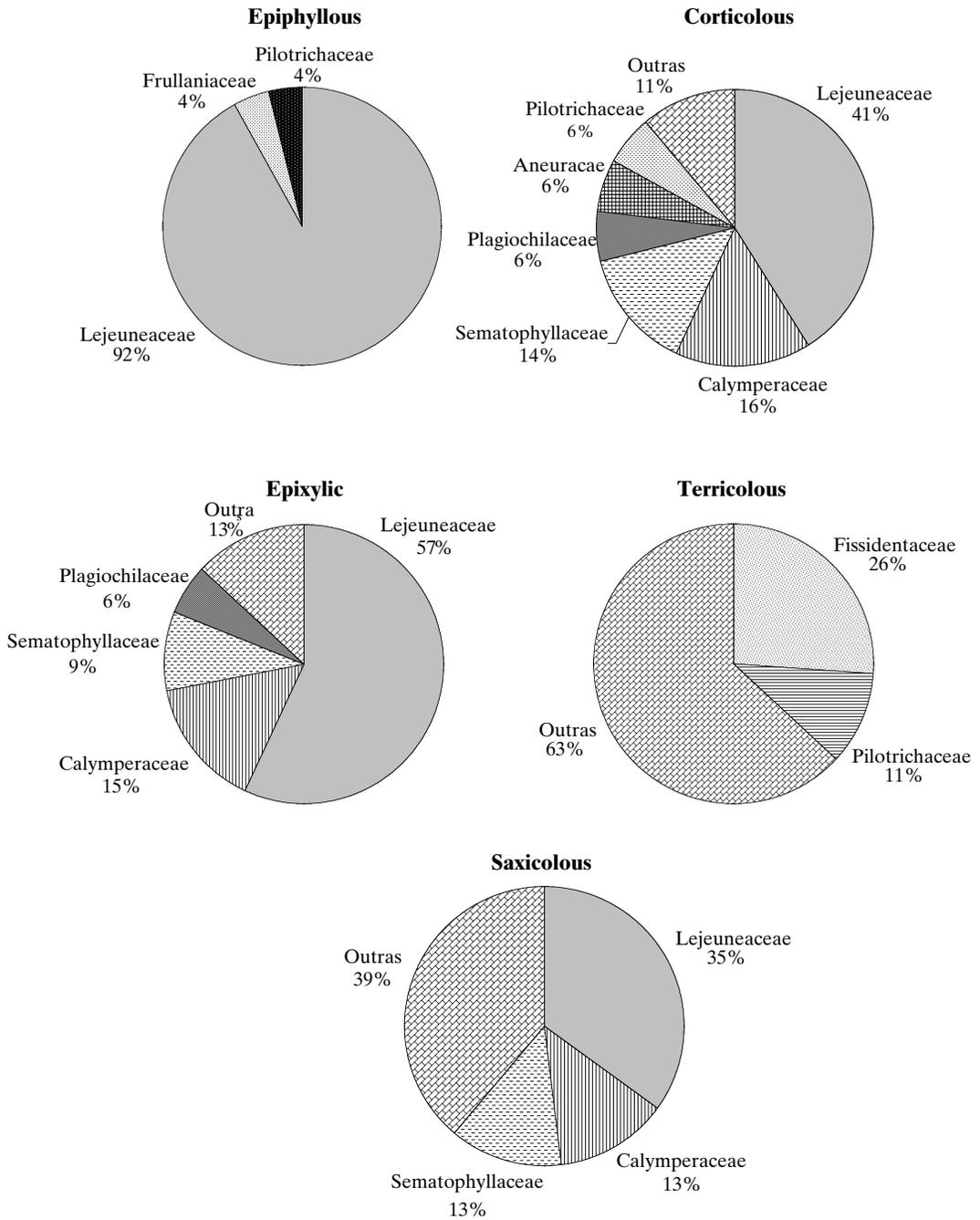
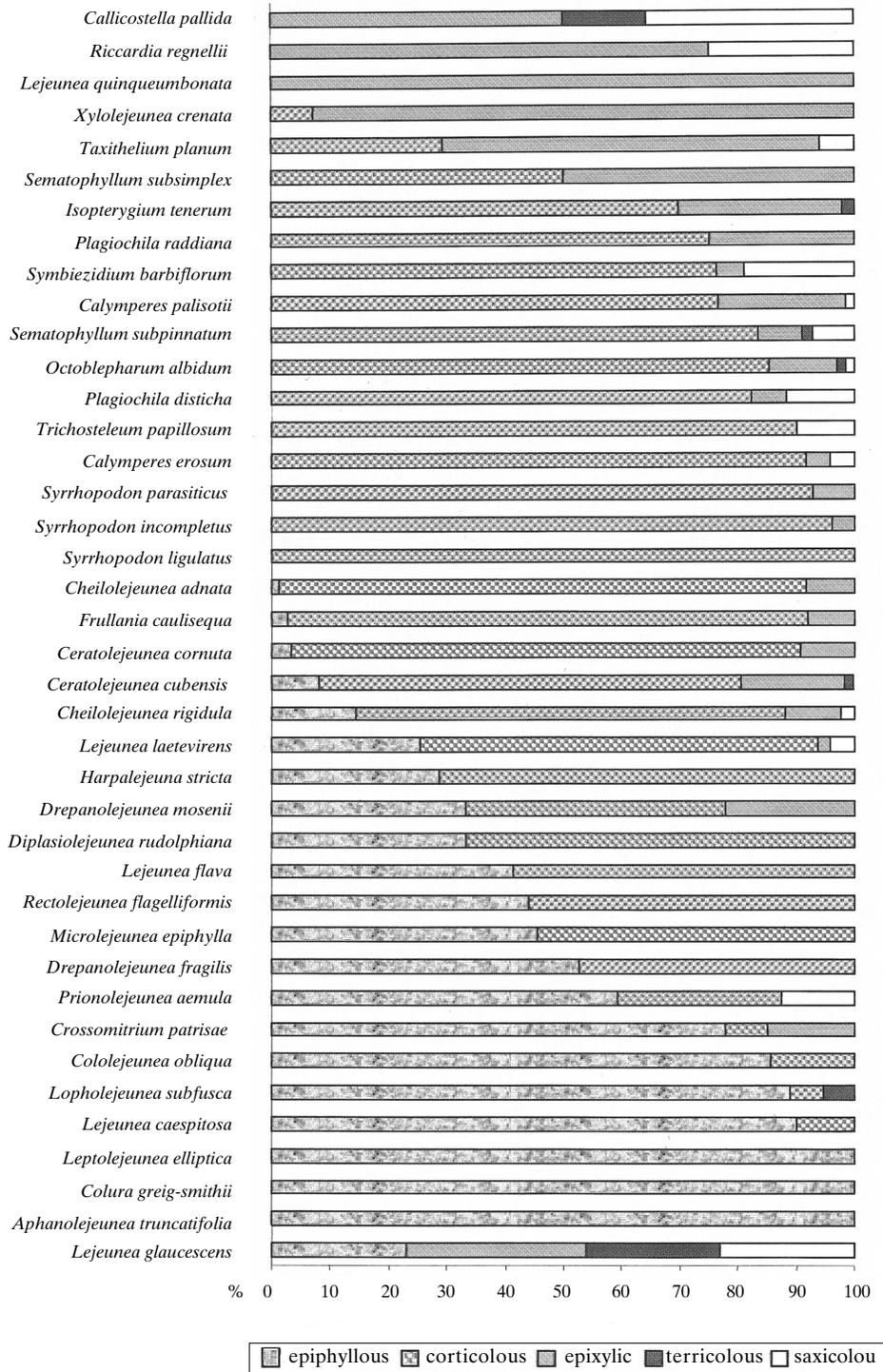


Fig. 2. Bryophyte family distribution per community at the Reserva Ecológica de Gurjaú – Pernambuco, Brazil.



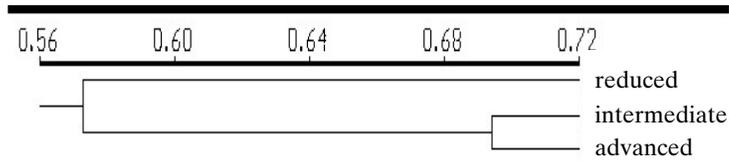


Fig. 4. Cluster analysis among the three deadwood decomposition levels in relation to the presence of bryophyte species at the Reserva Ecológica de Gurjaú – Pernambuco, Brazil. The Sørensen coefficient was used by applying the UPGMA method (group's cophenetic correlation = 0.75).

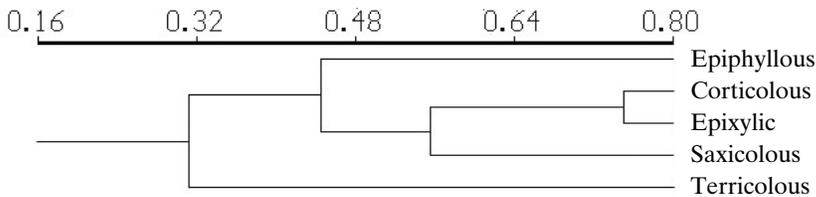


Fig. 5. Microhabitat cluster analysis in relation to the presence of bryophyte species in the Reserva Ecológica de Gurjaú – Pernambuco, Brazil. The Sørensen coefficient was used by applying the UPGMA method (group's cophenetic correlation = 0.87).

The list of epiphyllous species for the Gurjaú Reserve totaled 24 (Table 1). The Lejeuneaceae were highly representative (91.7%), among which there were three exclusive species: *Aphanolejeunea truncatifolia* Horik., *Colura greig-smithii* Jovet-Ast, and *Leptolejeunea elliptica* (Lehm. & Lindenb.) Schiffn. The only members of Frullaniaceae (*Frullania caulisequa* (Nees) Nees) and Pilotrichaceae (*Crossomitrium patrisae*) found showed occasional and semi-exclusive frequencies, respectively (Fig. 2).

In the Reserva Ecológica de Gurjaú, the terricolous bryophytes were represented by a relatively large number of families (14), although most families were represented by a single species (Fig. 3). No species was exclusive, one was semi-exclusive, and most were generalist. All occurred indiscriminately on flat soil and hillsides.

The saxicolous communities were associated with the presence of brooks, streams, and dams, almost always in the forest interior. Few species were found in this kind of community, and none could be considered exclusive or semi-exclusive (Fig. 2).

There was no significant difference in species richness regarding the trunks' decomposition levels. In relation to floristic composition, greater similarity was observed between communities in the intermediate and advanced stages (Fig. 4).



Fig. 3. Relative frequency of bryophyte species (> 5 occurrences) in the communities of the Reserva Ecológica de Gurjaú – Pernambuco, Brazil.

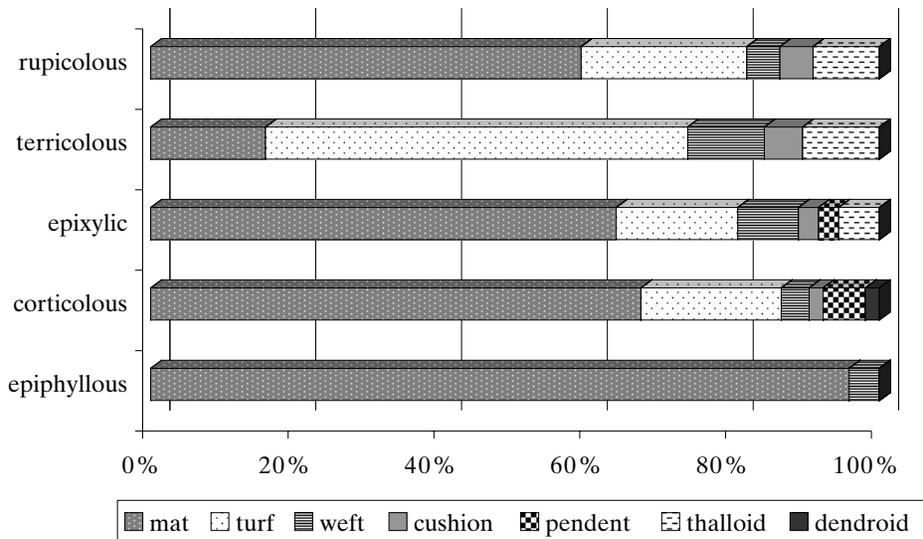


Fig. 6. Bryophyte growth form distribution per community in the Reserva Ecológica de Gurjaú – Pernambuco, Brazil.

In relation to similarity, the corticolous communities were most similar to the epixylic communities (75%), while the terricolous communities formed a unique group with the lowest similarity indexes (Fig. 5).

Seven growth forms were recognized in the bryophyte flora studied, and each species had a single form. The mat form was predominant in practically all of the microhabitats, with the exception of terricolous communities, in which the turf form was the most representative (Fig. 6). The forms – pendent, cushion, and dendroid – were each represented by a single species and occurred mainly in the corticolous and epixylic communities. Lowest diversity of growth-form was observed among epiphyllous communities.

DISCUSSION

In humid tropical lowland forests, the dominant bryophyte communities are the corticolous, the epixylic, and the epiphyllous communities; terricolous communities are poorly represented (Pócs, 1982; Richards, 1984).

In this environment, live trunks are densely colonized by corticolous species from their base to the canopy's upper branches (Pócs, 1982; Richards, 1984). In relation to the Reserva Ecológica de Gurjaú, species of Lejeuneaceae, Calymperaceae, and Sematophyllaceae dominated this type of community, although none was exclusive (most were semi-exclusive) and showed wide ecological amplitude in relation to substrate.

In bryophyte preference, dead trunks are second to live trunks. Fallen trees are initially colonized by epiphytic communities, and after being exposed to light and humidity alterations, they are gradually replaced by communities typical of decomposing bark and, finally, by communities typical of deadwood (Sastre de Jesús, 1992; Uniyal, 1999). These results were similar to those obtained by Pôrto (1992) for two forest remnants of Pernambuco, particularly in relation to the richness and composition of epixylic communities; also, no typical species occurred.

Germano & Pôrto (1997), while studying a forest remnant in Pernambuco, pointed out the lack of specificity in relation to decomposition levels of dead trunks. Nevertheless, they indicated the preference of *Sematophyllum caespitosum* (Hedw.) Mitt. (= *S. subpinnatum* (Brid.) Britt.) for trunks with reduced levels of decomposition and of *Lophocolea martiana* Nees for trunks in advanced stages of decomposition.

Epiphyllous communities commonly occur in the understory, near waterfalls and creeks, and in undisturbed shaded areas with high humidity levels, and are vulnerable due to habitat disturbance (Gradstein, 1992; Pócs, 1996).

Among neotropical taxa with typical epiphyllous species, Pócs (1996), Gradstein (1997) and Lücking (1997), listed the Lejeuneaceae (subfamily Lejeuneoideae) and, a single moss, namely *Crossomitrium patrisae* (Brid.) C. Müll. These taxa were also recorded in this study.

In general, typical epiphyllous communities show several characteristics that can be considered adaptations to colonizing leaves and vascular plants (Gradstein, 1997). Some of these characteristics were observed in the bryophyte flora studied, such as: mat growth form – prostrate on the soil and strongly adhered to the substrate (most species), rhizoidal disk (*Diplasiolejeunea* spp., *Cololejeunea* spp.), specialized asexual reproduction (gemmae, cladia, etc.), and neoteny – retention of the juvenile development stage (*Cheilolejeunea rigidula* (Nees & Mont.) Schiffn. and *Lejeunea* spp.). Although epiphyllous species' preference for pubescent and glabrous leaves has been mentioned (Vanden Berghen, 1973; Lücking, 1997), the presence of none of the species seems correlated with one or the other surface.

Terricolous bryophytes are poorly represented in the interior of tropical forests. Their occurrence is generally restricted to open areas at the edge of roads and paths, hillsides, and gaps. The absence or low representation of this group is attributed to foliage deposition combined with most bryophytes' difficulty in maintaining a positive photosynthetic balance in high temperatures and low light levels (Richards, 1984).

The growth form distribution pattern followed those obtained by Pôrto (1992) in the lowland rain forest (ca 100m) of Pernambuco, and by Costa (1999) for secondary and degraded lowland forests in the state of Rio de Janeiro, where the trama type predominated; this type adheres itself strongly to the substrate using rhizoids and ramifies and spreads itself on the same plane (a trunk or leaf, for example). This enlarges the contact surface area and makes water capture easier throughout all of the gametophyte. However, in the turf form, external conduction occurs predominantly by the process of capillarity. This is common among terricolous mosses, which are more tolerant to desiccation (Magdefraü, 1982).

The eco-physiological characteristics of bryophyte growth forms are related to abiotic factors, especially luminosity and humidity (Gimminham & Birse, 1957). Richards (1984) reported that in the humid tropical forests the mosses, especially, show a higher diversity of forms than in temperate and cold forests.

Community distribution patterns and their respective growth forms were similar to those observed in other humid tropical forests, although with lower specific richness values. A progressive deforestation process resulting in the conversion of forest fragments into degraded habitats can explain this.

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